TOWARD SUSTAINABLE PRIMARY PRODUCTION THROUGH THE APPLICATION OF LEAN MANAGEMENT IN SOUTH AFRICAN FRUIT HORTICULTURE

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Abstract:

This paper aims to understand the relationship between patterns of lean practice implementation, farm size and sustainable performance among fruit horticultural primary producers in South Africa. Utilizing a comprehensive lean framework, addressing 10 lean practice dimensions, the authors collected data from a sample of 132 fruit farming operations in South Africa. First, cluster analysis was applied to identify distinct clusters of farms with common lean practice implementation characteristics. Next, the distinct clusters were tested to identify significant differences in lean practice implementation and sustainable performance, with farm size incorporate as a control variable. In terms of common lean implementation characteristics, the analysis identified two distinct clusters of farms, labelled as the high lean practice cluster and the low lean practice cluster. It is determined that these two clusters differ significantly in practice implementation across all 10 dimension of lean management practice. It is further established that the two clusters differ significantly in terms of sustainable performance. Furthermore, Farm size is found to significantly differentiate (i) lean practice implementation across 5 of the 10 lean practice dimensions and (ii) levels of sustainable performance between medium and large sized farms. This empirical analyses of lean practices and sustainable performance outcomes in the primary production domain represents a novel contribution to the existing literature on lean management and horticultural management.

Highlights:

- Lean management implementation is a determinant of sustainable performance in horticultural primary production.
- Farm size significantly sustainable performance outcomes, but the effects are only significant for relatively larger farming operations.
- Farm size significantly influences lean implementation, but only for 5 of the 10 lean practices dimensions considered.
- The findings further allude to a set of market leading growers, who operate at a higher degree of lean managerial professionalism than the general universe of primary producers.

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1. Introduction

Trade liberalization and technological progress over recent decades has driven substantial transformation in global agriculture, opening markets and driving down the cost of cross border trade (Peter et al., 2018). For South African fruit producers, these trends have ushered in an era of unparalleled export market potential (Alford, 2016). However, these lucrative export prospects have brought with them the commensurate challenge of operating in the competitive international arena (Trienekens, 2011). In a bid to compete effectively the South African fruit sector has seen sizeable investments into the development of infrastructure, technology and systems of management (Ducastel and Anseeuw, 2017). In terms of systems of management, lean methodologies have been promulgated to suppress costs, improve efficiency and drive continuous improvement in operational sustainability (Wiltshire, 2018). However, at the level of primary production, industry efforts to stimulate lean adoption have taken place in a highly fragmented and selective (i.e., piecemeal) manner (Pearce et al., 2018). This has, over time, resulted in a gap in understanding, both of the lean practices as they have diffused within the sector and of the performance benefits which they confer. Now, as South African producer groups contemplate a more formalized and systematic approach to lean adoption, a need has emerged to establish both a clearer understanding of lean practice prevalence within this domain, as well as for a deeper understanding of the performance benefits, if any, which have resulted.

Originally developed by the Toyota Corporation for use in automotive manufacturing, lean is a system of management premised on maximizing value whilst eliminating waste (Holweg, 2007). Presented as an integrated set of self-reinforcing practices, the lean system has demonstrated a remarkable capacity to suppress costs whilst simultaneously improving product quality and delivery (Negrao et al., 2017). Moreover, through its core focus on waste elimination, the lean system has been shown to be highly supportive of organizational sustainability (Cherrafi et al., 2016). The successes of lean have seen the system adopted and adapted across a range of productive contexts (Marodin and Saurin, 2013). Within this broader picture, agricultural primary production represents a somewhat newer domain of consideration. The diffusion of lean into agricultural primary production has manifest in a small but growing body of literature investigating the application of lean in this area. To date a small constellation of exploratory studies have identified various benefits including cost savings (Zokaei and Simons, 2006), reduced production waste (Colgan et al., 2013) and improved food quality (Pearce et al., 2018). Nevertheless, the existing body of work is entirely exploratory in nature, being comprised of eight case-based studies and two small-sample mixed method studies *(See Table 1)*. The identified benefits of lean in primary production have yet to be demonstrated empirically. This remains as a key gap in the literature, and a potential constraint to extending and legitimizing research in this area. There is thus a need within the scientific literature to provide firmer evidence for the performance benefits of lean in primary production, and for a deeper understanding of the conditions under which its application would be effective.

Consequently, it is the objective of this study to contribute to the literature by conducting an empirical analysis of the performance benefits of lean management in fruit horticultural primary production. The specific research questions investigated by this study are as follows: Firstly, what is the latent prevalence of lean management practices as applied among fruit growing operations in South Africa? Secondly, does the application of lean management practices influence the sustainable performance of grower operations? The proceeding sections of this paper, purposed to address these questions, have been arranged as follows: Section two provides expository background to two key areas, the origin of lean practices and their diffusion into the field of agricultural management followed by the background to the South African fruit horticultural sector. Section three details the methodology employed in the design of this study, whilst section four looks to outline the basic findings and discussion related to the analysis. Lastly, the fifth and final section closes with conclusions, limitations of the study and some possibilities for future research.

2. Background

2.1 Lean Management and Lean Agriculture

Lean management, also known as lean manufacturing or lean production, is a managerial approach conceptualized by the Toyota Motor Corporation (TMC) over the latter half of the 20th century (Holweg, 2007). Premised on the notion of maximizing value whilst eliminating waste (Shah and Ward, 2007), the lean system has shown demonstrable success in suppressing costs whilst simultaneously improving quality and delivery across a range of productive contexts (Marodin and Saurin, 2013). Furthermore, with this central premise of waste elimination, the lean system has been shown to be highly supportive of sustainability strategies and practices (Pearce et al., 2018). In this respect, the lean literature has demonstrated various sustainable performance benefits, including reduced environmental impact (Ioppolo et al., 2014) and reduced non-compliance risk (Zhu and Sarkis, 2004). Presented as an integrated configuration of mutually reinforcing practices, the lean system's association with superior performance is well accepted among academics and practitioners alike (Negrao et al., 2017). Moreover, the literature emphasizes that it is the self-reinforcing aspect of lean practices, when effectively configured, that contribute to the non-linear synergistic effects associated with the system (Shah and Ward, 2003). The successes of lean have seen the system adopted and adapted across a range of contexts, including various forms of manufacturing, healthcare, and services sectors (Holweg, 2007).

This study adopts a comprehensive framework of lean management developed and validated by (Shah and Ward, 2007) which specifies 10 dimensions of lean management (The specific composition of which is further outlined in section 3.1). This holistic framework serves two key purposes. Firstly, as lean is a multi-dimensional system encompassing a wide variety of management practices, explicit definition of the framework's dimensions is necessary to avoid semantic confusion which may act to impede empirical testing (Shah and Ward, 2007). Secondly, conceptual studies acknowledging the integrated nature of lean practices underscore the importance of empirically inspecting the multiple dimensions of lean programs simultaneously (Marodin and Saurin, 2013). In this respect, the Shah and Ward (2007) framework provides a holistic encapsulation of the lean system, addressing both the internal and chain-oriented dimensions, as well as the social and technically oriented dimensions of the system. However, the specific benefit of this framework, sought for the purposes of this study, is that it defines the core concepts of lean and associated practices in a generally applicable framework and not one that is context (i.e., manufacturing) specific. As is argued by Voss et al. (2016) it may be beneficial for a theory of management to be adaptive to different contexts, stating that the use of a more general theory is useful in that context specific logic is less likely to manifest as a barrier to its application. As agricultural primary production represents a relatively new context for empirical lean performance analysis, this particular framework was identified as being the most suitable for this study.

Table 1: Summary of literature addressing the application of lean management in agricultural primary production.

Author:	Method:	Commodity:	Benefits:	Barriers:
Barth and Melin (2018)	Small Sample, Mixed Method	Dairy, Meat, Crops	- Optimize use of production inputs - Reduced changeover time	- Lack of manager / employee buy-in
Melin and Barth (2018)	Small Sample, Mixed Method	Dairy, Meat, Crops	- Cost reduction through control of waste - Improved safety awareness - Reduced feed shortages	- Production process is inherently unstable (climatic and biophysical) - Long lead times in production
Pearce et al. (2018)	Case Study	Fruit (Apples and Pears)	- Improved yield and quality - Improved workforce productivity - Improved inputs use efficiency - Reduced non-compliance risk w.r.t. sustainability standards	- Seasonal batch production - Volatility in operating context - Smaller farms resource constrained - Language barriers with workforce
Colgan et al. (2013)	Case Study	Multi-Commodity Farm	- Reduced waste and improved quality of food	- Chain power regime determines who reaps benefits of lean
Cox et al. (2007)	Case Study	Red Meat	- Some (minimal) commercial returns to producer end of the chain	- Lack of long-term price stability and certainty for producers
Simons and Taylor (2007)	Case Study	Red Meat	- Logistical benefits along the chain	- Inter-company alignment of systems - Chain organizational instability
Taylor (2006)	Case Study	Red Meat	- Positive logistical benefits along the chain	- Requires Equitable and explicit benefits sharing framework
Zokaei and Simons (2006)	Case Study	Red Meat	- 2-3% cost savings at each stage of the chain	- Unpredictability of the interaction of operational improvements
Simons and Zokaei (2005)	Case Study	Red Meat	- 25% productivity difference between lean & non-lean producers	- Chain fragmentation - Carcass is multi-product commodity
Cox and Chicksand (2005)	Case Study	Red Meat	- Internal productivity benefits	- Inter-organizational aspects difficult to apply

Over the last 10 to 20 years, lean and continuous improvement methodologies have found interest in agriculture, where interest has emerged as a byproduct of the shift toward industrialization of the domain (Pearce et al., 2018). This interest is evidenced by the emergence of sectoral initiatives in countries such as South Africa (Pearce et al., 2018), the United Kingdom (Colgan et al., 2013) and Sweden (Melin and Barth, 2018), seeking to understand the potential benefits of lean to primary production. Moreover, this interest has emerged in the scientific literature as evidenced by a small but growing body of research investigating lean in primary production, which has been summarized in Table 1. A study by Higgins et al. (2007) noted at that time that the application of operations management (OM) methodologies in primary production had been limited due to the complexity of the context. However, more recent studies note that increasing food prices in combination with increasingly constrained agricultural productive capacity are driving a renewed focus on functionality and sustainability in primary production (Dethier and Effenberger, 2011). Pearce et al. (2018) argues that the particular attributes of the lean system are a good fit with the needs of the agricultural sector. They contend that the anthropocentric and pragmatically hands-on nature of the lean system is a good fit with the operational needs of farmers. They furthermore highlight that the inherent focus on waste elimination is strongly aligned with the agricultural need to reduce operational waste, whether it be in the form of inefficiently utilized labor, food waste, water, energy, or inputs to production such as fertilizer and other chemical applicants. As is noted by Barth and Melin (2018) waste reduction for farmers directly corresponds to the suppression of costs, and therefore the operational profitability of any given farming operation.

2.2 Fruit Horticulture in South Africa

The South African fruit agricultural sector has, in these last 30 years, rose to a position of significance as an exporter of fresh fruit and other horticultural products to the greater global agri-food economy. This developing country is the 2nd largest producer of fresh fruit in the southern hemisphere, operating as the global 6th largest exporter of apples and plums, and the 5th largest exporter of pears (Hortgro, 2019). Driven by both global and national trends, South African fruit horticulture has, in the last 3 decades, seen significant evolution of structure, strategy and practice. Deregulation in 1996 saw the loss of state support and elimination of the single state controlled marketing channel (Trienekens and Willems, 2007). This development signaled the opening of and integration into the global market which brought with it substantial high-margin export market opportunity (Kritzinger et al., 2004). Nevertheless these reforms had the added consequence of opening up South African producers to the fierce competition and strictly enforced production standards which define the international export market (Alford, 2016). There, the stated production standards include not only the quality of the horticultural produce, but also the requirement to produce in compliance with sustainable environmental and ethical labor practice standards (Pearce et al., 2018). In the earliest years after deregulation, competitiveness of South African fruit horticulture was largely supported by productive efficiency in primary production (Boonzaaier and Van Rooyen, 2015). Meanwhile, studies conducted at the time identified that downstream elements of the chain were less competitive, characterized by high costs, chain fragmentation and a lack of coordination (Esterhuizen and Van Rooyen, 1999; Van Rooyen, 2008). The overarching conclusion being that the commodity chain as a whole was constrained by inconsistency in performance and quality. As a response, the proceeding period saw significant investments from industry as well as external sources toward developing the competitiveness of the chain (Conradie et al., 2009). This included investments into infrastructure, technology, and systems of management, resulting in extensive industrialization of the sector. With respect to systems of management and coordination, Wiltshire (2018) presents that lean methodologies were used to suppress costs, increase quality, and boost overall competitiveness. During this period, the sector saw significant investment in lean strategies, chain structures and on-farm practices with the objective to reduce cost, standardize practices and flexibilise the workforce (Pearce et al., 2018; Wiltshire, 2018).

