LEAN-AGRICULTURE: UNEARTHING THE PUZZLE PIECES ACROSS DIFFERENT INDUSTRIES

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ABSTRACT

The lean philosophy has long since moved from manufacturing plants to other operations such as insurance and healthcare. The agriculture industry is no different in terms of production processes, facilities, people, and challenges. However, agriculture provides a different set of challenges due to seasonal variability, bulk production, processing and problems in handling and storage. An opportunity exists to introduce the Lean concepts in more depth in agriculture given the magnitude of waste and losses in this industry. Therefore, the aim of this study is to conduct a rapid literature review in order to retrieve available research on Lean implementation in the agriculture industry to direct future research. The study identified one hundred and two studies highlighting the different applications of Lean-Agri. Given the increase in publication over the years, it is evident that research into Lean-Agri is increasing but more research is needed to further highlight its value and its range of applications.

Keywords: Lean, Agriculture, Rapid Literature review

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1 INTRODUCTION

Lean principles were originally developed in manufacturing as a set of tools and techniques that could eliminate waste from the production process. However, Lean techniques later moved from manufacturing plants to other operations, such as insurance, healthcare, government functions, non-profit businesses, and other economic activities, giving rise to Lean X concepts such as Lean accounting and Lean healthcare [1, 2].

The agriculture industry is no different from these industries in terms of production processes, supply chains, facilities and people. Also, its challenges are similar: less-than-desired throughput, facility layout that is not conducive to flow, a need for better project management and business engineering, the need for improved quality management and much-needed assistance with human resource planning and management.

The farmer is essentially a Jack of all trades and master of ALL, required to know various technical disciplines such as mechanics, hydraulics, electrical power, irrigation, structural design and, in recent years, electronics. Over and above these skills, farmers are required to understand how to run a profitable business, including the management of a workforce and resources. Additionally, farmers need an array of knowledge in the chemistry and the science of agriculture itself. They are expected to do all of this to provide for their families and produce for the country while facing unpredictable (natural) circumstances. In this sector, as in other sectors, global competition has resulted in a movement to large-scale production, greater use of standardised technology and more organisational and managerial innovations [2]. The management tools used in the agricultural sector are specialisation, formalisation and standardisation, all of which link to the trend towards fewer and larger farms [2].

Outside the farm, the Agricultural supply chains are complex systems that face the challenge of maintaining the freshness of agricultural products during staging, handling, packaging, and storage [3], while at the same time facing the challenges of integrating the agricultural supply chain into mainstream retail and distribution channels.

Fortunately, Lean is increasingly used in some parts of the agricultural sector [2]. However, differences exist in how Lean is used in the agricultural sector compared to how it is used in the manufacturing sector. It is not clear how Lean principles and tools adapt to farm operations or how farmers interpret Lean Thinking [2]. The challenge remains that Lean in agriculture provides a different set of challenges due to seasonal variability, bulk production, processing and problems in handling and storage [1]

An opportunity exists to introduce the Lean concepts in more depth in agriculture given the magnitude of waste and losses in this industry. However, before introducing Lean principles in more depth to a wider variety of agri-industries, it is important to understand in which of these agri-industries these principles have already been implemented. This will assist with a starting point to have the biggest impact.

The aim of this study is to conduct a rapid literature review, to identify available research on where Lean implementation has occurred in the agriculture industry. Future research can then focus on a further in-depth literature review to determine the details of each of the implementation processes.

The rapid review method that was followed is described in Section 2. The findings are presented in Section 3. Proof of validity is provided in Section 4, after which the conclusion and future research are presented in Sections 5 and 6, respectively.

2 METHOD

The rapid literature review process was used as guidance for this initial study before a more systematic review is conducted in future [4]. The methodology was selected for the rapid search and appraisal of existing research on Lean applications in the agriculture industry. By

using elements of a full systematic review, a rapid review provides a rigorous method for assessing existing literature while reducing the overall scope of the review process by allowing concessions such as focusing on the research question, limiting search strategies and/or performing less sophisticated analysis [5].

