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INNOVATIVE APPROACHES TO CONTROLLING IN AGRIBUSINESS: THE ROLE OF QUALITY MANAGEMENT SYSTEMS IN SUSTAINABLE PRODUCTION PRACTICES

Olena Smihunova[1*], Ihor Bohdaniuk[2], Yevheniya Polyakova[3], Artur Yehiozarian[4]

[1]Ph.D. in Economics, Associate Professor, Academic Secretary, Department of Economics, Management and Transfer of Innovations in Livestock Farming, Livestock Farming Institute of National Academy of Agrarian Sciences of Ukraine, Kharkiv, Ukraine. e-mail: elenasmigunova@gmail.com, orcid: https://orcid.org/0000-0002-9660-3361*
[2]Ph.D. in Law, Senior Researcher, Deputy Director for Organisational and Scientific Work and Technology Transfer, Department of Economics, Management and Transfer of Innovations in Livestock Farming, Livestock Farming Institute of National Academy of Agrarian Sciences of Ukraine, Kharkiv, Ukraine. e-mail: bogdanyuk.hniise@gmail.com, orcid: https://orcid.org/0000-0003-4782-9986
[3]Ph.D. in Economics, Associate Professor, Vice-Rector of Scientific and Pedagogical Work, Department of Finance, Banking, Insurance and Stock Market, International Technological University "Mykolayivs'ka Pollytechnics", Mykolaiv, Ukraine. e-mail: riske2074@gmail.com, orcid: https://orcid.org/0000-0002-7032-9421
[4]Ph.D. in Economics, Department of Economics, Management and Transfer of Innovations in Livestock Farming, Livestock Farming Institute of National Academy of Agrarian Sciences of Ukraine, Kharkiv, Ukraine. e-mail: yehiozarian.art@gmail.com, orcid: https://orcid.org/0009-0006-2245-8858

SUMMARY

Quality Management Systems (QMS) are increasingly the method of agribusiness addressing consumer demand for quality and transparency. These systems also play a crucial role in ensuring sustainable production, particularly in the face of climate change and regulatory pressures. The need to improve efficiencies in controlling production is becoming increasingly important. The aim is to highlight the benefits of QMS implementation within agribusiness, particularly in enhancing operational and sustainable efficiency. The application and concept of QMS will be explained, along with the potential benefits related to its adoption. The challenges of QMS execution will be analyzed, and the potential impact of QMS on product quality and environmental sustainability will be assessed. The study's report points to significant gains for the adoption of ISO standards after 2018: quality management, ISO 9001:2015 (1,265,216 certificates at 1,666,172 sites); environmental management, ISO 14001:2015 (529,853 certifications at 744,428 sites); and occupational health and safety, SO 45001:2018 (45,459 certifications at 51,535 sites). The article demonstrates that the adoption of QMS in agribusiness improves product quality and helps conserve natural resources. It also mirrors a favourable tendency in unifying quality management with sustainable operations. Consequently, the results of the research substantiated the practitioner's claims on the capacity of QMS to guide agribusiness towards a more sustainable future. A culture of 'quality' and 'continuous improvement' becomes a powerful factor in arming companies to cope with the vagaries of modern-day production.

Key words: *controlling, technology, agribusiness, management, sustainability, production, standards.*

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INTRODUCTION

As a result of emerging and growing consumer expectations, strict environmental regulations, and the severe problems associated with climate change, agribusinesses must find ways to either adapt or cease to continue. Given the forecasted burgeoning of the world's population and the need for food security [22], producers have little choice but to find more innovative ways to remain sustainable [37]. One potential mechanism by which this might happen is through the continual use of Quality Management Systems (QMS) [27]. This study will reason that the widespread and successful adoption of QMS within agribusiness can help leaders transform the practice to become more accountable, standardized, and continually seeking improvement. Firstly, the proper level of standardization must be enforced. These systems can help hold everyone to a higher expectation of excellence. For illustration, they can help to eliminate variation in processing. This will limit the potential for wastage by establishing the yield that should be obtained following available resources. Additionally, removing mistakes at the earlier stages will help reduce the need for post-processing corrections. Secondly, the standardization of business processes might also aid leaders in meeting the ever-evolving demands of consumers in a global marketplace [5].

Quality management systems are a set of quality assurance procedures and standards, typically applying to an agricultural production system, and making sure that robust quality controls are in place at all levels of production (Figure 1).

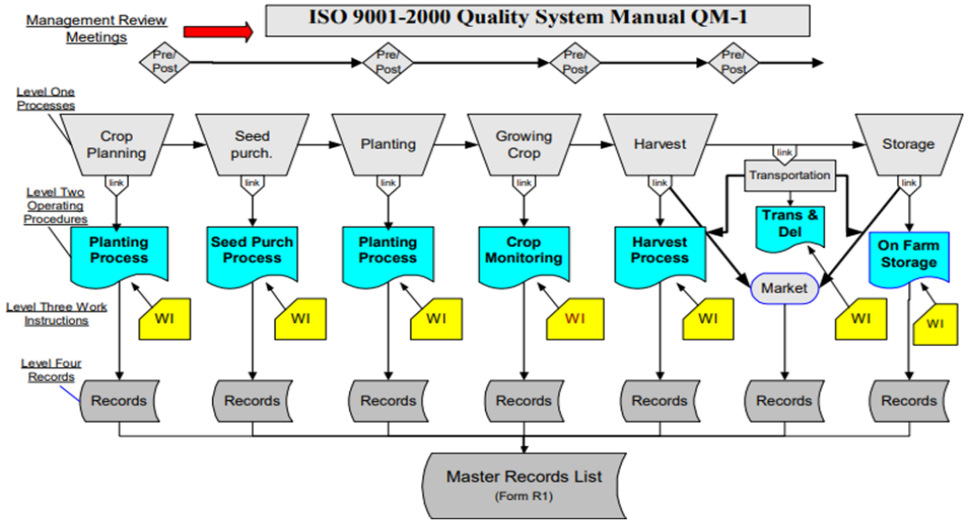

Figure 1. Characteristic function for a farm-based QMS*

*Source: Center for Industrial Research and Service [18]

By leveraging documentation systems, standard operating procedures, and performance metrics, QMS allows agribusinesses to maintain product quality while minimizing waste and enhancing the efficient use of resources. Through the establishment of QMS, which is conducive to complying with regulatory standards and offers operational efficiency, agribusinesses actively participate in the effort to make agriculture more sustainable [6].