South Africa's systems of horticultural cultivation are largely conventional with operations that are inherently labor intensive. Due to the meticulous requirements of fruit cultivation and the sensitivity of fruit to bruising and damage, orchard maintenance and fruit harvesting processes are all done by hand (Wiltshire, 2018). Consequently, a fruit farm's workforce is simultaneously the most essential, expensive and regulated input to production (Pearce et al., 2018). Followingly, the effective management of employed labor toward attaining a productive and financial return is given top priority across the sector as a whole. Though the specifics of estate management differ from farm to farm, the overarching approach to production is largely standardized across a range of operational practices, including orchard maintenance, workforce management, and harvest processes which include the associated quality controls (Pearce et al., 2018). Lean as it is applied in fruit horticulture is largely centered on the effective management of activities internal to the farm, whilst coordinating those internal activities with the needs and requirements of the chain. As is noted by Pearce et al. (2018), fruit producers are required to comply with procedural and product quality specifications at the point of aggregation, the packhouse, which is the entry point to the supply chain. Meeting those specifications requires that producers adhere to strict operational protocols in orchard maintenance and harvest processes.

In terms of standardizing practices across the producer base, Pearce et al. (2018) states that fruit sector associations (linked to the various fruit subtypes) together with the large integrated cooperatives play an important role in promulgating operational practices. Protocols and standards for environmental sustainability and ethical labor practice are specified, promoted, and audited (i.e., self-reported non-third-party audits) by the Sustainability Initiative of South Africa (SIZA), the official fruit sector sustainability body in South Africa. Verification audits are undertaken by external 3rd party companies, who play an essential role in authenticating production standards on behalf of retail buyers (Striebig et al., 2019). Here the standards for ethical labor practice address child and forced labor, freedom of association, discrimination and abuse, general health & safety, working hours, remuneration and other terms of employment. Further, the standards for environmental sustainability address compliance and environmental risks related to water, soil, energy, materials & waste, and ecosystem biodiversity.

3. Research Design & Methodology

3.1 Theoretical and Analytical Framework

This study adopts the operations management practice contingency research (OM PCR) model by Shah and Ward (2007) who holds that a fully developed contingency model should account for three sets of variables, (a) practices, (b) contingency factors relevant to the context of application and (c) the resultant performance outcomes (Sousa and Voss, 2008). The OM PCR model is rooted in contingency theory, an organizational theory which holds that the optimal mode of operation is contingent on the setting in which the firm operates. This theory is premised on the notion of fit, which may be defined as the suitability of composition or quality for a required purpose. Contingency theory holds that suitability of fit is directly proportional to performance, and that organizations should adapt to achieve fit. The OM PCR model is useful in that it may produce advice on which practices an organization should adopt to obtain or improve fit. However, a limitation of this model is that it is unable to establish why certain practice configurations lead to better performance outcomes than others (Sousa and Voss, 2008).

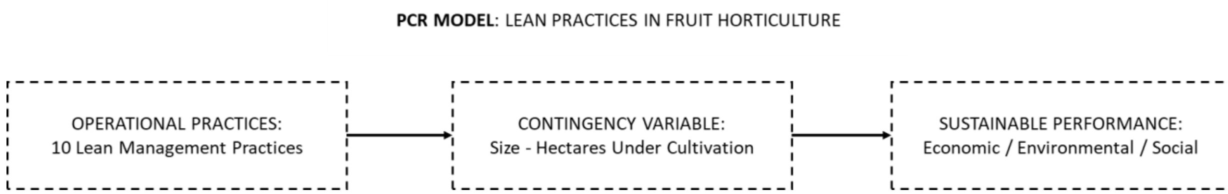

Figure 1: Theoretical and analytical framework to investigate the performance benefits of lean management in fruit horticultural primary production

The practices component of the OM PCR model developed for this study incorporates an adaptation of the Shah and Ward (2007) framework of lean management. Following the scale adaptation process set out by Shah and Ward (2007) and Morris and Lancaster (2006) the original framework was adapted for use in fruit horticulture using the contextual contingency map and detailed lean operating rationale provided by Pearce et al. (2018). The adapted framework specifies 10 dimensions of lean management, encapsulated as 2 supplier-oriented, 2 customer-oriented, and 6 internally oriented dimensions of lean management as summarized in Table 2. Each of these 10 operational dimensions are comprised of 3 operational measures, where the operational measures each represent a specific operational activity or practice. Followingly, the 10 operational dimensions of this framework are together comprised of 30 operational measures. The size of the farming operation stated as hectares under cultivation is incorporated into the model as the control (i.e., contingency) variable. Size is a commonly included control variable incorporated into empirical OM analysis, as it has been demonstrated to moderate the relationship between lean implementation and performance outcomes (Sousa and Voss, 2008). Moreover, Ren et al. (2019) states that farm size is a significant influential factor in the sustainable performance of agricultural operations though they emphasize that the specific causal mechanisms and magnitude of effects are not well understood.

Table 2: Detailed delineation of the Shah and Ward (2007) lean management framework

MAIN FRAMEWORK:	LATENT DIMENSIONS:	OPERATIONAL DIMENSIONS:	OPERATIONAL MEASURES:
LEAN MANAGEMENT FRAMEWORK	1. SUPPLIER RELATED	1. SUPPLIER FEEDBACK	3 x Measures
		2. DEVELOPING SUPPLIERS	3 x Measures
	2. CUSTOMER RELATED	3. INVOLVED CUSTOMERS	3 x Measures
		4. PULL	3 x Measures
	3. INTERNALLY RELATED	5. FLOW	3 x Measures
		6. LOW SETUP	3 x Measures
		7. CONTROLLED PROCESSES	3 x Measures
		8. TOTAL MAINTENANCE	3 x Measures
		9. INVOLVED EMPLOYEES	3 x Measures
		10. SIGNALLING / KANBAN	3 x Measures

The measure of sustainable performance is incorporated into the model through 3 self-reported items addressing economic viability, environmental sustainability, and ethical labor practices, respectively. These are collated into a single multi-item performance measure which for the purposes of this study is labeled as “sustainable performance”. These indicators were selected to align with the working definition of sustainable performance put forth by Carter and Rogers (2008) who state that a sustainable organization is an organization that understands and manages the economic, environmental, and social risks resulting from its operations. To measure economic viability, growers were asked to rate the likelihood of their operation turning an operating profit in the next season coming. In terms of environmental sustainability, respondents were asked to rate the likelihood of obtaining the highest rating in their next environmental audit. Likewise, for ethical labor practices respondents were asked to rate the likelihood of receiving the highest rating on their next social / labor audit. Collectively, this multi-item indicator assesses the ability of a given farming operation to attain an operating profit whilst managing sustainable environmental and ethical labor practice requirements. Furthermore, these indicators comply with the 3 sustainability indicator selection criteria set out by Lebacq, Baret and Stilmant (2013) in terms of (a) being relevant to the context, (b) practicability in terms of being specific, measurable, and attainable, and (c) being appropriate and comprehensible to stakeholders.

3.2 Instrument Development

The stated lean dimensions, contingency factor and measure of sustainable performance were incorporated into an instrument to survey fruit growers. The 30 lean operational measures and 3 sustainable performance measures were inserted into the instrument as Likert-type items, together forming 10 lean and 1 sustainable performance multi-item rating scales. The decision to utilize multi-item scales rather than single-item scales was based on the guidelines provided by Diamantopoulos et al. (2012) who advises that multi-item scales be used when the sample size is greater than 50 and when cross-item correlations are expected to exceed 0.30, as is the case in this study. The draft instrument was subjected to rigorous review, firstly, by a panel of experts and secondly through a pilot survey. Comments and feedbacks from these experts, as well as feedback from pilot survey respondents were utilized to guide amendments to the instrument. Procedural remedies including mixing the order of the questions and the use of different scale types were utilized to minimize the influence of common method variance (Chang et al., 2010). The final draft of the survey was kept short, taking approximately 5 minutes to complete. Cronbach’s Alpha was utilized to check the reliability of the resultant data obtained, exceeding the minimum value of 0.60 set for acceptability (Santos, 1999).

3.3 Data Collection

A total of 967 farmers were contacted, of which 132 interviews were successfully implemented to completion, concluding as a response rate of approximately 14%. This excludes those interviews undertaken to pilot the development of the questionnaire. The sample was drawn from several fruit growing regions across South Africa, representing a broad set of fruit commodity types. Following the recommendations of Zhou (2016), interviews were limited to senior management staff, including involved estate owners, estate managers and supporting general operations managers. The survey was implemented utilizing the telephonic survey method. Due to the geographic distribution of the sample population, this survey approach was deemed to be the most practical for the available time and budget. The advantages of the telephonic approach include affordability and convenience of administration, whilst disadvantages include resistance in terms of the time limitations of the respondents and barriers of perceived trust (Dillman et al., 2014).

3.4 Data Analysis

Data analysis, following the approach outlined by Marodin et al. (2016), progressed through 3 phases; basic statistical delineation, cluster analysis, and analysis of variance utilizing the ANOVA (analysis of variance) and MANCOVA (multiple analysis of covariance) models respectively. The ANOVA family of statistical models, of which MANCOVA is a member, is a collection of statistical models used to test for significant differences between the means of groups, where groups are defined by levels within the independent variable/s (Hair et al., 2014). Basic descriptive statistics were generated, seeking to delineate the general structure of the obtained sample, and to show the status of each of the 10 lean practices in use across the sample. Next, cluster analysis was applied to identify distinct clusters of growers based on levels of lean implementation. Cluster analysis was first carried out using hierarchical clustering based on Ward's method to determine the optimal number of clusters. This was then followed by a second round of clustering using the k-means clustering approach to refine the composition of the clusters (Hair et al. 2009). This approach is recommended by Ketchen and Shook (1996) to maximize homogeneity within clusters and heterogeneity between clusters. The 3rd phase of data analysis took place in two parts. Firstly, MANCOVA was used to test for significant differences in lean practice implementation scores across the 10 dimensions of the lean practice framework (the dependent variables), between the two groups defined by the high and low lean implementation clusters (the independent variable), whilst controlling for variation attributable to farm size (the covariate). Secondly, ANOVA was used to test for significant differences in sustainable performance scores between levels of 2 factors; the independent variables defined by the high and low lean implementation clusters (factor 1) and the small, medium, and large categories of farm size (factor 2). Tests for linearity, normality and homogeneity of variance / covariance were conducted and confirmed (Hair et al., 2009). Shapiro-Wilk was used to evaluate normality, linearity was tested through plots of partial regression for each of the lean practices, and Levene's Test was used to assess homogeneity of variance / covariance.

4. Results and Discussion

4.1 Sample Overview

The 132 fruit growing estates surveyed for this study account for a total of 5,509 hectares under cultivation. Mean and median values for the number of hectares under cultivation per estate are calculated at 41.73 and 33.50 hectares, respectively. The sample includes more than 20 different kinds of fruit including deciduous, citrus, and sub-tropical types; the proportions of which are summarized in Table 3. These reported figures for farm size and fruit crop composition lie approximately within the reported statistics for the sector. Whilst the study focused purely on farming estates engaged in the commercial production of fruit, a sizeable proportion of the sample engaged in other commercial activities including livestock farming, production of animal feed, vegetables, and non-fruit crops, agri-processing, and hospitality related services. This is in line with the general literature that most farms are multi-product enterprises (Chavas et al., 2010). Within the sample, general awareness around lean management is relatively low, where approximately 15.9% of respondents indicated an awareness of the lean management system. In contrast, the general awareness of continuous improvement was considerably higher, with 59.1% of respondents confirming an awareness of the concept. The results pertaining to the awareness are reported here together with the broad sample composition so as to contextualize the findings and discussion of this study. Pearce et al. (2018) states that on-farm operational practices in South African fruit horticulture are strongly influenced by cooperative and downstream supply chain structures, where the diffusion of practices into the producer base has taken place selectively and incrementally over time. They argue that lean methodologies have emerged in the sector as an accumulated set of legitimized practices, rather than as a formally adopted system, raising questions as to the depth of lean integration into this domain. As is highlighted by Gelmez et al. (2020), the level of awareness regarding the lean system, which may vary depending on context specific factors, has been shown to be a determinant of lean practice implementation.