This study utilised a rapid review strategy using the SALSA framework [5]:

1. Search - A systematic search of databases;
2. Appraise - Selection of relevant studies using inclusion and exclusion criteria and grouping by agri-industry;
3. Synthesis - Extraction of relevant data from literature sources; and
4. Analyse - An analysis of the literature found.

2.1 Search – Systematic search of electronic databases

The aim of the literature review was to investigate whether Lean principles are applied in the agricultural industry. The search was limited to journal articles, conference proceedings, books and book chapters and literature written in English. Since this was a rapid review, only one electronic database (Scopus) was searched using keyword search strings with Boolean logic. When publishing research related to Lean principles, different terminologies (Lean manufacturing, Lean philosophy, Lean Management, Lean production) are used, as Lean is polyonymous. In a similar vein, different terminologies are used in agriculture. Instead of running the risk of unintentionally excluding valuable literature, five different search strings were used. These search strings, as well as the numbers of studies retrieved from each search, are presented in the search protocol in

.

2.2 Appraise - Selection of relevant studies

Inclusion and exclusion criteria were developed to remove irrelevant articles from further analysis (Table 1). Studies that focussed on Lean implementation in agriculture were included while studies that referred to biological sciences, weight loss, Lean Six Sigma, lean meat, lean agricultural season, lean agricultural yield or lean agricultural periods were excluded.

2.3 Synthesis – Extraction of relevant data

The relevant data was extracted from the selected studies. The list of selected literature is presented in the appendix, categorised by agriculture industry.

2.4 Analyse – Analysis of literature found

The literature sources that were extracted were analysed in terms of 1) the type of agriculture industry in which the Lean principles were implemented, 2) the names of authors and 3) the date of publication. It was also noted if the study was based on the larger agri-supply chain or at the point of production, namely on farms. The findings are discussed in Section 3.

3 FINDINGS

Findings from the five different search strings (indicated in Table 1), combined with the inclusion and exclusion criteria, resulted in an initial 119 studies. These studies were combined and duplicate studies were removed, after which 102 studies remained.

3.1 Lean Management in Agriculture

Different, but complementary, results were found in the five different search strings, as explained in the following sections.

Table 1: Search protocol

Objective of study	To investigate whether Lean principles are applied in the agricultural industry.				
Search strategy	The search was limited to: • Journal articles, conference proceedings, books and book chapters, • Literature written in English.				
Databases	Scopus				
Inclusion criteria	Research regarding Lean implementations in agricultural industries				
Exclusion criteria	Biological Sciences Weight loss Lean Six Sigma studies Reference to “Lean” meat in the context of farming Reference to "lean agricultural season", "lean agricultural yield" or "lean agricultural periods"				
Quality assessment criteria	Repeatable and reputable scientific research methods should have been followed.				
Keywords	1	2	3	4	5
	"Lean agri*"	Lean AND agri	Lean philosophy OR Lean manufacturing OR Lean principles OR Lean implementation OR Lean production OR Lean management AND agriculture	Lean philosophy OR Lean manufacturing OR Lean principles OR Lean implementation OR Lean production Within the subject area: “Agricultural and Biological Sciences”	“Lean farm”
Results found	13	40	60	94	2
Inclusion and exclusion criteria applied	6	30	39	42	2
Duplicates removed	102				

3.1.1 Research protocol 1 – Lean Agri

When the phrase “Lean Agri*" was searched on Scopus, 13 results were found. Papers with the phrases "lean agricultural season", "lean agricultural yield" or "lean agricultural periods" were excluded since this referred to specific deficits in seasons (dry spells), profits and periods. After considering this, only six papers [1, 3, 6-9] remained that truly referred to the application of Lean principles in the agricultural industry.

3.1.2 Research protocol 2 – Lean AND agri

After search protocol 2 (Lean AND agri) was followed, 40 results were found. However, seven results were not agri-related since they referred to management practices or lean drilling techniques or lean seasons. Another 4 studies were removed since they referred to lean meat. The remaining 30 studies were considered further and are presented in the appendix.