To achieve this aim, it is necessary to study actual practices of using QMS implementation, examining the effectiveness of the systems in improving operating efficiency, and exploring available barriers for agribusinesses to unleash QMS. Also, such investigation will identify the constraints and prospects of a QMS set up in the production context and the role of organizational culture in fostering awareness and engagement of people on topics such as quality, safety, and sustainability. Likewise, [1] recently documented and interpreted a successful QMS application case study, highlighting the current environmental and macro-economic context and its emerging outcomes, pointing out alternative approaches that can orient the evolution of the agribusiness sector toward more and more sophisticated controlling technologies.

Linking managerial control practices to environmentally sustainable goals maximizes efficiency [33]. It enables agribusiness to deliver on the environmental stewardship and wider social responsibility that is anticipated (and demanded) of businesses in the interconnected global economy of the 21st century [12][23]. As such, this study is a relevant and timely contribution to the emerging field of innovation in agribusiness management.

THEORETICAL FRAMEWORK

The role of quality management systems in agribusiness has recently become a major research topic, reflecting the recent change in sustainable practice within the sector [35]. In this research field, the role of QMS as a driver for improving operational efficiency, the sustainable use of resources, production quality, competitiveness, and social benefits is explored along the agricultural production chain. An analysis of the studies already conducted indicates that the fundamentals of the QMS theories have been applied to agribusiness.

The continuous improvement and the customer satisfaction as a critical factor are much emphasized [8]. Other scholars, such as [4], have discussed how the basic quality principles should be adapted to agricultural environments to suit the market and regulatory requirements. More recent empirical analyses, including those [30] [9], have focused on how QMS frameworks could be adapted to peri-urban and small-scale agricultural production processes. They emphasize the specificity of agribusiness activity (for example, seasonality and sensitivity to environmental conditions) and conclude that a customized approach to QMS could improve both efficiency and product quality.

In fact, there is growing consensus over its net positive effect on the sustainability of agricultural practice: [15] conclude that QMS can contribute to several SDGs, including ending hunger and ensuring food security and improved nutrition, promoting sustainable agriculture, and good health and well-being, as well as ensuring sustainable consumption and production patterns. In this last SDG, they conclude that the 'implementation of QMS at farm level can help households reduce farm-waste which directly contribute to the objectives of achieving sustainability set by the UN SDGs.' The authors argue – using case-study data – that farms using QMS reported up to 30 % less waste being generated from each stage of their operations, with an improved environmental profile as a result. Outside this particular work, there was found the use of QMS as a means to ensure sustainability has also been promoted as essential for making agribusinesses comply with the law: [25], argues that QMS enables agribusinesses to also be cost-competitive with social and environmental safeguards as barriers to entry (including through the regulatory demand to actively monitor and control environmental impacts) by meeting existing (and therefore not adding costs) environmental regulations. Given the ongoing consumer push for more transparency from producers as to the environmental credentials of the food they buy, this is increasingly an important measure for ensuring that smallholders remain in the supply chain [29].

The advantages of QMS remain fairly well documented, and scholars have suggested various possible barriers to its implementation. Here, [3][24] [11], explained that the financial situation and capacity of many SMEs in the agricultural sector falls short of competencies required for QMS implementation in a business context. More than 60% of small farmers are either aware or unaware, or think that QMS is very difficult to implement. Contemporary publications increasingly highlight the role of technology as an important driver for the efficiency of QMS within agribusiness, with the most recent paper [7]. The authors also underlined the organic connections between digital tools such as data analytics [26], precision agriculture technologies, real-time monitoring systems [31], and so on, as well as the workings of QMS. The study found that the businesses that used the technologies were able to strengthen the operational flows of their production units and their capacity to react to the increasing demands from consumers and the growing environmental risks [14][17]. Van Nguyen et al. (2024) argue that these technologies themselves can 'overcome' the most important QMS obstacles, such as data collection and data management [34].

METHODOLOGY

A fundamental part of the explored collection comprises research materials on innovative management of the agro-industrial complex, which consists of academic research, case studies, and application

examples about the relevant problems in agriculture, digital transformation, innovation, management, etc. It enriched the research process based on free-access sources and resources of the research networks. They helped to identify sources for the systematization of the received information, applying analytical tools for highlighting the most significant trends and prospects of scientific and technical progress within the sphere of the innovative-industrial complex.

Comparative analysis has been used during the research process to identify repeated patterns and innovations to check and support our findings, signalling to the reader that our research process was valid and robust.

The widespread use of ISO 9000 Standard principles aims to establish and improve the Quality Management System (QMS), the efficiency of which is constantly under discussion and even seems to inhibit sustainable production (Figure 2).

Figure 2. ISO 9000: Quality Management Principles

Settling the remaining issues in this field directly impacts the success of sustainable production, a multifaceted concept even in basic forms of agricultural output, encompassing interconnected factors such as productivity, quality assurance, and environmental sustainability. By its nature, agriculture is far more complicated than manufacturing. It is fraught with environmental variability, biological variation, and market variability. Unlike in manufacturing, where the process (if it's a good one) is the same for every part, agribusinesses must constantly contend with shifting climate patterns, infestations, shifts in soil quality, and other challenges. Variations are frequent, and that's why QMS have largely not been used in the same way that conventional quality management has been. The result is that a method that allows for tracing a part to its original machine and then enables it to be taken apart and cleaned or repaired hasn't existed before. Much of the rigor and conscientiousness associated with quality management has yet to be lost in translation to industry. Developing a robust QMS that can handle agribusinesses' variability will require new, creative measures. They will also be necessary to implement crucial market-based strategies for adherence to sustainability standards.