Table 3: Descriptive statistics summarizing the composition of the sample.

Sample Composition:			
Farm Size:	**Median:**	**Mean:**	**Std. Dev.:**
Hectares under cultivation (Fruit only)	33.5	41.7	36.3
Composition of Cultivated Area:		**Hectares:**	**Perc:**
Apples and Pears		1,623.5	29.3%
Citrus		842.5	15.2%
Plums		723.0	13.1%
Table Grapes		633.0	11.4%
Wine Grapes		421.5	7.6%
Avocadoes		272.0	4.9%
Mangoes		232.0	4.2%
Peach		155.0	2.8%
Olives		143.5	2.6%
Apricots		132.0	2.4%
Other		355.5	6.4%

Table 4: General awareness of lean management and continuous improvement concepts.

General Awareness:	"Yes"		"No"	
	Num:	Perc:	Num:	Perc:
a. Has some awareness of the continuous improvement concept.	78	59.1%	54	40.9%
b. Has some awareness of the lean system of management.	17	12.9%	115	87.1%
c. Possesses a basic functional grasp of what a lean management system is.	6	4.5%	126	95.5%

4.2 Overall Lean Practice Implementation

Table 5 summarizes the mean values, standard deviations, and practice correlations for the 10 dimensions of lean management considered in this study. Mean values for lean practice maturity range from 3.35 to 5.21, indicating moderate levels of practice implementation across the sample. These figures are somewhat lower than comparable studies, whose lowest and highest mean values have been summarized in Table 6. Although no conclusive comparison may be made, the lean implementation values for this study appear to be only modestly lower than those presented in Table 6, lending support to the position that the focal sector of this study is in a relatively less advanced state of lean development. Consideration for the correlation matrix in table 5, reveals moderate to high levels of correlation between lean dimensions, with the maximum correlation coefficient of 0.668 occurring between LP6 "setup time reduction" and LP7 "statistical process control". The observed levels of correlation may be explained by the inter-related nature of the practices being investigated (Diamantopoulos et al., 2012). Moreover, they are comparable to levels of inter-practice correlation presented in similarly structured empirical studies by Marodin et al. (2016), Malmbrandt and Ahlstrom (2013), and Prasad et al. (2016) who investigate the application of lean in the automotive manufacturing, services, and metal foundry contexts, respectively. Most importantly, the observed levels of correlation fall short of the 0.8 cut-off for multicollinearity advised by Robinson (2018) and were thus deemed suitable for analysis to proceed.

Consideration for Table 5 identifies LP9 "involved employees" and LP6 "setup time reduction" as being the most prominent practice dimensions, with mean values of 5.21 and 5.12, respectively. The prominence of LP6 "Setup Time Reduction" is in alignment with Liker (2004) who holds that "setup time reduction" and "standardized practices" are commonly the first to be established on the lean implementation journey, for the reason that they are needed to establish basic stability at the process level. For reference, it should be noted that "standardized practices" are incorporate as an operational measure into the LP6 "setup time reduction" dimension as specified by the Shah and Ward (2007) lean framework. The prominence of LP9 "involved employees" bears a similarity to studies addressing lean practices in services contexts. A review of lean services studies by Dos el al. (2015) notes that research in this area consistently highlights the importance of human resources and workforce management practices. That being noted, it may be reasonably argued that the prominence of LP9 "involved employees" is a function of the labor-intensive nature of fruit horticulture, where Pearce et al. (2018) emphasizes that growers place enormous importance on the ability of their workforce to act independently and effectively.

Table 5: Correlation matrix and descriptive statistics for lean practice implementation in the sample

Lean Practices:		Mean:	S.D. :	LP1.	LP2.	LP3.	LP4.	LP5.	LP6.	LP7.	LP8.	LP9.	LP10.	SUS1.
LP1.	Supplier Feedback	4.94	0.91	1.00										
LP2.	Developed Suppliers	4.21	0.97	0.42	1.00									
LP3.	Involved Customers	4.64	0.81	0.24	0.48	1.00								
LP4.	Pull	4.41	1.12	0.45	0.58	0.47	1.00							
LP5.	Flow	4.49	0.86	0.48	0.54	0.35	0.31	1.00						
LP6.	Setup Time Reduction	5.12	0.76	0.36	0.51	0.46	0.60	0.29	1.00					
LP7.	Statistical Process Control	4.95	0.99	0.42	0.48	0.43	0.62	0.35	0.67	1.00				
LP8.	Total Prev. Maintenance	4.61	1.05	0.28	0.41	0.27	0.44	0.17	0.37	0.43	1.00			
LP9.	Involved Employees	5.21	0.80	0.43	0.29	0.15	0.42	0.32	0.41	0.36	0.25	1.00		
LP10.	Signaling	3.35	1.04	0.27	0.35	0.15	0.53	0.15	0.38	0.41	0.34	0.39	1.00	
SUS1.	Sustainable Performance	4.44	0.77	0.47	0.52	0.50	0.76	0.43	0.62	0.64	0.45	0.45	0.46	1.00

Table 6: Comparable studies addressing lean practice implementation (Values all converted to 1 – 7 Likert scale)

Authors:	**Country:**	**Industry:**	**Dimensions of Lean Practice**	**Range of Mean Values:**	
				Low	**High:**
Marodin et al. (2016)	Brazil	Automotive	11	4.34	5.32
Dora et al. (2014)	Europe	Food Processing	8	3.46	5.83
Ghosh (2012)	India	Manufacturing	7	5.04	6.02
Sezen et al. (2012)	Turkey	Automotive	10	6.3	6.58
Taj and Morosan (2011)	China	Manufacturing	8	2.66	5.32
* *All values converted to 1 to 7 Likert Scale.*					

4.3 Differences in Lean Implementation

Clustering of the sample according to lean practice implementation scores generated a 2-cluster solution. The elbow diagram in Figure 2 supports the case that a two-cluster solution would be best, providing the optimal balance of heterogeneity between groups and homogeneity within groups for the given sample. The two-cluster output resulted in a first cluster of 44 farms with relatively higher lean practice implementation scores and a second cluster of 88 farms with relatively lower lean practice implementation scores, which are summarized for consideration in Table 7. For ease of discussion these two clusters are labelled as the high LP cluster and the low LP cluster. The high LP and low LP clusters were subjected to MANCOVA analysis to test for significant differences between their lean implementation scores whilst incorporating farm size as a covariate to control for associated effects. As is outlined by Ren et al. (2019) farm size is a critical determinant of sustainable performance in agricultural operations. The results of the MANCOVA analysis, shown in Table 8, indicate that there are significant differences in lean implementation between the high LP and low LP clusters. Deeper consideration for the between subjects effects reveals significant differences between the clusters across all of the 10 lean practice dimensions. Furthermore, farm size is supported as being significantly related to lean practice implementation across five of the ten lean practice dimensions.

4.3.1 Evidence of Distinct Clusters

The outcomes of the analysis lend credence to the efficacy of the clustering process. These findings provide support for the presence of two distinct groups or clusters of growers in the study population, differing substantially and comprehensively across all 10 dimensions of lean practice implementation. Arguably, these findings resemble what Trienekens (2011) describes as distinct segments of farmers that have emerged within the producer groups of developing countries. It is explained by Trienekens (2011), that within developing countries, quality demands, internationalization and market differentiation have led to the emergence of distinct producer segments, at different levels of development, serving different market channels. Following the rationale of Trienekens (2011), and in consideration of the supporting evidence of this study, the high LP cluster might be likened to an export-oriented producer segment, comprised principally of medium to large scale producers. Such producers are primarily focused on export markets although low quality or damaged products may be sold to local markets and fruit processors. Secondly, the low LP cluster might be likened to a locally oriented middle to high income producer segment, comprised primarily of small to medium scale producers. Though these producers also aim to export their produce, they exhibit greater dependence on local markets, and achieve export via relatively less direct routes to market, generally through fruit traders and/or other export chain intermediaries.

4.3.2 Farm Size and Lean Implementation

Consideration for the farm size covariate yields additional insights. As demonstrated by the findings in Table 8, farm size is shown to be significantly related to lean implementation scores across five of the ten lean practice dimensions. This broad finding is supported by `Pearce et al. (2018) who posits that farm size may be a significant determinant of lean practice implementation through greater capacity for workforce development. This argument is reinforced by Ren et al. (2019) who states that larger farms possess relatively greater capability to develop managerial and workforce proficiency. However, the findings of this study support that only 5 of the 10 dimensions of lean implementation are significantly related to the size of the farm. This position is affirmed by Sousa and Voss (2008) who through their review of contingencies in OM research note that the effects of firm size on management practices may vary according to either the context or the practices being considered. A more detailed explanation is offered by Alkhoraif et al. (2019) who detail two mechanisms through which firm size may shape practice implementation. Firstly, the implementation of certain lean practices may be influenced by the level of control the farm has over its supply chain and the influence it has over the demand for its products. In this respect it is argued that small firms may suffer from relatively less bargaining power to negotiate with external stakeholders whose practices interface with their own. Secondly, they note that the importance of certain organizational practices may be linked to organizational scale, where the relative importance of those practices increases or decreases relative to the size of the organization. For example, the importance of workforce management practices may arguably bear some proportion to the scale of a fruit farming estate, where a larger estate together with a relatively larger workforce might demand a more rigorous system of coordination.

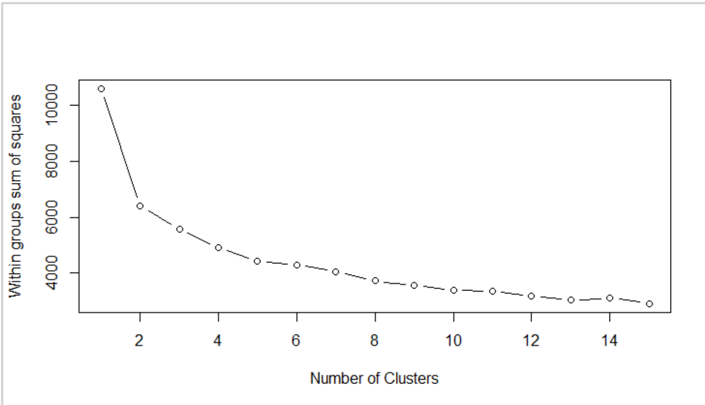

Figure 2: Elbow diagram comparing within group sum of squares (Y-axis) against the number of clusters (X-axis)

Table 7: Comparison of lean practices between clusters

Cluster Comparison:				
	High Lean Practice Cluster		Low Lean Practice Cluster	
	(n1 = 44)		(n2 = 88)	
LP Practices:	Mean:	Std. Dev:	Mean:	Std. Dev:
LP1. Supplier Feedback	5.56	0.64	4.64	0.73
LP2. Developed Suppliers	5.17	0.78	3.73	0.64
LP3. Involved Customers	5.21	0.58	4.36	0.76
LP4. Pull	5.64	0.66	3.80	0.68
LP5. Flow	5.06	0.75	4.20	0.77
LP6. Setup Time Reduction	5.83	0.51	4.77	0.61
LP7. Statistical Process Control	5.82	0.71	4.51	0.79
LP8. Total Preventative Maintenance	5.23	1.14	4.30	0.80
LP9. Involved Employees	5.73	0.77	4.95	0.68
LP10. Signaling (Kanban)	4.16	1.08	2.95	0.71