3.1.3 Research protocol 3 – Lean XX AND agriculture

After searching, 60 studies were found. Of these results, 19 were not related to the study since they referred to electricity, government, agri machines/implements, and the automotive industry. One study was excluded since it referred to plant genetics and another study was excluded since Lean was only mentioned in future research. Overall, the remaining 39 studies met the inclusion criteria and are captured in the appendix.

3.1.4 Research protocol 4 – Lean in agri

After following the search protocol, 94 conference proceedings, journal articles and books/book chapters were found. Of these findings, 33 were not agri-related, since they referred to other industries such as healthcare, construction, aeronautical, marine, software development, research facility, green engineering, automotive, restaurants, and agile manufacturing. Another 6 studies were excluded since they referred to Six Sigma in combination with Lean. One study was excluded since it referred to human weight loss and six studies were excluded that referred to animal/plant genetics to grow lean plants or lean meats. Three studies were excluded because Lean was not the focus of the study, it was only part of a bigger study. Another three studies were excluded since Lean was only referred to in future research. Ultimately, 42 studies remained.

3.1.5 Research protocol 5 – Lean farm

The search protocol delivered two papers, which were both relevant to the study and are therefore presented in the appendix.

3.2 Lean applied to different agri-industries

Of the 102 studies, four studies focussed on Lean management in agriculture. Of the remaining 98 agricultural studies that incorporated Lean principles, the majority came from the food and beverage industry (41 studies) and the timber industry (14 studies), as indicated in Table 2 and Figure 1. The detailed citations per industry are presented in the appendix.

After the food and beverage industry and the timber industry, the next highest numbers were from the crops industry and mixed farms (8 studies each), the red meat industry (5 studies), textile, dairy and fruit industry (4 studies each) and the fertilizer industry (3 studies). Single Lean studies were found in the poultry, coffee, floriculture, horticulture, pesticides, vertical farming and equestrian industries. These have been grouped as “other”.

Table 2: Number of research studies per agri-industry

Agri industry	Nr of research studies
Food and Beverages	41
Timber	14
Crops	8
Mixed farms	8
Red meat	5
Textile	4

Agri industry	Nr of research studies
Dairy	4
Fruit	4
Fertiliser	3
Other	7
Total:	98

It is evident that Lean principles are being applied to a variety of agricultural industries. However, in the overall context of lean implementation, these are not a lot of studies.