Digital technologies also contain important opportunities and dilemmas for agribusinesses. Precision agriculture, the Internet of Things (IoT), big data analytics and related technologies – all of these hold much promise in terms of supporting QMS endeavors. But they also pose serious questions: who owns or can access these tools, how, and who develops the skills that these new technologies might necessitate,

but also how might digital systems interface with existing management systems? And if to manage tackling these issues, it can be expected more equitable and effective QMS geared to sustainably produced outputs.

At the heart of the current conundrum of agribusiness is the inevitable dichotomy between increased economic competitiveness and environmental sustainability. An assurance-based QMS, in its conventional approach, is unapologia-tically pragmatic in asserting the pre-eminent position of product quality and yield as its key parameters for defining assurance-based sustainable production. Striking a balance between environmental and economic aims is difficult and often reduced to minimizing compliance issues such as the overuse of chemicals, land degradation, and loss of biodiversity, notwithstanding the need to improve profit returns. Arranging a liaison between the sometimes conflicting paradigms of QMS and sustainable agriculture is fraught with compliance issues. This quandary is a case in point. Proposals regarding 'harmonization,' 'alignment,' and 'integration' have not been very forthcoming with specific, workable options for exploring the 'balance' between these two opposing paradigms of agribusiness. If the entrenchment between the QMS and the sustainable-agriculture paradigms is deep, resolving the issue of economically viable yet environmentally responsible production practices for the long haul is yet to receive the undivided attention of agribusiness operations, which face stiff competitiveness.

The other main set of stakeholders in both agribusiness and food marketing buyers, from distributors to the final consumers, are often necessary for adding value to the product (think of rose-packed ice bags) but are also hard to keep involved in meeting sustainability targets and using the QMS in the field (even though consumers want and are, increasingly, able to trace the detailed origins of their food). It would be valuable to know precisely how QMS was useful in stakeholder engagement issues and which aspects of management impeded the ability at every level of the agribusiness to work towards sustainability simply because they needed access to the necessary information. With growing awareness about ethical and sustainable food sources among consumers, many of these decision layers are becoming increasingly complicated.

The regulatory environments highly influence quality management and sustainable farming practices. Compliance with a combination of local, national, and international standards puts the burden of QMS adoption on the shoulders of all agribusinesses, but in particular, small firms. The fragmented regulatory regimes might lead to confusion and hinder the adoption of QMS. An important task still to be addressed is overcoming compliance issues and providing a more uniform set of regulations for the adaptation of QMS in order to facilitate the realization of innovative control measures in agribusiness.

The primary purpose of the article is to reveal novel methods of control employed in agribusiness, emphasizing the role of Quality Management Systems in environmental sustainability of output. One of the key objectives of this paper is to analyze the implementation of Quality Management Systems in agribusiness and understand how these systems can enhance oversight of crops and livestock. For this purpose, it is required to evaluate current methodologies for QMS in the sector, the strengths and weaknesses of existing implementations of QMS, and propose approaches to make QMS flexible and suited for agriculture's unique needs. This scientific work will be educative on how QMS can improve manufacturing quality and production efficiency while tracking product sustainability. In an age where even the most established food systems worldwide approach their limits on climate change, depleted natural resources and consumers' growing food ethics, practices for sustainability have also become the norm. The proactive approaches within QMS that promote sustainable production, such as organic farming, integrated pest management, and resource conservation, among others are going to be explored. Beyond enhancing the commitment to sustainable development, the article is interested in identifying and addressing the key bottlenecks of implementing a (more) effective QMS in these agribusinesses, irrespective of their sizes and specializations. Having more technical issues in achieving the QMS targets and more stakeholders (from the farm to the marketplace), to convince on, resistant to change, a stronger case needs to be made for change, and there's even a bigger resource gap among these agribusinesses in particular if they're smallholder farmers.

Mapping all the hurdles, the article proposes concrete measures and recommendations to ensure innovation in order to face challenges of the agribusinesses as well as to offers step by step implementable recommendations to sustain the development of the sector, large or small, even ecosystem-specialists. The next important area of discussion will be the potential use of digital technologies as powerful enablers to support or boost QMS in AM. Focusing on the applications of big data, IoT, and precision farming to ensure quality control and real-time monitoring of all production processes, the article will present guidelines on how digitalization can improve decision-making capabilities in a food production environment. The article will give a close look at these digital trends to provide a better ground for discussion, lessons, and experience to understand, follow, or exploit.

RESULTS AND DISCUSSIONS

The task of competing in the agriculture, where the pressure is high due to a growing planetary population telling us that our food production shouldn't double in the near future only, has brought additional challenges and has made digital solutions extremely important and urgent. Climbing prices on supplies, geopolitical factors in the form of lack of workers who are ready to do all types of unpleasant things that are required to keep our food production industry working, changing demands of clients who want to use more and more healthy and organic food while expecting lower prices, strong pressure on every segment of production in terms of their ability to fully embrace sustainable development, as well as transparency and providing full information on their products, are forcefully pushing every part of our industry towards adoption of digital technologies. The livestock farms and greenhouses, which became highly technological tanks with automated control systems, are based on modern software.

Digital agriculture, also termed precision agriculture, is humankind's utilization of computers and other electronic devices in agricultural matters, as well as in agricultural farming and other related activities. It enables the farmers and all participants of the agricultural supply chain to increase food production by introducing advanced agriculture technologies and agriculture trends into a single system and making faster decisions to maximize profit with ease. Precision agriculture is referred to as the agricultural database because it has almost all information related to cultivation and contains myriad data from soil conditions to market forecasts. One that comes with a complex decision support tool to make the right decision at different production and distribution stages. In other words, it is a substantial input that aids in agricultural risk management, such as climate change risks, formation of income protection strategies, laying the foundation of soil quality management programs, etc. Most modern farmers nowadays depend on the latest technological devices to do data gatherings and analyses from their farms with the aim of continuously maximizing agricultural productivity (Figure 3).