Table 8: Summary of the MANCOVA results

MANCOVA Results:		
Main Effects:	**High LP vs Low LP Cluster**	**Farm Size:**
LP01 TO LP10	0.000 ***	0.006 **
Between Subjects Effects:		
LP1. Supplier Feedback	0.000 ***	0.065 .
LP2. Developed Suppliers	0.000 ***	0.393
LP3. Involved Customers	0.000 ***	0.082 .
LP4. Pull	0.000 ***	0.038 *
LP5. Flow	0.000 ***	0.025 *
LP6. Setup Time Reduction	0.000 ***	0.115
LP7. Statistical Process Control	0.000 ***	0.018 *
LP8. Total Preventative Maintenance	0.001 **	0.058 .
LP9. Involved Employees	0.000 ***	0.032 *
LP10. Signaling (Kanban)	0.000 ***	0.011 *
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1		

4.4 Differences in Sustainable Performance

The results of the ANOVA provide evidence for significant differences in sustainable performance between the high LP and low LP clusters whilst controlling for the effects of farm size. As the clusters are, in essence, a proxy for lean management implementation, the result may be extended to infer that lean management implementation has a beneficial impact on sustainable performance in horticultural primary production. This finding is in broad alignment with the extant lean management literature which holds that lean practices may have a beneficial impact on sustainable organizational performance (Cherrafi et al., 2016). This is an entirely new contribution to the literature on lean agriculture and agricultural management, demonstrating that lean practice intensity is significantly related to the sustainable performance outcomes attained by fruit horticultural operations. Interpretation of these results should consider two lines of argument. The first and direct interpretation is that lean management implementation supports sustainable performance outcomes in fruit horticultural operations. The second and indirect line of interpretation is that degrees of lean management implementation may covary relative to certain fruit farm characteristics, such as biophysical or climatic suitability, which Archer et al. (2009) states has a significant impact on the performance outcomes attained by a farm. The literature on lean management demonstrates in several respects that organizational attributes may act to mediate the relationship between lean practice implementation and sustainable performance outcomes (Hajmohammad et al., 2013). Investigation of such effects could make for interesting avenues of future research in this area. In terms of farm size, the results of the analysis support that farm size is a significant determinant of sustainable performance outcomes. This finding is in alignment with the position of Pearce et al. (2018) who argues that the size of the fruit farming operation is positively related to the capacity of said operation to attain sustainable performance outcomes, however deeper consideration is warranted. Post hoc analysis (see Table 10) supports that whilst farm size does significantly differentiate between the sustainable performance scores of large and medium, and large and small farms, it does not do so between small and medium sized farms. It is stated by Ren et al. (2019) that whilst farm size is a critical determinant of agricultural sustainability, the magnitude of the effects and their main causes are not well understood. In this respect the findings of this study support that whilst farm size is significantly related to sustainable performance outcomes, the impact of those effects may only be significant beyond a certain size of farm.

Table 9: Results of the Two-Way ANOVA

ANOVA Results			
Dependent Variable: Sustainable Performance			
Independent Variables		**F**	**Sig.**
LP Clusters	(High LP vs Low LP)	46.205	< 0.001
Farm Size	(Small, Medium, Large)	7.97	0.001
LP Clusters x Farm Size	(Interaction Variable)	0.985	0.376
a. R Squared = .620 (Adjusted R Squared = .605)			

Table 10: Post hoc comparison of sustainable performance scores between categories of farm size.

Post-Hoc Comparison				
Independent Variable: Sustainable Performance		Mean Difference:	Standard Error:	Significance:
Large Farms	Medium Farms	0.299	0.106	0.016***
Large Farms	Small Farms	0.665	0.191	0.002**
Medium Farms	Small Farms	0.365	0.192	0.177
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 11: Basic descriptive statistics illustrating sustainable performance scores for each factorial grouping.

Descriptive Statistics				
Dependent Variable: Sustainable Performance		Mean:	Std. Dev.:	N:
High Lean Adoption Cluster	Small Farms	4.500	0.240	2
	Medium Farms	5.118	0.486	17
	Large Farms	5.426	0.414	25
Low Lean Adoption Cluster	Small Farms	3.913	0.448	42
	Medium Farms	4.025	0.599	27
	Large Farms	4.315	0.491	19

5. Conclusions

This study provides an empirical assessment of lean practice patterns and their impact on sustainable performance in the context of fruit horticultural primary production. A comprehensive and holistic framework for lean management, comprising 10 dimensions of lean practice, was used to assess lean practice prevalence and its relationship to farm size and sustainable performance within the fruit horticultural sector in South Africa. As such, this study extends the existing body of knowledge both in terms of the linkages between lean and sustainable performance, lean in agriculture, and agricultural/horticultural management. With regards to the sustainable performance measures considered, the broad findings of this study demonstrate that lean management practices have the potential to support sustainable performance, defined as the attainment of operational profitability whilst maintaining compliance to sustainable environmental and ethical labor practice standards. Consideration for the detailed findings of this study lend support to a number of specific conclusions. Firstly, the evidence provides support for the presence of two distinct segments of growers within the study population, with the one segment operating at a relatively higher level of lean managerial proficiency than the other. Secondly, lean as it is applied in fruit horticulture places a relatively greater emphasis on practices related to workforce management, reflecting the labor-intensive nature of this production context. This result is comparable to studies addressing lean practices in services sectors, where workforce management plays a central role. Thirdly, size of the farming operation is shown to be significantly related both to the depth of lean practice implementation as well as to the extent of sustainable performance outcomes attained. With regard to the former, the data supports that farm size is a significant determinant of implementation, but only for a subset of lean practices. This conclusion is in alignment with the broader literature that mechanisms of interaction between the size of the organization and lean practice implementation may vary according to the specific practices being considered. In terms of the relationship between farm size and sustainable performance, this study concludes that the benefits of scale may only be realized beyond a certain size of farm and may be negligible for smaller farms. The results of this study represent a novel contribution to the scientific literature, and the learnings herein should find interest to consultants and practitioners in the agricultural domain seeking deeper insight into the application of lean management practices and/or the development of organizational capacity to enhance sustainable performance outcomes. To the academic community, this study will optimistically act to extend the legitimacy of and generate interest in furthering the development of lean management theories and frameworks within the agricultural domain. Furthermore, this paper may also be of use to agents of policy seeking to drive greater competitiveness and sustainability within the fruit horticultural sector. The question of whether or not managerial practices could enhance performance in sustainable agriculture, sans the availability of better inputs to production is one that should be of interest in the policy arena.

5.1 Limitations and Future Research

This study makes a significant contribution toward the field of lean management and agricultural operations management. However, there are several study limitations and avenues for future research which require comment. Firstly, the use of self-reported measures, both for lean practices and for sustainable performance measures is a significant limitation to this study, as it allows for greater influence of common method variance and the possibility of respondent bias in reporting performance. The sustainability related practices of farming operations is a sensitive topic in developing country contexts, where sustainability standards are a determinant of market access, and as such could influence respondents. Future empirical studies addressing lean in agriculture should strongly consider the use of non-reported measures of sustainable performance, to reduce the possible effects of both common method variance and respondent bias. A second significant limitation of this study is the incorporation of only one contingency variable, farm size, into the analysis. Agricultural performance outcomes are heavily influenced by a broad set of factors both internal (soil fertility, climatic suitability) and external (market access, horizontal or vertical integration) to the farm. Any future studies seeking to address the relationship between lean management and agricultural performance outcomes could benefit from the consideration of a broader set of contingency factors in their analysis, to account for confounding effects. Nevertheless, the empirical analysis of lean practices and sustainable performance benefits in horticultural primary production represent a new contribution to the existing body of knowledge. The learnings of this study will hopefully support practitioners and researchers in furthering the development of lean systems of practice in the primary production domain.

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TOWARD SUSTAINABLE PRIMARY PRODUCTION THROUGH THE APPLICATION OF LEAN MANAGEMENT IN SOUTH AFRICAN FRUIT HORTICULTURE

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i. List of Tables and Figures:

ii. Abstract:

This paper aims to understand the relationship between patterns of lean practice implementation, farm size and sustainable performance among fruit horticultural primary producers in South Africa. Utilizing a comprehensive lean framework, addressing 10 lean practice dimensions, the authors collected data from a sample of 132 fruit farming operations in South Africa. First, cluster analysis was applied to identify distinct clusters of farms with common lean practice implementation characteristics. Next, the distinct clusters were tested to identify significant differences in lean practice implementation and sustainable performance, with farm size incorporate as a control variable. In terms of common lean implementation characteristics, the analysis identified two distinct clusters of farms, labelled as the high lean practice cluster and the low lean practice cluster. It is determined that these two clusters differ significantly in practice implementation across all 10 dimension of lean management practice. It is further established that the two clusters differ significantly in terms of sustainable performance. Furthermore, Farm size is found to significantly differentiate (i) lean practice implementation across 5 of the 10 lean practice dimensions and (ii) levels of sustainable performance between medium and large sized farms. This empirical analyses of lean practices and sustainable performance outcomes in the primary production domain represents a novel contribution to the existing literature on lean management and horticultural management.

1. Introduction

Trade liberalization and technological progress over recent decades has driven substantial transformation in global agriculture, opening markets and driving down the cost of cross border trade (Peter et al., 2018). For South African fruit producers, these trends have ushered in an era of unparalleled export market potential (Alford, 2016). However, these lucrative export prospects have brought with them the commensurate challenge of operating in the competitive international arena (Trienekens, 2011). In a bid to compete effectively the South African fruit sector has seen sizeable investments into the development of infrastructure, technology and systems of management (Ducastel and Anseeuw, 2017). In terms of systems of management, lean methodologies have been promulgated to suppress costs, improve efficiency and drive continuous improvement in operational sustainability (Wiltshire, 2018). However, at the level of primary production, industry efforts to stimulate lean adoption have taken place in a highly fragmented and selective (i.e., piecemeal) manner (Pearce et al., 2018). This has, over time, resulted in a gap in understanding, both of the lean practices as they have diffused within the sector and of the performance benefits which they confer. Now, as South African producer groups contemplate a more formalized and systematic approach to lean adoption, a need has emerged to establish both a clearer understanding of lean practice prevalence within this domain, as well as for a deeper understanding of the performance benefits, if any, which have resulted.

Originally developed by the Toyota Corporation for use in automotive manufacturing, lean is a system of management premised on maximizing value whilst eliminating waste (Holweg, 2007). Presented as an integrated set of self-reinforcing practices, the lean system has demonstrated a remarkable capacity to suppress costs whilst simultaneously improving product quality and delivery (Negrao et al., 2017). Moreover, through its core focus on waste elimination, the lean system has been shown to be highly supportive of organizational sustainability (Cherrafi et al., 2016). The successes of lean have seen the system adopted and adapted across a range of productive contexts (Marodin and Saurin, 2013). Within this broader picture, agricultural primary production represents a somewhat newer domain of consideration. The diffusion of lean into agricultural primary production has manifest in a small but growing body of literature investigating the application of lean in this area. To date a small constellation of exploratory studies have identified various benefits including cost savings (Zokaei and Simons, 2006), reduced production waste (Colgan et al., 2013) and improved food quality (Pearce et al., 2018). Nevertheless, the existing body of work is entirely exploratory in nature, being comprised of eight case-based studies and two small-sample mixed method studies *(See Table 1)*. The identified benefits of lean in primary production have yet to be demonstrated empirically. This remains as a key gap in the literature, and a potential constraint to extending and legitimizing research in this area. There is thus a need within the scientific literature to provide firmer evidence for the performance benefits of lean in primary production, and for a deeper understanding of the conditions under which its application would be effective.

Consequently, it is the objective of this study to contribute to the literature by conducting an empirical analysis of the performance benefits of lean management in fruit horticultural primary production. The specific research questions investigated by this study are as follows: Firstly, what is the latent prevalence of lean management practices as applied among fruit growing operations in South Africa? Secondly, does the application of lean management practices influence the sustainable performance of grower operations? The proceeding sections of this paper, purposed to address these questions, have been arranged as follows: Section two provides expository background to two key areas, the origin of lean practices and their diffusion into the field of agricultural management followed by the background to the South African fruit horticultural sector. Section three details the methodology employed in the design of this study, whilst section four looks to outline the basic findings and discussion related to the analysis. Lastly, the fifth and final section closes with conclusions, limitations of the study and some possibilities for future research.