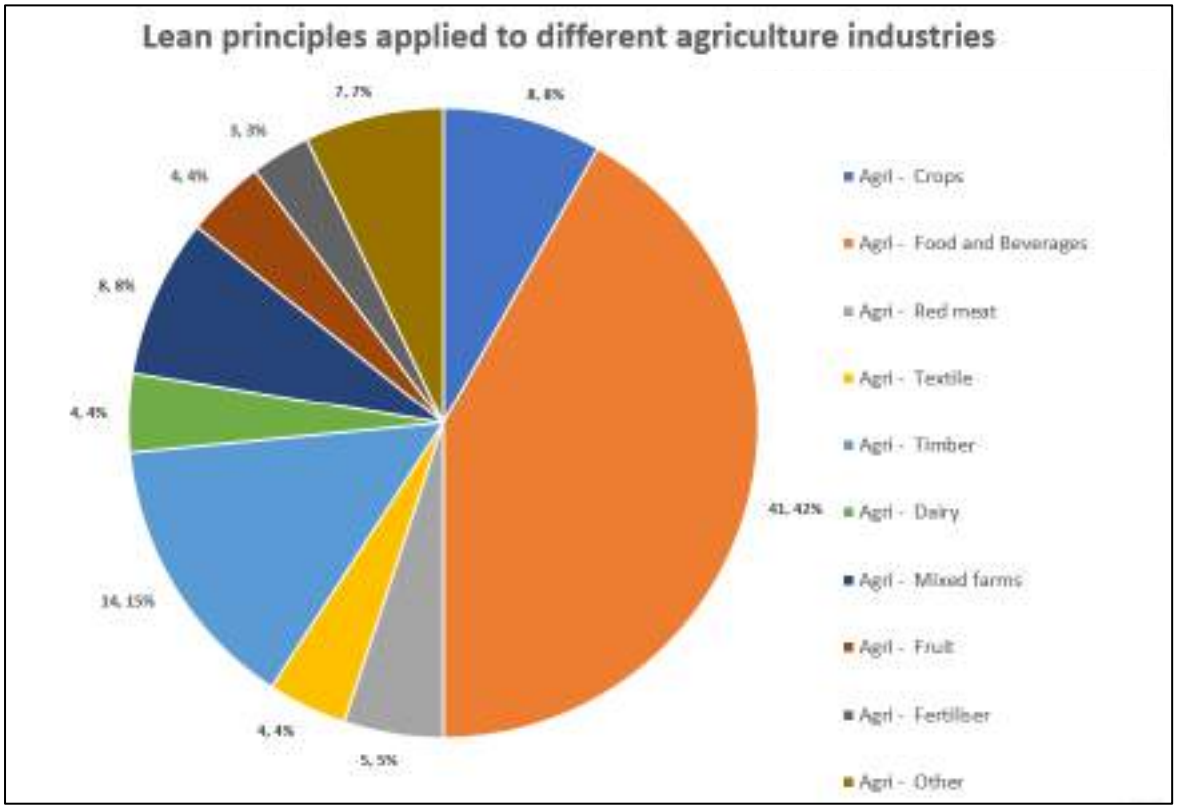

Figure 1: Lean principles applied to different agricultural industries

3.3 Authors

It emerged that there are a few prominent authors writing on the topic of Lean research in agriculture. Table 3 indicates the breakdown of the number of studies per first author, for the authors that published more than one study on the topic (as first author).

Table 3: Number of studies (if more than one) per first author

Authors	Nr of studies (As first author)
Caicedo Solano, N. E.	4
Melin, M. and H. Barth	3
Chen, H.	2
Dora, M.	2
Muñoz-Villamizar, A.	2
Pearce, D.	2

Authors	Nr of studies (As first author)
Taylor, D. H.	2
Zokaei, K.	2

Caicedo Solano, N. E. has four studies published [10-13] on using Lean principles for developing an operational model for minimising cost in agricultural systems. Sowing, cropping, and harvesting are usually treated independently. Waste and the sustainability of operations are generally not integrated into operational planning methodologies for agricultural production bBut Caicedo Solano [11] points out the need to have a clear and precise methodology to minimize waste in agricultural production systems to ensure sustainability. In this study, Lean manufacturing principles are used to identify agricultural operations and the variables that represent waste, build mathematical models, define constraints and illustrate the cost of waste, as well as its minimization through an objective function. In his 2022 study [10], he presents a mixed integer nonlinear programming problem model to solve the planning of agricultural production systems in the stages of sowing, crop maintenance and harvesting.

Melin, M. published two Lean studies done in Sweden. The purpose of the first study [2] was to develop a framework for Lean implementation in the agricultural sector, from an operational and strategic perspective. The study was conducted with a group of Swedish farmers. The aim of the second study [14] was to increase the understanding of Lean implementation in which value stream mapping (VSM) is used to create an action plan at a small dairy and cattle farm in southwest Sweden. Melin [15] also published a third paper (as the second author) to propose a Lean Implementation Framework that small and mid-size farms can use to increase production and profit and yet support environmental sustainability.

Chen, H., *et al*. published 2 studies [16, 17] on Lean supply chains in the agri-food industry. The first paper aimed to support food supply chain decisions to achieve lean performance (that is to reduce/eliminate non-value-adding activities, or "waste" in Lean terms) [16]. The second study aimed to explore an approach to integrating knowledge mobilisation within agri-food supply chains to enhance the collaboration of all value chain actors and achieve a holistic reduction of waste [17].

Muñoz-Villamizar, A. also focussed on the agri-food industry in three studies [18-20]. The first study [19] analysed the gaps and trends, and suggested approaches and methodologies that should be addressed by future studies for implementing Lean and Green management in the agri-food sector. According to Muñoz-Villamizar[18], environmental efficiency should not be treated independently of production efficiency. Therefore, the second study integrated existing methodologies and approaches from Lean thinking, Industry 4.0 and mathematical optimization, and presented a toolkit for integrating, measuring, controlling and improving production and environmental performance in companies. The third study [20] presented a multi-case study in the agri-food industry in which water consumption in company activities is monitored, allowing them to improve their industrial processes based on Lean and Green practices, leading to a zero-waste strategy for this critical resource.