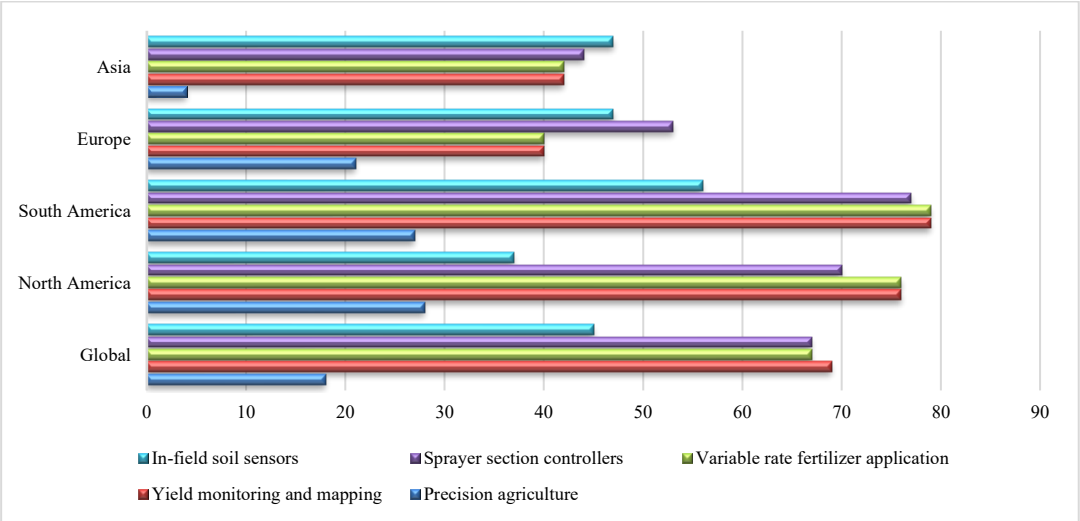

Figure 3. Global Farmer Insights 2022 (based on McKinsey & Company's data, posted [10])

For arable land, digital agricultural technologies monitor moisture levels, nutrient flows, soil composition and wind dynamics. The regions where this is most evident are in precision-agriculture hardware, a primary driver of sustainable, low-emission farming and conservation tillage practices, with

those seeing the most adoption being in North America – 28 %, followed by South America –27 % and then Europe at 21 %. The bigger areas of adoption are in yield mapping and monitoring software – 69 %, variable rate fertilizer-application technology – 67 %, and automatic sprayer-section shutoffs – 67 %. Asia is a relative latecomer in terms of adoption, with only 4 % adoption of the sustainability-related technology categories.

Machine-learning can assemble these data and interpret the knowledge for farmers in order for them to take decisions. Robotics and new equipment implement these decisions with high speed and accuracy and give farmers feedback on the reality of their course of action. The trend line for the ISO Survey results in 2018, 2019 shows that more agribusiness companies are embracing the QMS, which reflects the movement towards quality, safety and sustainability (Table 1).

Table 1. ISO Survey results 2018, 2019: Total valid certificates [32]

Standard (ISO)	2018	2019	In (%)
ISO 9001	878.664	883.521	0,5%
ISO 14001	307.059	312.580	1,8%
ISO/IEC 27001	31.910	36.362	12,2%
ISO 22000	32.120	33.502	4,1%
ISO 45001	11.952	38.654	69,1%
ISO 13485	19.472	23.045	15,5%
ISO 50001	18.059	18.227	0,9%
ISO 22301	1.506	1.693	11,0%
ISO 20000-1	5.308	6.047	12,2%
ISO 28000	617	1.874	67,1%
ISO 37001	389	872	55,4%
ISO 39001	547	864	36,7%

A steady increase in the number of valid certificates, from 878,664 in 2018 to 883,521 in 2019, just a 0.5% growth, shows not only that the growth of agribusiness is stable but also that agribusinesses see quality management as the rock-steady basis of their activity. The fact that agribusinesses issued 1.8 % more certificates (from 307,059 to 312,580) than in the previous December also speaks to this shift. In an industry with these numbers, growing demand for ecologically responsible production from consumers is an encouraging sign that regulatory forces may get the green light to reign in the worst environmental threats.

However, the huge increase in certifications – from 11,952 to 38,654 – shows that the commitments of many employers and the workforce in these settings were on the rise, as reported by the 69.1 per cent increase in certification. Continued growth in the number of certificates from 31,910 in 2019 to 36,362 in 2020 indicates that information security is becoming more important as agribusiness digitalises. This explains why the sector is adopting this standard since secure management of data is critical to operational integrity. The most striking growth was seen in the newer standards, with a 0.9% rise for ISO 50001 and a 4.1% increase for ISO 22000.

While these are both evidence of continued interest, the low growth rates could reflect the fact that many agribusinesses still have pressure points when attempting to fully integrate energy management and food safety practices into business operations. Growth in certifications of standards like ISO 37001 (anti-bribery) and ISO 28000 (supply chain security), with increases of 55.4 % and 67.1 % respectively over the year, reflects growing awareness of social responsibility and security of the agribusiness supply chain. The following Table 2 shows the ISO survey of the number of certified sites in operation that have been established following some ISO standards in the period from 2018 to 2019.