2. Background

2.1 Lean Management and Lean Agriculture

Lean management, also known as lean manufacturing or lean production, is a managerial approach conceptualized by the Toyota Motor Corporation (TMC) over the latter half of the 20th century (Holweg, 2007). Premised on the notion of maximizing value whilst eliminating waste (Shah and Ward, 2007), the lean system has shown demonstrable success in suppressing costs whilst simultaneously improving quality and delivery across a range of productive contexts (Marodin and Saurin, 2013). Furthermore, with this central premise of waste elimination, the lean system has been shown to be highly supportive of sustainability strategies and practices (Pearce et al., 2018). In this respect, the lean literature has demonstrated various sustainable performance benefits, including reduced environmental impact (Ioppolo et al., 2014) and reduced non-compliance risk (Zhu and Sarkis, 2004). Presented as an integrated configuration of mutually reinforcing practices, the lean system's association with superior performance is well accepted among academics and practitioners alike (Negrao et al., 2017). Moreover, the literature emphasizes that it is the self-reinforcing aspect of lean practices, when effectively configured, that contribute to the non-linear synergistic effects associated with the system (Shah and Ward, 2003). The successes of lean have seen the system adopted and adapted across a range of contexts, including various forms of manufacturing, healthcare, and services sectors (Holweg, 2007).

This study adopts a comprehensive framework of lean management developed and validated by (Shah and Ward, 2007) which specifies 10 dimensions of lean management (The specific composition of which is further outlined in section 3.1). This holistic framework serves two key purposes. Firstly, as lean is a multi-dimensional system encompassing a wide variety of management practices, explicit definition of the framework's dimensions is necessary to avoid semantic confusion which may act to impede empirical testing (Shah and Ward, 2007). Secondly, conceptual studies acknowledging the integrated nature of lean practices underscore the importance of empirically inspecting the multiple dimensions of lean programs simultaneously (Marodin and Saurin, 2013). In this respect, the Shah and Ward (2007) framework provides a holistic encapsulation of the lean system, addressing both the internal and chain-oriented dimensions, as well as the social and technically oriented dimensions of the system. However, the specific benefit of this framework, sought for the purposes of this study, is that it defines the core concepts of lean and associated practices in a generally applicable framework and not one that is context (i.e., manufacturing) specific. As is argued by Voss et al. (2016) it may be beneficial for a theory of management to be adaptive to different contexts, stating that the use of a more general theory is useful in that context specific logic is less likely to manifest as a barrier to its application. As agricultural primary production represents a relatively new context for empirical lean performance analysis, this particular framework was identified as being the most suitable for this study.

Table 1: Summary of literature addressing the application of lean management in agricultural primary production.

Author:	Method:	Commodity:	Benefits:	Barriers:
Barth and Melin (2018)	Small Sample, Mixed Method	Dairy, Meat, Crops	- Optimize use of production inputs - Reduced changeover time	- Lack of manager / employee buy-in
Melin and Barth (2018)	Small Sample, Mixed Method	Dairy, Meat, Crops	- Cost reduction through control of waste - Improved safety awareness - Reduced feed shortages	- Production process is inherently unstable (climatic and biophysical) - Long lead times in production
Pearce et al. (2018)	Case Study	Fruit (Apples and Pears)	- Improved yield and quality - Improved workforce productivity - Improved inputs use efficiency - Reduced non-compliance risk w.r.t. sustainability standards	- Seasonal batch production - Volatility in operating context - Smaller farms resource constrained - Language barriers with workforce
Colgan et al. (2013)	Case Study	Multi-Commodity Farm	- Reduced waste and improved quality of food	- Chain power regime determines who reaps benefits of lean
Cox et al. (2007)	Case Study	Red Meat	- Some (minimal) commercial returns to producer end of the chain	- Lack of long-term price stability and certainty for producers
Simons and Taylor (2007)	Case Study	Red Meat	- Logistical benefits along the chain	- Inter-company alignment of systems - Chain organizational instability
Taylor (2006)	Case Study	Red Meat	- Positive logistical benefits along the chain	- Requires Equitable and explicit benefits sharing framework
Zokaei and Simons (2006)	Case Study	Red Meat	- 2-3% cost savings at each stage of the chain	- Unpredictability of the interaction of operational improvements
Simons and Zokaei (2005)	Case Study	Red Meat	- 25% productivity difference between lean & non-lean producers	- Chain fragmentation - Carcass is multi-product commodity
Cox and Chicksand (2005)	Case Study	Red Meat	- Internal productivity benefits	- Inter-organizational aspects difficult to apply

Over the last 10 to 20 years, lean and continuous improvement methodologies have found interest in agriculture, where interest has emerged as a byproduct of the shift toward industrialization of the domain (Pearce et al., 2018). This interest is evidenced by the emergence of sectoral initiatives in countries such as South Africa (Pearce et al., 2018), the United Kingdom (Colgan et al., 2013) and Sweden (Melin and Barth, 2018), seeking to understand the potential benefits of lean to primary production. Moreover, this interest has emerged in the scientific literature as evidenced by a small but growing body of research investigating lean in primary production, which has been summarized in Table 1. A study by Higgins et al. (2007) noted at that time that the application of operations management (OM) methodologies in primary production had been limited due to the complexity of the context. However, more recent studies note that increasing food prices in combination with increasingly constrained agricultural productive capacity are driving a renewed focus on functionality and sustainability in primary production (Dethier and Effenberger, 2011). Pearce et al. (2018) argues that the particular attributes of the lean system are a good fit with the needs of the agricultural sector. They contend that the anthropocentric and pragmatically hands-on nature of the lean system is a good fit with the operational needs of farmers. They furthermore highlight that the inherent focus on waste elimination is strongly aligned with the agricultural need to reduce operational waste, whether it be in the form of inefficiently utilized labor, food waste, water, energy, or inputs to production such as fertilizer and other chemical applicants. As is noted by Barth and Melin (2018) waste reduction for farmers directly corresponds to the suppression of costs, and therefore the operational profitability of any given farming operation.

2.2 Fruit Horticulture in South Africa

The South African fruit agricultural sector has, in these last 30 years, rose to a position of significance as an exporter of fresh fruit and other horticultural products to the greater global agri-food economy. This developing country is the 2nd largest producer of fresh fruit in the southern hemisphere, operating as the global 6th largest exporter of apples and plums, and the 5th largest exporter of pears (Hortgro, 2019). Driven by both global and national trends, South African fruit horticulture has, in the last 3 decades, seen significant evolution of structure, strategy and practice. Deregulation in 1996 saw the loss of state support and elimination of the single state controlled marketing channel (Trienekens and Willems, 2007). This development signaled the opening of and integration into the global market which brought with it substantial high-margin export market opportunity (Kritzinger et al., 2004). Nevertheless these reforms had the added consequence of opening up South African producers to the fierce competition and strictly enforced production standards which define the international export market (Alford, 2016). There, the stated production standards include not only the quality of the horticultural produce, but also the requirement to produce in compliance with sustainable environmental and ethical labor practice standards (Pearce et al., 2018). In the earliest years after deregulation, competitiveness of South African fruit horticulture was largely supported by productive efficiency in primary production (Boonzaaier and Van Rooyen, 2015). Meanwhile, studies conducted at the time identified that downstream elements of the chain were less competitive, characterized by high costs, chain fragmentation and a lack of coordination (Esterhuizen and Van Rooyen, 1999; Van Rooyen, 2008). The overarching conclusion being that the commodity chain as a whole was constrained by inconsistency in performance and quality. As a response, the proceeding period saw significant investments from industry as well as external sources toward developing the competitiveness of the chain (Conradie et al., 2009). This included investments into infrastructure, technology, and systems of management, resulting in extensive industrialization of the sector. With respect to systems of management and coordination, Wiltshire (2018) presents that lean methodologies were used to suppress costs, increase quality, and boost overall competitiveness. During this period, the sector saw significant investment in lean strategies, chain structures and on-farm practices with the objective to reduce cost, standardize practices and flexibilise the workforce (Pearce et al., 2018; Wiltshire, 2018).

South Africa's systems of horticultural cultivation are largely conventional with operations that are inherently labor intensive. Due to the meticulous requirements of fruit cultivation and the sensitivity of fruit to bruising and damage, orchard maintenance and fruit harvesting processes are all done by hand (Wiltshire, 2018). Consequently, a fruit farm's workforce is simultaneously the most essential, expensive and regulated input to production (Pearce et al., 2018). Followingly, the effective management of employed labor toward attaining a productive and financial return is given top priority across the sector as a whole. Though the specifics of estate management differ from farm to farm, the overarching approach to production is largely standardized across a range of operational practices, including orchard maintenance, workforce management, and harvest processes which include the associated quality controls (Pearce et al., 2018). Lean as it is applied in fruit horticulture is largely centered on the effective management of activities internal to the farm, whilst coordinating those internal activities with the needs and requirements of the chain. As is noted by Pearce et al. (2018), fruit producers are required to comply with procedural and product quality specifications at the point of aggregation, the packhouse, which is the entry point to the supply chain. Meeting those specifications requires that producers adhere to strict operational protocols in orchard maintenance and harvest processes.

In terms of standardizing practices across the producer base, Pearce et al. (2018) states that fruit sector associations (linked to the various fruit subtypes) together with the large integrated cooperatives play an important role in promulgating operational practices. Protocols and standards for environmental sustainability and ethical labor practice are specified, promoted, and audited (i.e., self-reported non-third-party audits) by the Sustainability Initiative of South Africa (SIZA), the official fruit sector sustainability body in South Africa. Verification audits are undertaken by external 3rd party companies, who play an essential role in authenticating production standards on behalf of retail buyers (Striebig et al., 2019). Here the standards for ethical labor practice address child and forced labor, freedom of association, discrimination and abuse, general health & safety, working hours, remuneration and other terms of employment. Further, the standards for environmental sustainability address compliance and environmental risks related to water, soil, energy, materials & waste, and ecosystem biodiversity.

3. Research Design & Methodology

3.1 Theoretical and Analytical Framework

This study adopts the operations management practice contingency research (OM PCR) model by Shah and Ward (2007) who holds that a fully developed contingency model should account for three sets of variables, (a) practices, (b) contingency factors relevant to the context of application and (c) the resultant performance outcomes (Sousa and Voss, 2008). The OM PCR model is rooted in contingency theory, an organizational theory which holds that the optimal mode of operation is contingent on the setting in which the firm operates. This theory is premised on the notion of fit, which may be defined as the suitability of composition or quality for a required purpose. Contingency theory holds that suitability of fit is directly proportional to performance, and that organizations should adapt to achieve fit. The OM PCR model is useful in that it may produce advice on which practices an organization should adopt to obtain or improve fit. However, a limitation of this model is that it is unable to establish why certain practice configurations lead to better performance outcomes than others (Sousa and Voss, 2008).

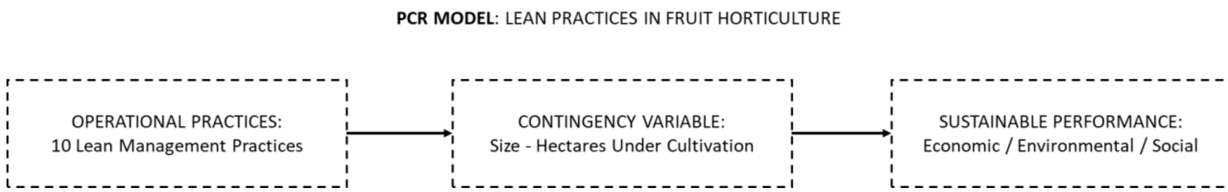

Figure 1: Theoretical and analytical framework to investigate the performance benefits of lean management in fruit horticultural primary production

The practices component of the OM PCR model developed for this study incorporates an adaptation of the Shah and Ward (2007) framework of lean management. Following the scale adaptation process set out by Shah and Ward (2007) and Morris and Lancaster (2006) the original framework was adapted for use in fruit horticulture using the contextual contingency map and detailed lean operating rationale provided by Pearce et al. (2018). The adapted framework specifies 10 dimensions of lean management, encapsulated as 2 supplier-oriented, 2 customer-oriented, and 6 internally oriented dimensions of lean management as summarized in Table 2. Each of these 10 operational dimensions are comprised of 3 operational measures, where the operational measures each represent a specific operational activity or practice. Followingly, the 10 operational dimensions of this framework are together comprised of 30 operational measures. The size of the farming operation stated as hectares under cultivation is incorporated into the model as the control (i.e., contingency) variable. Size is a commonly included control variable incorporated into empirical OM analysis, as it has been demonstrated to moderate the relationship between lean implementation and performance outcomes (Sousa and Voss, 2008). Moreover, Ren et al. (2019) states that farm size is a significant influential factor in the sustainable performance of agricultural operations though they emphasize that the specific causal mechanisms and magnitude of effects are not well understood.