Pearce, D. has been involved in 4 studies in different countries to apply Lean principles in the food industry [21], horticulture [8, 22] and the dairy industry [23]. For the food industry, a systematic review (of 24 studies) was used to show the potential of Value Stream Mapping (VSM), not only to identify and reduce food losses and wastes but also to establish links with nutrient retention in supply chains. The horticulture study [22] determined the factors that drive sustainable performance through the application of Lean methods in the primary production segment of the supply chain for apples and pears. The South African study on horticulture [8] investigated the relationship between patterns of Lean practice implementation, farm size and sustainable performance among fruit horticultural primary producers in South Africa. Lastly, the dairy value chain was investigated in Uganda and used

Value Stream Mapping (VSM) analysis to identify hotspots and analyse the magnitude of both food and nutritional losses in the food value chain.

In 2014, **Dora** [24] stated that a very limited number of studies have focused on the implementation of Lean manufacturing practices within small and medium-sized enterprises (SMEs) operating in the food sector. The study then analysed the status of Lean manufacturing practices and their benefits and barriers among European food processing SMEs. Dora warned that Lean in agriculture provides a different set of challenges due to seasonal variability, bulk production, processing and problems in handling and storage. The study identified and categorised Lean waste and created a Lean implementation readiness index based on the operations management literature. Dora was also a co-author with Pearce, D. on the two horticulture studies [8, 22] as well as the systematic review of the food industry [21] and the value chain study of the dairy industry [25]. Preceding the dairy study of 2019 [23]. Dora also took part in the 2018 study [25] during which a survey was conducted among 246 supply chain actors about their general understanding of nutrition-sensitive agriculture while linking it with food and nutrient loss or waste reduction strategies.

Taylor, D.H. published two studies on applying lean in the agri-food industry. The first study [26] develop an innovative methodology to apply Lean value chain improvement techniques to a complete supply chain for a food product from farm to consumer. The second study [9] showed how value chain analysis techniques have highlighted opportunities for strategic change in a UK agri-food supply chain and presented an initial model of an integrated supply chain based on the application of lean principles.

Zokaei, K. investigated Lean implementation in the red meat industry[27, 28] and the agri-food industry [29]. The first red-meat study [27] highlighted the benefits of Lean production in one specific manufacturing area, the “cutting room”, where meat is split down from a carcass into retail cuts of meat. The second red meat study [28] continued to highlight the benefits of Lean production techniques in different stages of the red meat value chain and reported 2- 3% potential cost savings at each stage of the chain. The agri-food reference by Zokaei [29] is a book chapter in Delivering Performance in Food Supply Chains. The chapter reports on the findings from a major research project (33 extended supply chains) into the UK agri-food industry over a period of four years and across four primary food sectors (cereals, red meat, horticulture and dairy).

3.4 Lean farms

From the above search results, Lean Agri is applied mostly in production/manufacturing type environments like the food and beverage industry and the timber industry.

Agri-industries that are more farm-based are on the lower half of the results, such as crop production, mixed farms, the red meat industry, dairy and fruit industries.

Already in 2015 Dora [1] pointed out that there had been little literature and understanding of Lean in the context of agriculture and specifically farming. It appears that this was the first study that pointed towards lean farming (as opposed to Lean Agri in general).

During the literature search, only six studies [30], [1], [7], [15], [31], [32] referred to implementing Lean specifically on farms (not agri-processing industries). And when searching the term “Lean farm”, only two studies were found [30] [33].

3.5 Publication years

Without limiting the search to any period, the search results are spread between 2004 and 2023 (Figure 2). Since 2004 there has been a steady increase in the number of publications, with the highest number of publications (18) being in 2020. The publications of 2021 focussed on food and beverage (3 studies), mixed farming (3 studies), lean agri management (2 studies),

timber (1 study), crops (2 studies), textile (1 study), dairy (1 study), fertilizer (1 study), fruit (1 study) and three "other" studies.