Table 2. ISO Survey results 2018, 2019: Total number of sites [32]

Standard (ISO)	2018	2019	In (%)
ISO 9001	1.118.065	1.217.972	8,2%
ISO 14001	447.547	487.950	8,3%
ISO/IEC 27001	59.934	68.765	12,8%
ISO 22000	36.105	39.651	8,9%
ISO 45001	14.607	62.889	76,8%
ISO 13485	24.123	31.508	23,4%
ISO 50001	46.770	42.215	-10,8%
ISO 22301	5.282	6.231	15,2%
ISO 20000-1	7.225	7.778	7,1%
ISO 28000	666	2.403	72,3%
ISO 37001	1.541	4.096	62,4%
ISO 39001	1.422	1.852	23,2%

Most notable of these trends is the net increase in the total number of certified sites under each of the ISOs, most notably for the ISO 9001 standard, which increased from 1,118,065 in 2018 to 1,217,972 in 2019 – a 8.2 % increase – reflecting a rising trend of the agribusiness to comply with the standards and best practices driven by the quality management to increase the operational efficiency and fulfill the requirements and expectations of its customers. Meanwhile, ISO 14001, which relates to environmental management, likewise increased by 8.3 %, from 447,547 to 487,950 sites, as more agribusinesses became aware of and sought to prioritize sustainability in terms of environmental management. This was part of a growing global trend towards lowering agricultural ecological footprints [13].

The vast majority of the additional standards relate to ISO 45001, with sites rising from 14,607 to 62,889, a 76.8 % increase. Greater attention to occupational health and safety in agribusiness, as a result of governmental regulations and increased social expectations of how firms should treat their workers, has led to increased usage of ISO 45001 standards. ISO/IEC 27001 (information security) was up by 12.8 %, ISO 13485 (medical devices) by 23.4 %. This clearly shows increased awareness of data security and quality management in the specialized areas of agribusiness.

Another trend is the opposite: the certified site number for ISO 50001 went down by 10.8 %, from 46,770 to 42,215, meaning that the energy management protocol hasn't worked or maybe that there are so many initial certifications that have been satisfied, there's a need to understand better the barriers to effective continuous improvement. Certifications under the ISO 37001 anti-bribery and ISO 28000 supply chain security standards climbed by 62.4 % and 72.3 %, respectively, indicating that a growing number of businesses, from downstream traders to large-scale factory farms, were taking action to avoid direct or indirect complicity in corruption and shore up supply chain security. These trends reflect broader global concerns about agribusiness security and openness.

The table 3 shows the results of the ISO survey carried out in 2020 showing the total number of certifications (No of cert.) and certified sites (No 'sites') under consideration for various ISO standards. This data gives an interesting insight into the trend of QMS in agribusiness, reflecting a widespread commitment to quality and environmental sustainability and operating safety (Table 3).

Table 3. ISO Survey results: 2020 [19]

Starndards (ISO)	No cert.	No 'sites'
ISO 9001:2015	916842	1298666
ISO 14001:2015	348218	568518
ISO 45001:2018	190429	251136
ISO ISO/IEC 27001	44486	84196
ISO 22000	33375	39981
ISO 13485	25656	35253
ISO 50001	19721	45082
ISO/IEC 20000-1	7846	9927
ISO 22301	2205	4661
ISO 22301	2065	4662
ISO 37001	2065	5946
ISO 39001	936	2305
ISO 28000	520	968

The above table data reveals data on 190,429 certifications of ISO 45001:2018 (replacing OHSAS 18000:2007) which covers 251,136 sites. A rise in the certifications is an evidence of growing emphasis on worker safety and health standards. The physical nature of the work in agribusiness, as well as the obvious risks, means protecting its labor force is critical. The ISO 22000 ISO standard focuses on food safety management systems in the agribusiness context. This standard has 33,375 certificates and 39,981 sites. This is evidence that a commitment to food safety and quality from a farm to the consumer, and then to their table is steady and shows the importance of compliance in food supply chains. A look at the spreading roles of such standards as ISO 13485 (medical devices) and ISO/IEC 27001 (information security) suggest a sector becoming increasingly active and serious about agribusiness operations being better managed in line with high standards of quality and security – critical both for the provision of alcohol-based hand sanitizers and agricultural biotechnology, just as much as the availability of fertilizer in international markets.

Up-and-coming standards include 2,065 and 520 certificates, respectively, for ISO 37001 (anti-bribery) and ISO 28000 (supply chain security) worldwide. Although the numbers still pale in comparison with older and more established standards, the very existence of the certifications would demonstrate a growing trend in the focus on ethics and security in the agribusiness sector, not to mention a growing political expectation to meet a growing demand from consumers.

The statistic showed in Table 4 display a significant trend on ISO certification about 3 different types Quality Management Systems (QMS) in agricultural business industries based on the amount of certificate and total number of sites over story unit in yearly burst of 2021-2022 (Table 4).

Table 4. ISO Survey results: 2021 and 2022 [20]

	Number certificates from providers took part in 2021 and 2022	Variation total	Variation in %
ISO 9001:2015	1024674	126524	12
ISO 14001:2015	485054	85725	21
ISO 45001:2018	367182	83076	29
ISO/IEC 27001:2013	67326	11549	21
ISO 50001:2011&2018	26625	6611	33
	Number sites from providers took part in 2021 and 2022	Variation total	Variation in %
ISO 9001:2015	1522996	159911	12
ISO 14001:2015	682402	108641	19
ISO 45001:2018	471414	119544	34
ISO/IEC 27001:2013	110693	17463	19
ISO 50001:2011&2018	48246	9534	25

The ISO certificate is for advanced energy, which carries 17996 in its certificates, whereas the 1D ISO certificate occupies the 22000 figures with 1041295. This number means the highest percentage of presence in the certification year because there are more sites applying to this institution. The percentage of presence depends on the number of sites applying to a specific ISO certificate. According to the graphs, 822096 applies for 9001 ISO certificate. The 14001 and 22000 occupy 917637 and 22623444. The increasing rate of total certification and the number of sites is higher than the ones in 9001. The reason behind that could be obvious: the agribusiness institutions became more excited with the idea of implementing more QMS as the main approach of sustainable production. The concerns of safety, quality, and even the environment became more prioritized by this sector. The considerable differences between the total certification number and the number of sites that applied for it were also noteworthy since it proved that the QMS changed from the past to the future. The point is that, nowadays, many agribusiness institutions have broadened their interests and concerns from the products' quality and safety to specific methods and standards of production in general, which includes the environmental aspects.