Table 2: Detailed delineation of the Shah and Ward (2007) lean management framework

MAIN FRAMEWORK:	LATENT DIMENSIONS:	OPERATIONAL DIMENSIONS:	OPERATIONAL MEASURES:
LEAN MANAGEMENT FRAMEWORK	1. SUPPLIER RELATED	1. SUPPLIER FEEDBACK	3 x Measures
		2. DEVELOPING SUPPLIERS	3 x Measures
	2. CUSTOMER RELATED	3. INVOLVED CUSTOMERS	3 x Measures
		4. PULL	3 x Measures
	3. INTERNALLY RELATED	5. FLOW	3 x Measures
		6. LOW SETUP	3 x Measures
		7. CONTROLLED PROCESSES	3 x Measures
		8. TOTAL MAINTENANCE	3 x Measures
		9. INVOLVED EMPLOYEES	3 x Measures
		10. SIGNALLING / KANBAN	3 x Measures

The measure of sustainable performance is incorporated into the model through 3 self-reported items addressing economic viability, environmental sustainability, and ethical labor practices, respectively. These are collated into a single multi-item performance measure which for the purposes of this study is labeled as "sustainable performance". These indicators were selected to align with the working definition of sustainable performance put forth by Carter and Rogers (2008) who state that a sustainable organization is an organization that understands and manages the economic, environmental, and social risks resulting from its operations. To measure economic viability, growers were asked to rate the likelihood of their operation turning an operating profit in the next season coming. In terms of environmental sustainability, respondents were asked to rate the likelihood of obtaining the highest rating in their next environmental audit. Likewise, for ethical labor practices respondents were asked to rate the likelihood of receiving the highest rating on their next social / labor audit. Collectively, this multi-item indicator assesses the ability of a given farming operation to attain an operating profit whilst managing sustainable environmental and ethical labor practice requirements. Furthermore, these indicators comply with the 3 sustainability indicator selection criteria set out by Lebacq, Baret and Stilmant (2013) in terms of (a) being relevant to the context, (b) practicability in terms of being specific, measurable, and attainable, and (c) being appropriate and comprehensible to stakeholders.

3.2 Instrument Development

The stated lean dimensions, contingency factor and measure of sustainable performance were incorporated into an instrument to survey fruit growers. The 30 lean operational measures and 3 sustainable performance measures were inserted into the instrument as Likert-type items, together forming 10 lean and 1 sustainable performance multi-item rating scales. The decision to utilize multi-item scales rather than single-item scales was based on the guidelines provided by Diamantopoulos et al. (2012) who advises that multi-item scales be used when the sample size is greater than 50 and when cross-item correlations are expected to exceed 0.30, as is the case in this study. The draft instrument was subjected to rigorous review, firstly, by a panel of experts and secondly through a pilot survey. Comments and feedbacks from these experts, as well as feedback from pilot survey respondents were utilized to guide amendments to the instrument. Procedural remedies including mixing the order of the questions and the use of different scale types were utilized to minimize the influence of common method variance (Chang et al., 2010). The final draft of the survey was kept short, taking approximately 5 minutes to complete. Cronbach's Alpha was utilized to check the reliability of the resultant data obtained, exceeding the minimum value of 0.60 set for acceptability (Santos, 1999).

3.3 Data Collection

A total of 967 farmers were contacted, of which 132 interviews were successfully implemented to completion, concluding as a response rate of approximately 14%. This excludes those interviews undertaken to pilot the development of the questionnaire. The sample was drawn from several fruit growing regions across South Africa, representing a broad set of fruit commodity types. Following the recommendations of Zhou (2016), interviews were limited to senior management staff, including involved estate owners, estate managers and supporting general operations managers. The survey was implemented utilizing the telephonic survey method. Due to the geographic distribution of the sample population, this survey approach was deemed to be the most practical for the available time and budget. The advantages of the telephonic approach include affordability and convenience of administration, whilst disadvantages include resistance in terms of the time limitations of the respondents and barriers of perceived trust (Dillman et al., 2014).

3.4 Data Analysis

Data analysis, following the approach outlined by Marodin et al. (2016), progressed through 3 phases; basic statistical delineation, cluster analysis, and analysis of variance utilizing the ANOVA (analysis of variance) and MANCOVA (multiple analysis of covariance) models respectively. The ANOVA family of statistical models, of which MANCOVA is a member, is a collection of statistical models used to test for significant differences between the means of groups, where groups are defined by levels within the independent variable/s (Hair et al., 2014). Basic descriptive statistics were generated, seeking to delineate the general structure of the obtained sample, and to show the status of each of the 10 lean practices in use across the sample. Next, cluster analysis was applied to identify distinct clusters of growers based on levels of lean implementation. Cluster analysis was first carried out using hierarchical clustering based on Ward's method to determine the optimal number of clusters. This was then followed by a second round of clustering using the k-means clustering approach to refine the composition of the clusters (Hair et al. 2009). This approach is recommended by Ketchen and Shook (1996) to maximize homogeneity within clusters and heterogeneity between clusters. The 3rd phase of data analysis took place in two parts. Firstly, MANCOVA was used to test for significant differences in lean practice implementation scores across the 10 dimensions of the lean practice framework (the dependent variables), between the two groups defined by the high and low lean implementation clusters (the independent variable), whilst controlling for variation attributable to farm size (the covariate). Secondly, ANOVA was used to test for significant differences in sustainable performance scores between levels of 2 factors; the independent variables defined by the high and low lean implementation clusters (factor 1) and the small, medium, and large categories of farm size (factor 2). Tests for linearity, normality and homogeneity of variance / covariance were conducted and confirmed (Hair et al., 2009). Shapiro-Wilk was used to evaluate normality, linearity was tested through plots of partial regression for each of the lean practices, and Levene's Test was used to assess homogeneity of variance / covariance.

4. Results and Discussion

4.1 Sample Overview

The 132 fruit growing estates surveyed for this study account for a total of 5,509 hectares under cultivation. Mean and median values for the number of hectares under cultivation per estate are calculated at 41.73 and 33.50 hectares, respectively. The sample includes more than 20 different kinds of fruit including deciduous, citrus, and sub-tropical types; the proportions of which are summarized in Table 3. These reported figures for farm size and fruit crop composition lie approximately within the reported statistics for the sector. Whilst the study focused purely on farming estates engaged in the commercial production of fruit, a sizeable proportion of the sample engaged in other commercial activities including livestock farming, production of animal feed, vegetables, and non-fruit crops, agri-processing, and hospitality related services. This is in line with the general literature that most farms are multi-product enterprises (Chavas et al., 2010). Within the sample, general awareness around lean management is relatively low, where approximately 15.9% of respondents indicated an awareness of the lean management system. In contrast, the general awareness of continuous improvement was considerably higher, with 59.1% of respondents confirming an awareness of the concept. The results pertaining to the awareness are reported here together with the broad sample composition so as to contextualize the findings and discussion of this study. Pearce et al. (2018) states that on-farm operational practices in South African fruit horticulture are strongly influenced by cooperative and downstream supply chain structures, where the diffusion of practices into the producer base has taken place selectively and incrementally over time. They argue that lean methodologies have emerged in the sector as an accumulated set of legitimized practices, rather than as a formally adopted system, raising questions as to the depth of lean integration into this domain. As is highlighted by Gelmez et al. (2020), the level of awareness regarding the lean system, which may vary depending on context specific factors, has been shown to be a determinant of lean practice implementation.

Table 3: Descriptive statistics summarizing the composition of the sample.

Sample Composition:			
Farm Size:	**Median:**	**Mean:**	**Std. Dev.:**
Hectares under cultivation (Fruit only)	33.5	41.7	36.3
Composition of Cultivated Area:		**Hectares:**	**Perc:**
Apples and Pears		1,623.5	29.3%
Citrus		842.5	15.2%
Plums		723.0	13.1%
Table Grapes		633.0	11.4%
Wine Grapes		421.5	7.6%
Avocadoes		272.0	4.9%
Mangoes		232.0	4.2%
Peach		155.0	2.8%
Olives		143.5	2.6%
Apricots		132.0	2.4%
Other		355.5	6.4%

Table 4: General awareness of lean management and continuous improvement concepts.

General Awareness:	"Yes"		"No"	
	Num:	Perc:	Num:	Perc:
a. Has some awareness of the continuous improvement concept.	78	59.1%	54	40.9%
b. Has some awareness of the lean system of management.	17	12.9%	115	87.1%
c. Possesses a basic functional grasp of what a lean management system is.	6	4.5%	126	95.5%

4.2 Overall Lean Practice Implementation

Table 5 summarizes the mean values, standard deviations, and practice correlations for the 10 dimensions of lean management considered in this study. Mean values for lean practice maturity range from 3.35 to 5.21, indicating moderate levels of practice implementation across the sample. These figures are somewhat lower than comparable studies, whose lowest and highest mean values have been summarized in Table 6. Although no conclusive comparison may be made, the lean implementation values for this study appear to be only modestly lower than those presented in Table 6, lending support to the position that the focal sector of this study is in a relatively less advanced state of lean development. Consideration for the correlation matrix in table 5, reveals moderate to high levels of correlation between lean dimensions, with the maximum correlation coefficient of 0.668 occurring between LP6 "setup time reduction" and LP7 "statistical process control". The observed levels of correlation may be explained by the inter-related nature of the practices being investigated (Diamantopoulos et al., 2012). Moreover, they are comparable to levels of inter-practice correlation presented in similarly structured empirical studies by Marodin et al. (2016), Malmbrandt and Ahlstrom (2013), and Prasad et al. (2016) who investigate the application of lean in the automotive manufacturing, services, and metal foundry contexts, respectively. Most importantly, the observed levels of correlation fall short of the 0.8 cut-off for multicollinearity advised by Robinson (2018) and were thus deemed suitable for analysis to proceed.

Consideration for Table 5 identifies LP9 "involved employees" and LP6 "setup time reduction" as being the most prominent practice dimensions, with mean values of 5.21 and 5.12, respectively. The prominence of LP6 "Setup Time Reduction" is in alignment with Liker (2004) who holds that "setup time reduction" and "standardized practices" are commonly the first to be established on the lean implementation journey, for the reason that they are needed to establish basic stability at the process level. For reference, it should be noted that "standardized practices" are incorporate as an operational measure into the LP6 "setup time reduction" dimension as specified by the Shah and Ward (2007) lean framework. The prominence of LP9 "involved employees" bears a similarity to studies addressing lean practices in services contexts. A review of lean services studies by Dos el al. (2015) notes that research in this area consistently highlights the importance of human resources and workforce management practices. That being noted, it may be reasonably argued that the prominence of LP9 "involved employees" is a function of the labor-intensive nature of fruit horticulture, where Pearce et al. (2018) emphasizes that growers place enormous importance on the ability of their workforce to act independently and effectively.