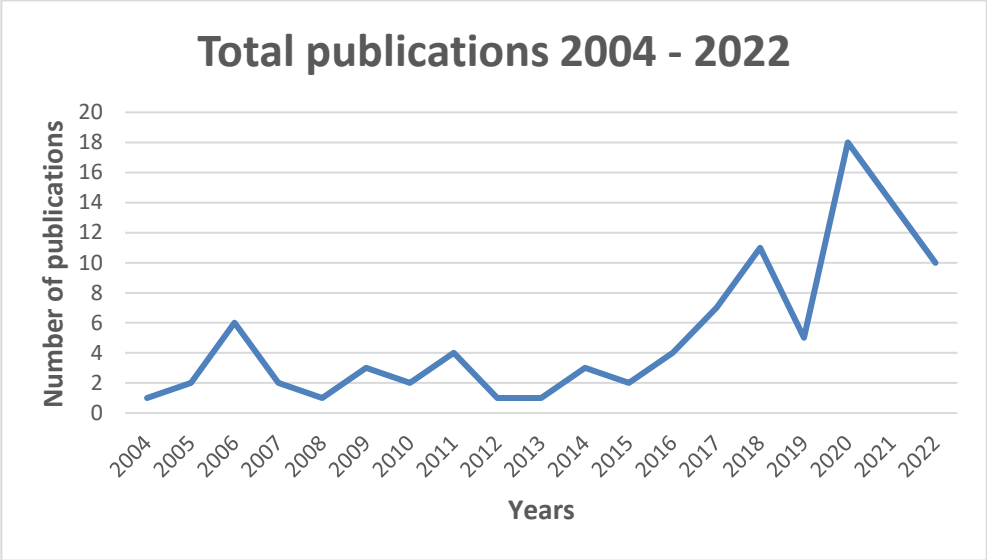

Figure 2: Total publications for the search period

The industries that have more than one citation per year are highlighted in Table 5. There seems to have been an increase in publications over the years, specifically in the food and beverage industry, crops, timber and mixed farming.

3.6 Title of studies

Given the titles of each of the 102 studies (presented in the appendix), a word cloud (Figure 3) of the 100 most used words was generated to illustrate the most pronounced themes of ideas captured by authors.

From Figure 3 the most used words (except for "lean") are: value, agri-food, food, management, supply, development, production and sustainable. This is indicative of the change and focus that Lean agriculture offers the community by adding value. Support is provided to management and supply chains to increase production. Moreover, lesser-used phrases like "reduction", "modelling", "improving", "integrating", "adoption", "strategy" and "design" also indicate the offering of lean-focused principles in agriculture by highlighting the benefits.

Table 4: Search results per agri-industry per year

	Crops	Food and Beverages	Red meat	Textile	Timber	Dairy	Mixed farms	Fruit	Fertiliser	Other	Total
2004					1						**1**
2005		1	1								**2**
2006		1	2		2					1	**6**
2007	1		1								**2**
2008					1						**1**
2009		1			1				1		**3**
2010		1			1						**2**
2011		2			1	1					**4**
2012		1									**1**

	Crops	Food and Beverages	Red meat	Textile	Timber	Dairy	Mixed farms	Fruit	Fertiliser	Other	Total
2013		1									**1**
2014		2							1		**3**
2015							1				**2**
2016		1		1	1		1				**4**
2017		6				1					**7**
2018		1		1	2	1	2			3	**11**
2019	1	4									**5**
2020	2	3		1	1	1	3	1	1	3	**18**
2021	1	7	1	1	2			2			**14**
2022	1	7					1	1			**10**
2023	2	2			1						**5**
Total	**8**	**41**	**5**	**4**	**14**	**4**	**8**	**4**	**3**	**7**	**102**

3.7 Keywords of studies

When looking at the details of the 102 studies, it was clear that there was a trend in the keywords used by authors. Thus, an analysis was conducted on the total number of occurrences of each keyword of the studies. Figure 4 depicts a clustered bar graph indicating the total count of keywords.