Presently, most of the world's agribusinesses are increasingly concerned with their environmental performance and energy efficiency, signifying a profound shift towards greening. This means that many

agribusinesses are not only concerned with the product's quality and safety, but also the environmental impact of their business activities in "green", consumer and regulator-friendly approach. The depicted data indicates that agribusiness played a significant role in adopting Quality Management Systems, revealing that the adoption of QMS gradually improved. Also, the practice improved its quality management system, further influencing sustainability. The increased adoption of QMS in agribusiness has brought numerous benefits. This emerges in higher productivity, safety and environmental stewardship that, together, will almost certainly lead to greater resilience, sustainability and responsibility in farming practices, reinforcing confidence among stakeholders about the future of the industry.

Table 5 represents the result of ISO Survey 2022 [20] and explains how the probability of QMS is shown in the productivity chain.

Table 5. ISO Survey resuts 2022 [20]

Starndards (ISO)	No cert.	No 'sites'
ISO 9001:2015	1265216	1666172
ISO 14001:2015	529853	744428
ISO 45001:2018	397339	512069
ISO 13485:2016	29741	40449
ISO 50001:2018	28164	55883
ISO 20000-1:2018	27009	29616
ISO 37001:2016	5969	12837
ISO 22301:2012&2019	3200	10658
ISO 39001:2012	1550	3662
ISO 55001:2014	997	2449
ISO 28000:2007	521	973
ISO 20121:2012	247	526
ISO 29001:2020	177	253
ISO 44001:2017	118	166

In terms of the number of certificates and in terms of operational sites, an interesting reality that emerges from the data chart is significant from the double point of view of research and pertinent practice in the management of productive processes in agribusiness and the related sectors in terms of itineraries of innovation towards process management in sustainable terms, starting from the view of production. ISO 9001:2015 certification stands at 1,265,216 with 1,666,172 sites. It is clearly being shown as a key element for the global quality management today, and also established as a baseline for all agribusinesses which wish to secure customer satisfaction and to achieve better performing operational procedures.

Given the popularity of quality assurance implementation across industries worldwide, it is easy to see how the organization has become so prevalent today. Meanwhile, the management system standard ISO 14001:2015 (Environmental management), which addresses environmental responsibility and compliance with environmental sustainability governance, has 529,853 certificates and 744,428 sites. In occupational health and safety, a total of 397,339 certifications and 512,069 sites are certified to the relevant ISO 45001:2018 standard. This standard speaks directly to how an organization manages employees to ensure they aren't injured or killed at work.

Given the rudimentary nature of many agricultural operations and the prevalence of dangerous physical tasks of many farm activities, a good health and safety management system has the potential to make a real difference in the lives of workers. These arrangements can help employers mitigate the risks that naturally arise during agricultural activities, which include increasing accident rates and worker illness. Somewhat unexpectedly, the sectoral differentiation of QM pointed out earlier in the following highly specialized standards, namely ISO 13485:2016 (medical devices), ISO 50001:2018 (energy management), and ISO 20000-1:2018 (IT service management). The examples of the nearly 30,000 certificates for ISO 13485 show the sectoral differentiation of safety and quality management in agribusiness, while nearly 30,000 certificates for ISO 50001 indicate a focus on efficiency in terms of energy management. They show that, in addition to quality systems, agribusiness is increasingly implementing operational sustainability (for example, in the form of energy management). Therefore, the adoption of these different standards is encouraging (Figure 4).

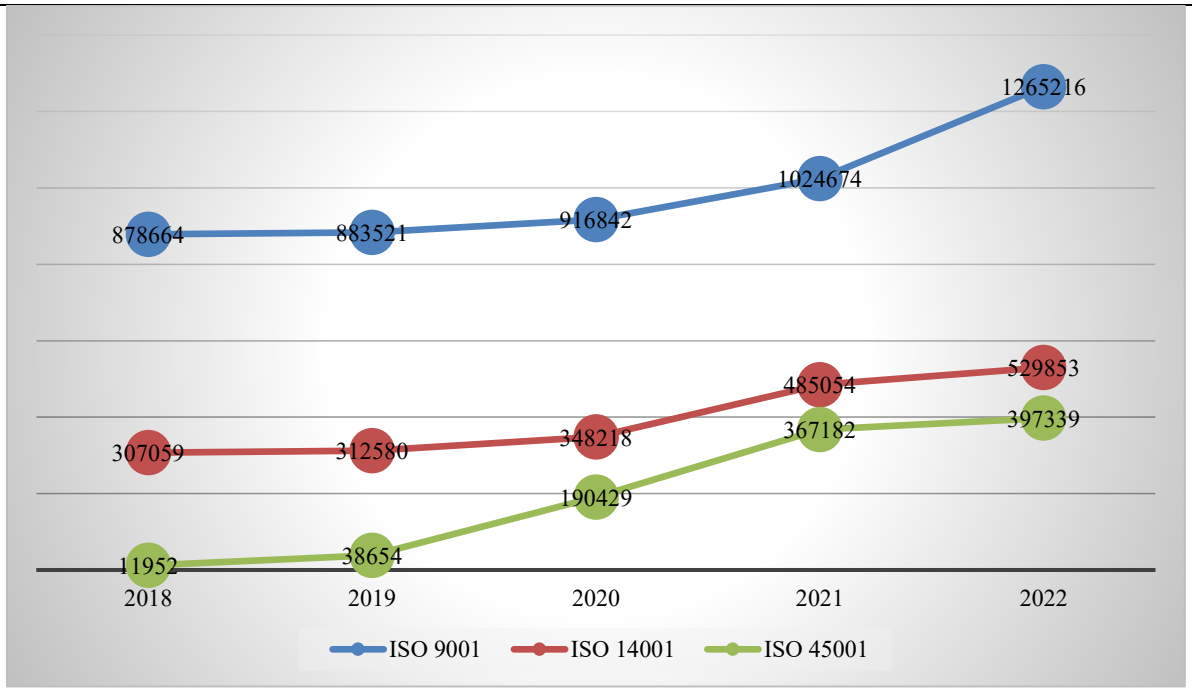

Figure 4. Overall growth in Certifications and Sites (under ISO 9001, ISO 14001, ISO 45001)