Table 5: Correlation matrix and descriptive statistics for lean practice implementation in the sample

Lean Practices:		Mean:	S.D. :	LP1.	LP2.	LP3.	LP4.	LP5.	LP6.	LP7.	LP8.	LP9.	LP10.	SUS1.
LP1.	Supplier Feedback	4.94	0.91	1.00										
LP2.	Developed Suppliers	4.21	0.97	0.42	1.00									
LP3.	Involved Customers	4.64	0.81	0.24	0.48	1.00								
LP4.	Pull	4.41	1.12	0.45	0.58	0.47	1.00							
LP5.	Flow	4.49	0.86	0.48	0.54	0.35	0.31	1.00						
LP6.	Setup Time Reduction	5.12	0.76	0.36	0.51	0.46	0.60	0.29	1.00					
LP7.	Statistical Process Control	4.95	0.99	0.42	0.48	0.43	0.62	0.35	0.67	1.00				
LP8.	Total Prev. Maintenance	4.61	1.05	0.28	0.41	0.27	0.44	0.17	0.37	0.43	1.00			
LP9.	Involved Employees	5.21	0.80	0.43	0.29	0.15	0.42	0.32	0.41	0.36	0.25	1.00		
LP10.	Signaling	3.35	1.04	0.27	0.35	0.15	0.53	0.15	0.38	0.41	0.34	0.39	1.00	
SUS1.	Sustainable Performance	4.44	0.77	0.47	0.52	0.50	0.76	0.43	0.62	0.64	0.45	0.45	0.46	1.00

Table 6: Comparable studies addressing lean practice implementation (Values all converted to 1 – 7 Likert scale)

Authors:	**Country:**	**Industry:**	**Dimensions of Lean Practice**	**Range of Mean Values:**	
				Low	**High:**
Marodin et al. (2016)	Brazil	Automotive	11	4.34	5.32
Dora et al. (2014)	Europe	Food Processing	8	3.46	5.83
Ghosh (2012)	India	Manufacturing	7	5.04	6.02
Sezen et al. (2012)	Turkey	Automotive	10	6.3	6.58
Taj and Morosan (2011)	China	Manufacturing	8	2.66	5.32
** All values converted to 1 to 7 Likert Scale.*					

4.3 Differences in Lean Implementation

Clustering of the sample according to lean practice implementation scores generated a 2-cluster solution. The elbow diagram in Figure 2 supports the case that a two-cluster solution would be best, providing the optimal balance of heterogeneity between groups and homogeneity within groups for the given sample. The two-cluster output resulted in a first cluster of 44 farms with relatively higher lean practice implementation scores and a second cluster of 88 farms with relatively lower lean practice implementation scores, which are summarized for consideration in Table 7. For ease of discussion these two clusters are labelled as the high LP cluster and the low LP cluster. The high LP and low LP clusters were subjected to MANCOVA analysis to test for significant differences between their lean implementation scores whilst incorporating farm size as a covariate to control for associated effects. As is outlined by Ren et al. (2019) farm size is a critical determinant of sustainable performance in agricultural operations. The results of the MANCOVA analysis, shown in Table 8, indicate that there are significant differences in lean implementation between the high LP and low LP clusters. Deeper consideration for the between subjects effects reveals significant differences between the clusters across all of the 10 lean practice dimensions. Furthermore, farm size is supported as being significantly related to lean practice implementation across five of the ten lean practice dimensions.

4.3.1 Evidence of Distinct Clusters

The outcomes of the analysis lend credence to the efficacy of the clustering process. These findings provide support for the presence of two distinct groups or clusters of growers in the study population, differing substantially and comprehensively across all 10 dimensions of lean practice implementation. Arguably, these findings resemble what Trienekens (2011) describes as distinct segments of farmers that have emerged within the producer groups of developing countries. It is explained by Trienekens (2011), that within developing countries, quality demands, internationalization and market differentiation have led to the emergence of distinct producer segments, at different levels of development, serving different market channels. Following the rationale of Trienekens (2011), and in consideration of the supporting evidence of this study, the high LP cluster might be likened to an export-oriented producer segment, comprised principally of medium to large scale producers. Such producers are primarily focused on export markets although low quality or damaged products may be sold to local markets and fruit processors. Secondly, the low LP cluster might be likened to a locally oriented middle to high income producer segment, comprised primarily of small to medium scale producers. Though these producers also aim to export their produce, they exhibit greater dependence on local markets, and achieve export via relatively less direct routes to market, generally through fruit traders and/or other export chain intermediaries.

4.3.2 Farm Size and Lean Implementation

Consideration for the farm size covariate yields additional insights. As demonstrated by the findings in Table 8, farm size is shown to be significantly related to lean implementation scores across five of the ten lean practice dimensions. This broad finding is supported by `Pearce et al. (2018) who posits that farm size may be a significant determinant of lean practice implementation through greater capacity for workforce development. This argument is reinforced by Ren et al. (2019) who states that larger farms possess relatively greater capability to develop managerial and workforce proficiency. However, the findings of this study support that only 5 of the 10 dimensions of lean implementation are significantly related to the size of the farm. This position is affirmed by Sousa and Voss (2008) who through their review of contingencies in OM research note that the effects of firm size on management practices may vary according to either the context or the practices being considered. A more detailed explanation is offered by Alkhoraif et al. (2019) who detail two mechanisms through which firm size may shape practice implementation. Firstly, the implementation of certain lean practices may be influenced by the level of control the farm has over its supply chain and the influence it has over the demand for its products. In this respect it is argued that small firms may suffer from relatively less bargaining power to negotiate with external stakeholders whose practices interface with their own. Secondly, they note that the importance of certain organizational practices may be linked to organizational scale, where the relative importance of those practices increases or decreases relative to the size of the organization. For example, the importance of workforce management practices may arguably bear some proportion to the scale of a fruit farming estate, where a larger estate together with a relatively larger workforce might demand a more rigorous system of coordination.

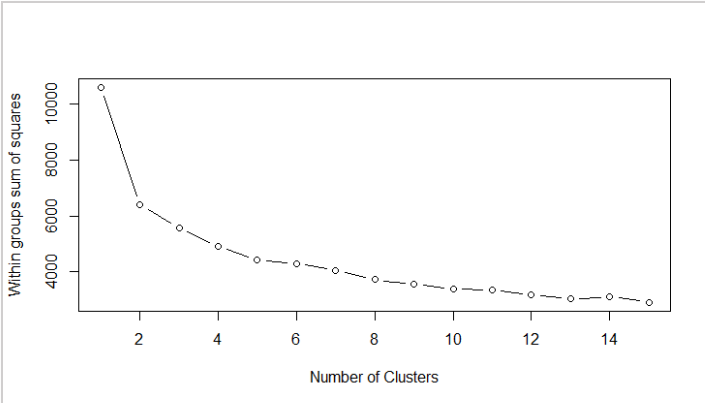

Figure 2: Elbow diagram comparing within group sum of squares (Y-axis) against the number of clusters (X-axis)

Table 7: Comparison of lean practices between clusters

Cluster Comparison:				
	High Lean Practice Cluster		Low Lean Practice Cluster	
	(n1 = 44)		(n2 = 88)	
LP Practices:	Mean:	Std. Dev:	Mean:	Std. Dev:
LP1. Supplier Feedback	5.56	0.64	4.64	0.73
LP2. Developed Suppliers	5.17	0.78	3.73	0.64
LP3. Involved Customers	5.21	0.58	4.36	0.76
LP4. Pull	5.64	0.66	3.80	0.68
LP5. Flow	5.06	0.75	4.20	0.77
LP6. Setup Time Reduction	5.83	0.51	4.77	0.61
LP7. Statistical Process Control	5.82	0.71	4.51	0.79
LP8. Total Preventative Maintenance	5.23	1.14	4.30	0.80
LP9. Involved Employees	5.73	0.77	4.95	0.68
LP10. Signaling (Kanban)	4.16	1.08	2.95	0.71

Table 8: Summary of the MANCOVA results

MANCOVA Results:		
Main Effects:	**High LP vs Low LP Cluster**	**Farm Size:**
LP01 TO LP10	0.000 ***	0.006 **
Between Subjects Effects:		
LP1. Supplier Feedback	0.000 ***	0.065 .
LP2. Developed Suppliers	0.000 ***	0.393
LP3. Involved Customers	0.000 ***	0.082 .
LP4. Pull	0.000 ***	0.038 *
LP5. Flow	0.000 ***	0.025 *
LP6. Setup Time Reduction	0.000 ***	0.115
LP7. Statistical Process Control	0.000 ***	0.018 *
LP8. Total Preventative Maintenance	0.001 **	0.058 .
LP9. Involved Employees	0.000 ***	0.032 *
LP10. Signaling (Kanban)	0.000 ***	0.011 *
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1		

4.4 Differences in Sustainable Performance

The results of the ANOVA provide evidence for significant differences in sustainable performance between the high LP and low LP clusters whilst controlling for the effects of farm size. As the clusters are, in essence, a proxy for lean management implementation, the result may be extended to infer that lean management implementation has a beneficial impact on sustainable performance in horticultural primary production. This finding is in broad alignment with the extant lean management literature which holds that lean practices may have a beneficial impact on sustainable organizational performance (Cherrafi et al., 2016). This is an entirely new contribution to the literature on lean agriculture and agricultural management, demonstrating that lean practice intensity is significantly related to the sustainable performance outcomes attained by fruit horticultural operations. Interpretation of these results should consider two lines of argument. The first and direct interpretation is that lean management implementation supports sustainable performance outcomes in fruit horticultural operations. The second and indirect line of interpretation is that degrees of lean management implementation may covary relative to certain fruit farm characteristics, such as biophysical or climatic suitability, which Archer et al. (2009) states has a significant impact on the performance outcomes attained by a farm. The literature on lean management demonstrates in several respects that organizational attributes may act to mediate the relationship between lean practice implementation and sustainable performance outcomes (Hajmohammad et al., 2013). Investigation of such effects could make for interesting avenues of future research in this area. In terms of farm size, the results of the analysis support that farm size is a significant determinant of sustainable performance outcomes. This finding is in alignment with the position of Pearce et al. (2018) who argues that the size of the fruit farming operation is positively related to the capacity of said operation to attain sustainable performance outcomes, however deeper consideration is warranted. Post hoc analysis (see Table 10) supports that whilst farm size does significantly differentiate between the sustainable performance scores of large and medium, and large and small farms, it does not do so between small and medium sized farms. It is stated by Ren et al. (2019) that whilst farm size is a critical determinant of agricultural sustainability, the magnitude of the effects and their main causes are not well understood. In this respect the findings of this study support that whilst farm size is significantly related to sustainable performance outcomes, the impact of those effects may only be significant beyond a certain size of farm.

Table 9: Results of the Two-Way ANOVA

ANOVA Results			
Dependent Variable: Sustainable Performance			
Independent Variables		**F**	**Sig.**
LP Clusters	(High LP vs Low LP)	46.205	< 0.001
Farm Size	(Small, Medium, Large)	7.97	0.001
LP Clusters x Farm Size	(Interaction Variable)	0.985	0.376
a. R Squared = .620 (Adjusted R Squared = .605)			

Table 10: Post hoc comparison of sustainable performance scores between categories of farm size.

Post-Hoc Comparison				
Independent Variable: Sustainable Performance		Mean Difference:	Standard Error:	Significance:
Large Farms	Medium Farms	0.299	0.106	0.016***
Large Farms	Small Farms	0.665	0.191	0.002**
Medium Farms	Small Farms	0.365	0.192	0.177
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

Table 11: Basic descriptive statistics illustrating sustainable performance scores for each factorial grouping.