As indicated in Figure 4, the most common keywords (except for “lean”) are “food”, “manufacturing”, “production”, “supply chain”, and “sustainability". This corresponds to the earlier discussions which identified the focus of the majority of the studies. It is evident that the studies emphasise the improvements and integrations that the lean philosophy has to offer the agricultural industry.

Figure 3: Word Cloud of literature titles

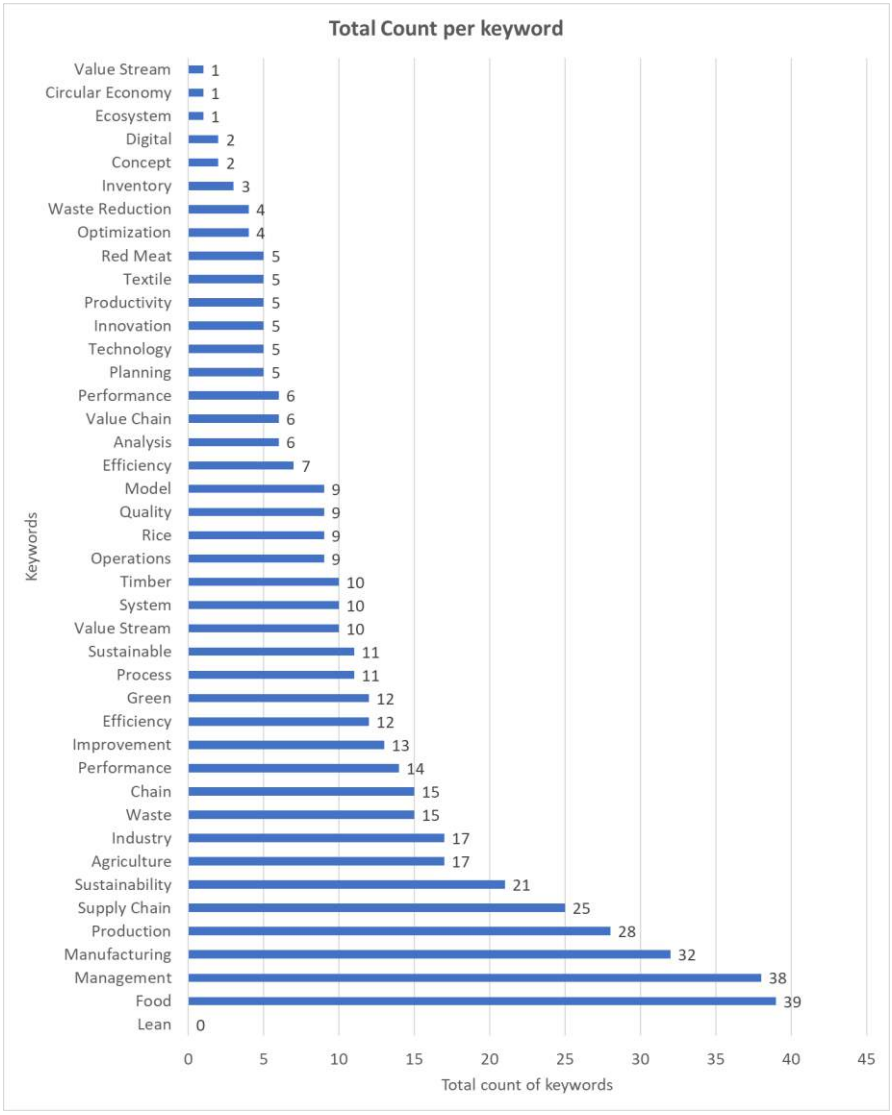

Figure 4: Clustered bar graph indicating the total count per keyword

4 VALIDATION

To ensure that the rapid literature review is valuable to users, a transparent complete, and accurate account of why the review was done, what was done, and what was found, was presented in the study [34].

Furthermore, an adapted version of the PRISMA checklist [34] is used for validating the review conducted in this study (

Table 5). As can be seen from the checklist in

Table 5, this study adequately addressed the data gathering and data analysis phases of the research and the results and discussion of the various aspects of the study were adequately presented.