For the ISO standards, the number of certificates issued and the number of certified sites have shown an upward trend over the years, suggesting that QMS continues to gain significance in improving agribusiness productivity and sustainability. Still, because the number of quality standards continues to rise, the low numbers for some of the more recent standards, for example ISO 37001:2016 (anti-bribery) with 5,969, or ISO 22301:2012&2019 (business continuity) with 3,200, illustrates an opportunity for closer attention to develop these further. For those in the agribusiness sector, it seems that more resources and an increased awareness of these standards should be given as these are important areas for sound risk management practices, suggesting scope for agribusinesses to evolve QMS further by incorporating them into digital tools and analytics: increasingly complex supply chains and markets require advanced technologies to ease compliance and add value through improved traceability and enhanced operational efficiency. Reliance on ISO standards points to a growing commitment to sustainability in agribusiness. ISO's quality and environmental standards can be adopted to meet the industry's aspirations of aligning with the global goals of sustainability and meeting the growing consumer demands, as a QMS could provide a means through which the industry can provide rigorous proof of meeting these standards. Enhanced competitiveness would follow if consumers, interest groups and regulators were assured that these standards, which are recognised internationally, were met. QM thinking in the agro-sector is being formalised, and draws clear aspirations for sustainability and innovation. It is how QMS becomes embedded that becomes another important part of the industry risk-management story, its optimization of operations, and its path to more green production systems. On both research and practice agendas, it is worthwhile paying a bit more attention to the how of implementation and how digitalization can help performance and quality management processes to improve [16]; thus, it is possible to continue to encourage a path of transformation for agribusiness that will keep the industry to the economic and environmental ambitions.

The flow of processes in agribusiness illustrated in Figure 5 shows that QMS are important in improving operational efficiency and sustainability of production practices. Quality Management Systems ensure that the agricultural sector becomes more efficient and sustainable through enhanced control over its inputs, processes, outputs, and customers.

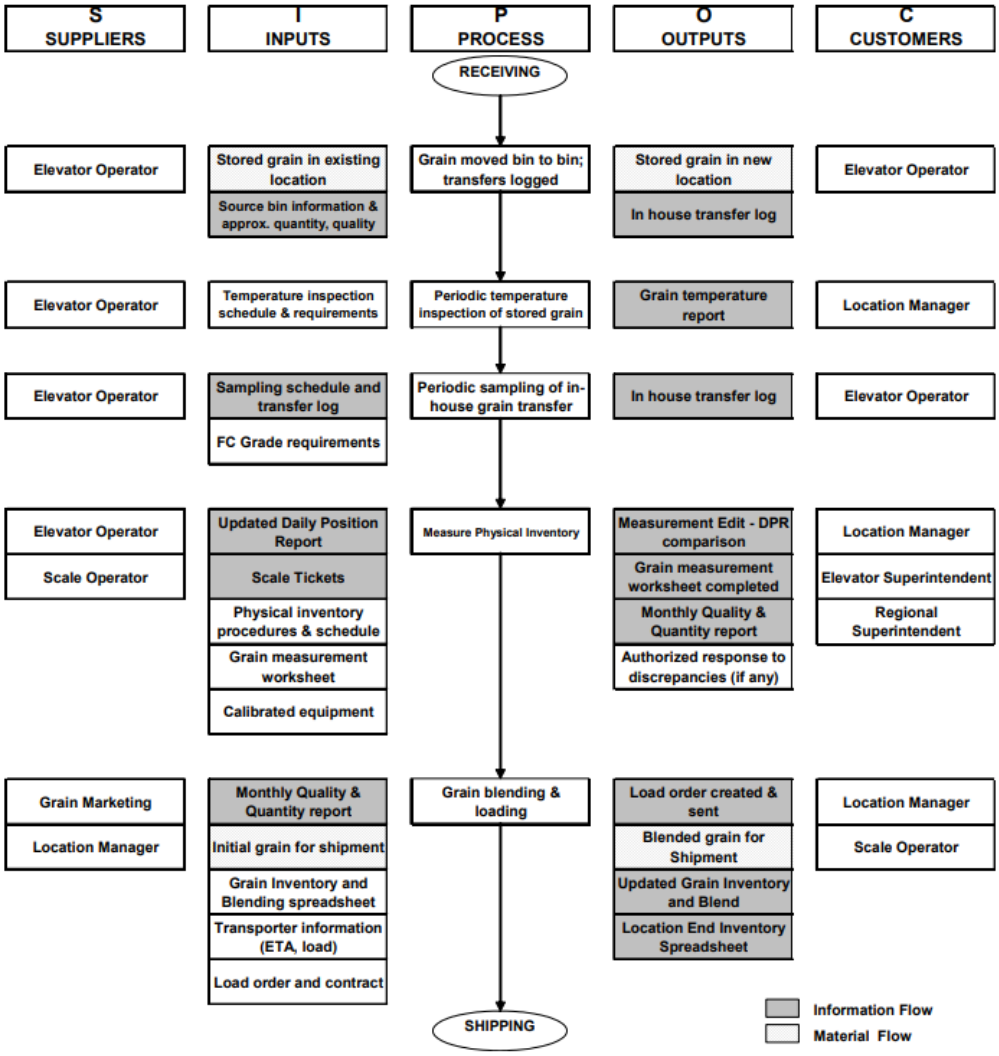

Figure 5. Overall process map according to the QMS

Figure 3 illustrates agribusinesses' operations and reliance on proper supplier coverage. Also, it can be seen how the structure of receiving and managing inputs was designed clearly and supported by controlled input supply with grain elevator operators. Suppliers were chosen based on good results and carefully reviewed. Also included are some parts of the QMS that are followed in the procedure of storing grain, guaranteeing security and conforming with quality specifications. Through creating protocols – such as temperature checks and inventory spot checks – agribusinesses can minimize input quality risk and thus improve product safety and consistency, which are important sustainability outcomes. This preventative management approach aligns with the concept of sustainable practices, which, by their nature, emphasize high-quality inputs.