Table 5: PRISMA checklist for validation

Section and Topic	Checklist item	Section where the item is reported
INTRODUCTION		
Rationale	Describe the rationale for the review in the context of existing knowledge.	1.
Objectives	Provide an explicit statement of the objective(s) or question(s) the review addresses.	2.1.
METHODS		
Eligibility criteria	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	2.1.
Information sources	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	3.
Search strategy	Present the full search strategies for all databases including any filters and limits used.	2.1.
Data collection and selection process	Specify the methods used to decide whether a study met the inclusion criteria of the review.	2.1
Synthesis methods	Describe the processes used to decide which studies were eligible for synthesis.	2.1.
RESULTS		
Study selection	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	2.1.
Study characteristics	Cite each included study and present its characteristics.	Appendix
Results of syntheses	Present the results of all investigations of possible causes of heterogeneity among study results.	3
DISCUSSION		
Discussion	Provide a general interpretation of the results in the context of other evidence.	3
	Discuss any limitations of the evidence included in the review.	6
	Discuss any limitations of the review processes used.	6
	Discuss the implications of the results for practice and future research.	6
OTHER INFORMATION		
Support	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	NA

5 CONCLUSION

This study utilised a rapid review for unearthing 102 different Lean Agri puzzle pieces across different agricultural industries. For example the food and beverage industry, timber, crops, mixed farms, red meat, textile, dairy, fruit, poultry, coffee, floriculture, horticulture, pesticides, vertical farming and equestrian were identified). Solving the puzzle highlighted the different possibilities of lean applications within agricultural industries.

This study found that many authors are well-known for publishing in the lean-agri space. It will be interesting to see how these researchers further develop the discipline in the future.

It was also found that most studies made use of “food”, “manufacturing”, “production”, “supply chain” and “sustainability". This is evident in the improvements and integrations that the Lean philosophy has to offer the agricultural industry.

A few studies were found on the topic of lean management, indicating future (and needed) research in this area, as opposed to just the technical application of Lean in agri.

It was also found that Lean Agri is applied primarily in production/manufacturing type environments, like the food and beverage industry and the timber industry, and less on farm-based operations. It seems that little research has been done on understanding lean farming (as opposed to Lean Agri in general).

Given the upward trend and increase in publication over the years, it is evident that Lean-Agri is ascendant but more research is needed to further highlight its value and range of applications.

6 LIMITATIONS AND FUTURE RESEARCH

A rapid literature review allows for the review of a large body of literature. However, it may include limitations due to shortened timeframes, such as a lack of depth of analysis in the findings of each article, challenges in repeatability of the study and the potential for bias in interpretation of results [4].

Future research should now continue with a thorough systematic literature review to investigate the details of each study, as well as retrieve any studies that were missed.

While this study provided a full presentation of the current research of 102 studies, it did not focus on the detail of each of the studies. Future research should investigate the specific lean principles that were applied in each study. This will provide further guidance on the required research into Lean Agri.

This study has pointed out the application of lean in different agri-industries. It is suggested that future research focus on the in-depth analysis and investigation of each of the industry applications of Lean-Agri to determine the focus of further research.

It is commonly understood that Lean philosophy is quite popular in many spaces as there are numerous search results on academic databases yet, only 102 studies were found in the Lean agriculture space. It is worthwhile investigating why lean implementation is lagging behind in this application field.

The highest search results were found in the food and beverage industry and the timber industry, both of which are very “production-like” industries. Future research should focus on the application of Lean principles in non-production farm-based environments, eg. crop production, mixed farms, the red meat industry, the textile industry, dairy, fruit, and the fertiliser industry. Only two studies were found using the phrase “Lean farms”. Future research should further investigate this concept and what a Lean farm would entail, by definition.

While there are several limitations to the study, it is important to understand the value that Lean philosophy can bring to any industry, especially agriculture. With the agricultural industry being one of the largest contributors to the South African GDP, it must continue to

develop and grow for the betterment of the country. Lean offers an advantage that is worth more investigation and implementation in South Africa. Future research should explore the increased use of Lean-Agri in South Africa.

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APPENDIX

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