The flow from receiving inputs to processing shows a repeated system of quality control at every step—the integration of temperature checks and random grain samples ensures not only the safety standards but also the integrity of the process as a whole. The need to maintain a measurement edit for purposes of daily inventory also highlights the approach by which QMS can offer actionable granular insights into operational performance. Inventory can be tracked with accuracy, which in turn can enable agribusinesses to optimise resource usage, minimise stockouts and shrinkage due to spoilage or faulty reporting.

Outputs are initiated when products are delivered, expectations are met, and the competencies largely inform them of preceding processes. QMS allows agribusinesses to create reporting infrastructures comprising blending reports and location manager logs to flag and guard against deviations from established quality expectations. If product quality is measured or if customers are surveyed, then

feedback mechanisms will encourage costless, continuous improvement, allowing agribusinesses to more flexibly and opportunistically respond to changing demands and preferences.

As the customer flow chart illustrates, it is essential for agribusinesses to match their production capacity with the demand of their customers. That's because continuously maintaining a two-way communication with the clients about their products' quality and sustainability practices will not only help agribusiness reputation but also improve customer trust and reliability. Overall, if agribusinesses are able to market quality food products and proudly showcase transparent processing procedures, they can attract more customers and maintain their position in the market. This also implies the wise use of customer feedback that is fed back into the QMS in order to improve the sustainability of production practices through ongoing adjustments. In fact, under PSC, this bi-directional communication between the customer and the manufacturer is imperative as it enables the latter to satisfy the specific needs of the former. Hence, this requirement facilitates the reduction of the gap between consumer perceptions (which may be unrealistic or unreasonable) and the actual practices of food production in terms of environmental and ethical standards.

The role of technology in quality management also points to a more significant role in the digitalization of information systems in quality management. This includes currently available information management systems, which can track inventory, monitor suppliers, or analyse customer feedback, as well as other digital production tools that build on their advantages for efficiency and sustainability. Agribusinesses' ability to integrate different technologies enables farmers and herders to automate the production process. This allows them to gather real-time data and insights, making it easier for them to adapt to changing circumstances. Understanding what is happening and acting fast when necessary is critical in an environment, where getting the timing right could be the difference between failure and success.

The reflective practice demanded by QMS help enterprises move towards a more sustainable approach when implementing a form of QMS. Many organizations reported using fewer synthetic chemicals and improved biodiversity in their farming system as part of a total QMS framework [28] [2]. Although this seemed like a cost mainly incurred to achieve compliance, farmers also considered it a competitive advantage in niche markets where increasing environmental consciousness turned consumers into 'eco-heroes.'

Need to note, digital technologies could improve the functionality of QMS in agribusiness [36]. The use of digital technologies through the Internet of Things (IoT) devices, big data analytics, and cloud-based solutions to accelerate data collection and decision-making across the agribusiness sector. Javaid et al. (2022) demonstrated in their work, that farms that deployed IoT sensors reported more timely interventions alongside improved monitoring of environmental conditions, thereby aiding in enhanced crop yields [21]. This allows for real-time quality monitoring and also increases compliance with regulatory requirements. Using digital elements to create QMS helps agribusinesses better manage quality assurance risks and make the supply chains more transparent.

CONCLUSIONS AND FURTHER RESEARCHES DIRECTIONS

This study confirms that using QMS improved agribusiness process efficiency and adherence to regulatory compliance. The data show that companies using QMS frameworks have reported less waste, better resource use, and increased profitability in recent years. A recurring theme across the literature is the degree to which QMS can help deliver sustainability objectives. The adoption of ISO standards such as ISO 14001 for environmental management is central to the goal that agribusinesses must deliver both higher levels of productivity and sustainable ways of operating to reduce their ecological footprint. Results reveal a new potential for accelerating the impact of a QMS using digital technologies. Digital technologies, including IoT (internet of things), big data analytics, intelligent sensors and precision agriculture tools can build on QMS for transformation. Real-time data monitoring could be deployed for data-dependable assessment and improve processes to make them effective and qualitative prediction of problems before it actualizes. By undertaking digital strategies, a QMS will become much more robust and better equipped for quality sustainability. In contemporary agriculture, it means survival of the

fittest, where digital technologies can assist farmers in sustaining their farming activity in a changing environment (unseasonal rainfall, climate change, etc). Digitalizing an agribusiness organization is a transformative change as the need for food-driven consumers looking for sustainability of food will increase.

Need to acknowledge that more research is required, including longitudinal studies to answer the question of how agribusiness is coping once QMS is in place (and are therefore embedded over the long term), and how they have changed their practice to effect tangible alterations and improvements in productivity and sustainability outcomes. This would help provide a robust business case for QMS. A forward-looking study could enquire about the technologies that further QMS in agribusiness and explore how new technologies could be applied. It could assess which technologies can be used as add-ons to existing management systems, such as traceability through blockchain and predictive analysis through AI, and what novel capabilities cutting-edge applications of IoT add to existing agribusiness structures. Research is also needed to define adaptive QMS models that recognize that different contexts may exist in agribusiness – for example, settings with smallholder farmers who might face specific challenges. Adapting QMS approaches and models to these settings could enlarge their capacity and usability and bring positive change.

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