Descriptive Statistics				
Dependent Variable: Sustainable Performance		Mean:	Std. Dev.:	N:
High Lean Adoption Cluster	Small Farms	4.500	0.240	2
	Medium Farms	5.118	0.486	17
	Large Farms	5.426	0.414	25
Low Lean Adoption Cluster	Small Farms	3.913	0.448	42
	Medium Farms	4.025	0.599	27
	Large Farms	4.315	0.491	19

5. Conclusions

This study provides an empirical assessment of lean practice patterns and their impact on sustainable performance in the context of fruit horticultural primary production. A comprehensive and holistic framework for lean management, comprising 10 dimensions of lean practice, was used to assess lean practice prevalence and its relationship to farm size and sustainable performance within the fruit horticultural sector in South Africa. As such, this study extends the existing body of knowledge both in terms of the linkages between lean and sustainable performance, lean in agriculture, and agricultural/horticultural management. With regards to the sustainable performance measures considered, the broad findings of this study demonstrate that lean management practices have the potential to support sustainable performance, defined as the attainment of operational profitability whilst maintaining compliance to sustainable environmental and ethical labor practice standards. Consideration for the detailed findings of this study lend support to a number of specific conclusions. Firstly, the evidence provides support for the presence of two distinct segments of growers within the study population, with the one segment operating at a relatively higher level of lean managerial proficiency than the other. Secondly, lean as it is applied in fruit horticulture places a relatively greater emphasis on practices related to workforce management, reflecting the labor-intensive nature of this production context. This result is comparable to studies addressing lean practices in services sectors, where workforce management plays a central role. Thirdly, size of the farming operation is shown to be significantly related both to the depth of lean practice implementation as well as to the extent of sustainable performance outcomes attained. With regard to the former, the data supports that farm size is a significant determinant of implementation, but only for a subset of lean practices. This conclusion is in alignment with the broader literature that mechanisms of interaction between the size of the organization and lean practice implementation may vary according to the specific practices being considered. In terms of the relationship between farm size and sustainable performance, this study concludes that the benefits of scale may only be realized beyond a certain size of farm and may be negligible for smaller farms. The results of this study represent a novel contribution to the scientific literature, and the learnings herein should find interest to consultants and practitioners in the agricultural domain seeking deeper insight into the application of lean management practices and/or the development of organizational capacity to enhance sustainable performance outcomes. To the academic community, this study will optimistically act to extend the legitimacy of and generate interest in furthering the development of lean management theories and frameworks within the agricultural domain. Furthermore, this paper may also be of use to agents of policy seeking to drive greater competitiveness and sustainability within the fruit horticultural sector. The question of whether or not managerial practices could enhance performance in sustainable agriculture, sans the availability of better inputs to production is one that should be of interest in the policy arena.

5.1 Limitations and Future Research

This study makes a significant contribution toward the field of lean management and agricultural operations management. However, there are several study limitations and avenues for future research which require comment. Firstly, the use of self-reported measures, both for lean practices and for sustainable performance measures is a significant limitation to this study, as it allows for greater influence of common method variance and the possibility of respondent bias in reporting performance. The sustainability related practices of farming operations is a sensitive topic in developing country contexts, where sustainability standards are a determinant of market access, and as such could influence respondents. Future empirical studies addressing lean in agriculture should strongly consider the use of non-reported measures of sustainable performance, to reduce the possible effects of both common method variance and respondent bias. A second significant limitation of this study is the incorporation of only one contingency variable, farm size, into the analysis. Agricultural performance outcomes are heavily influenced by a broad set of factors both internal (soil fertility, climatic suitability) and external (market access, horizontal or vertical integration) to the farm. Any future studies seeking to address the relationship between lean management and agricultural performance outcomes could benefit from the consideration of a broader set of contingency factors in their analysis, to account for confounding effects. Nevertheless, the empirical analysis of lean practices and sustainable performance benefits in horticultural primary production represent a new contribution to the existing body of knowledge. The learnings of this study will hopefully support practitioners and researchers in furthering the development of lean systems of practice in the primary production domain.

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Figure 1:

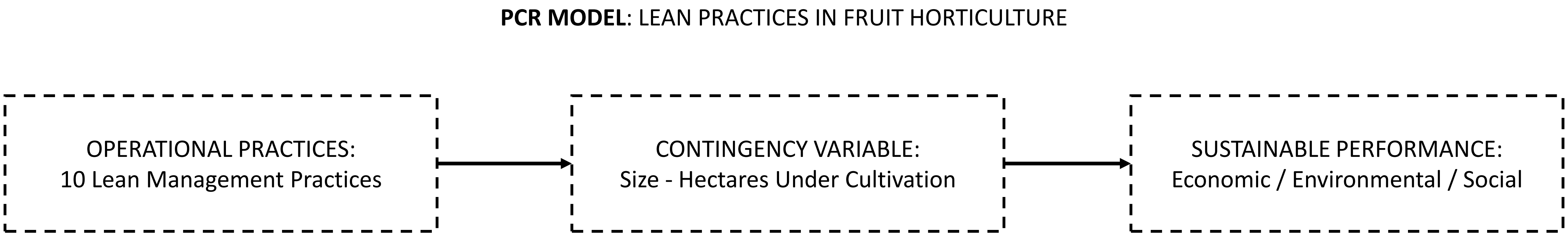
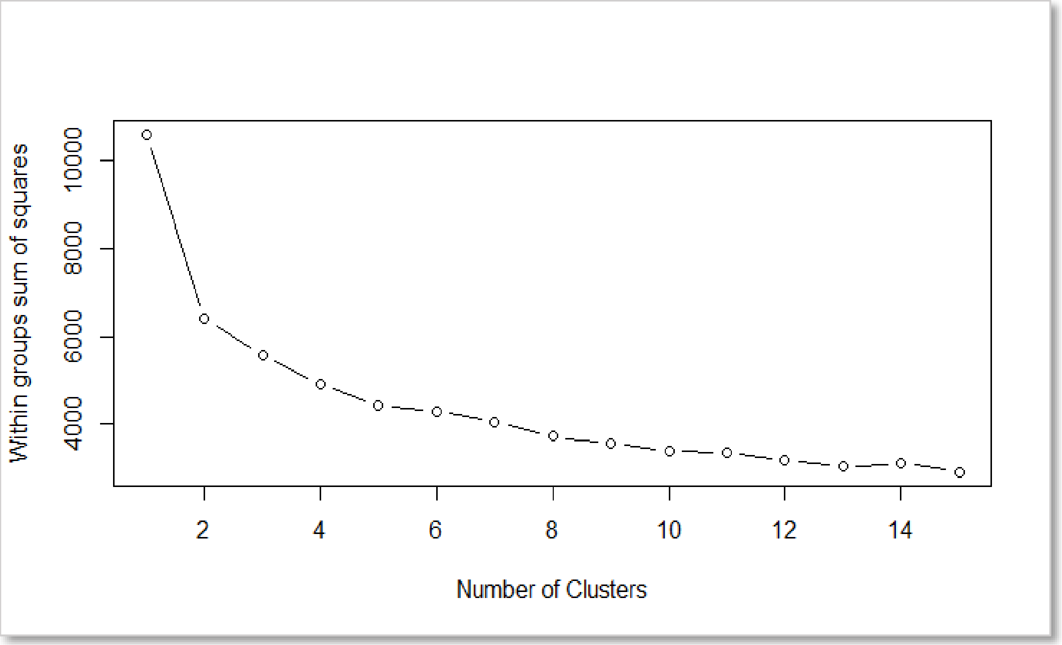

PCR MODEL: LEAN PRACTICES IN FRUIT HORTICULTURE
OPERATIONAL PRACTICES:
10 Lean Management Practices
CONTINGENCY VARIABLE:
Size - Hectares Under Cultivation
SUSTAINABLE PERFORMANCE:
Economic / Environmental / Social

Figure 2:



Within groups sum of squares
4000
6000
8000
10000
2
4
6
8
10
12
14
Number of Clusters

List of Tables:

Table 1: Summary of literature addressing the application of lean management in agricultural primary production.

Author:	**Method:**	**Commodity:**	**Benefits:**	**Barriers:**
Barth and Melin (2018)	Small Sample, Mixed Method	Dairy, Meat, Crops	- Optimize use of production inputs - Reduced changeover time	- Lack of manager / employee buy-in
Melin and Barth (2018)	Small Sample, Mixed Method	Dairy, Meat, Crops	- Cost reduction through control of waste - Improved safety awareness - Reduced feed shortages	- Production process is inherently unstable (climatic and biophysical) - Long lead times in production
Pearce et al. (2018)	Case Study	Fruit (Apples and Pears)	- Improved yield and quality - Improved workforce productivity - Improved inputs use efficiency - Reduced non-compliance risk w.r.t. sustainability standards	- Seasonal batch production - Volatility in operating context - Smaller farms resource constrained - Language barriers with workforce
Colgan et al. (2013)	Case Study	Multi-Commodity Farm	- Reduced waste and improved quality of food	- Chain power regime determines who reaps benefits of lean
Cox et al. (2007)	Case Study	Red Meat	- Some (minimal) commercial returns to producer end of the chain	- Lack of long-term price stability and certainty for producers
Simons and Taylor (2007)	Case Study	Red Meat	- Logistical benefits along the chain	- Inter-company alignment of systems - Chain organizational instability
Taylor (2006)	Case Study	Red Meat	- Positive logistical benefits along the chain	- Requires Equitable and explicit benefits sharing framework
Zokaei and Simons (2006)	Case Study	Red Meat	- 2-3% cost savings at each stage of the chain	- Unpredictability of the interaction of operational improvements
Simons and Zokaei (2005)	Case Study	Red Meat	- 25% productivity difference between lean & non-lean producers	- Chain fragmentation - Carcass is multi-product commodity
Cox and Chicksand (2005)	Case Study	Red Meat	- Internal productivity benefits	- Inter-organizational aspects difficult to apply

Table 2: Detailed delineation of the Shah and Ward (2007) lean management framework

MAIN FRAMEWORK:	LATENT DIMENSIONS:	OPERATIONAL DIMENSIONS:	OPERATIONAL MEASURES:
LEAN MANAGEMENT FRAMEWORK	1. SUPPLIER RELATED	1. SUPPLIER FEEDBACK	3 x Measures
		2. DEVELOPING SUPPLIERS	3 x Measures
	2. CUSTOMER RELATED	3. INVOLVED CUSTOMERS	3 x Measures
		4. PULL	3 x Measures
	3. INTERNALLY RELATED	5. FLOW	3 x Measures
		6. LOW SETUP	3 x Measures
		7. CONTROLLED PROCESSES	3 x Measures
		8. TOTAL MAINTENANCE	3 x Measures
		9. INVOLVED EMPLOYEES	3 x Measures
		10. SIGNALLING / KANBAN	3 x Measures

Table 3: Descriptive statistics summarizing the composition of the sample.

Sample Composition:			
Farm Size:	**Median:**	**Mean:**	**Std. Dev.:**
Hectares under cultivation (Fruit only)	33.5	41.7	36.3
Composition of Cultivated Area:		**Hectares:**	**Perc:**
Apples and Pears		1,623.5	29.3%
Citrus		842.5	15.2%
Plums		723.0	13.1%
Table Grapes		633.0	11.4%
Wine Grapes		421.5	7.6%
Avocadoes		272.0	4.9%
Mangoes		232.0	4.2%
Peach		155.0	2.8%
Olives		143.5	2.6%
Apricots		132.0	2.4%
Other		355.5	6.4%

Table 4: General awareness of lean management and continuous improvement concepts.

General Awareness:	"Yes"		"No"	
	Num:	Perc:	Num:	Perc:
a. Has some awareness of the continuous improvement concept.	78	59.1%	54	40.9%
b. Has some awareness of the lean system of management.	17	12.9%	115	87.1%
c. Possesses a basic functional grasp of what a lean management system is.	6	4.5%	126	95.5%

Table 5: Correlation matrix and descriptive statistics for lean practice implementation in the sample

Lean Practices:		Mean:	S.D. :	LP1.	LP2.	LP3.	LP4.	LP5.	LP6.	LP7.	LP8.	LP9.	LP10.	SUS1.
LP1.	Supplier Feedback	4.94	0.91	1.00										
LP2.	Developed Suppliers	4.21	0.97	0.42	1.00									
LP3.	Involved Customers	4.64	0.81	0.24	0.48	1.00								
LP4.	Pull	4.41	1.12	0.45	0.58	0.47	1.00							
LP5.	Flow	4.49	0.86	0.48	0.54	0.35	0.31	1.00						
LP6.	Setup Time Reduction	5.12	0.76	0.36	0.51	0.46	0.60	0.29	1.00					
LP7.	Statistical Process Control	4.95	0.99	0.42	0.48	0.43	0.62	0.35	0.67	1.00				
LP8.	Total Prev. Maintenance	4.61	1.05	0.28	0.41	0.27	0.44	0.17	0.37	0.43	1.00			
LP9.	Involved Employees	5.21	0.80	0.43	0.29	0.15	0.42	0.32	0.41	0.36	0.25	1.00		
LP10.	Signaling	3.35	1.04	0.27	0.35	0.15	0.53	0.15	0.38	0.41	0.34	0.39	1.00	
SUS1.	Sustainable Performance	4.44	0.77	0.47	0.52	0.50	0.76	0.43	0.62	0.64	0.45	0.45	0.46	1.00

Table 6: Comparable studies addressing lean practice implementation (Values all converted to 1 – 7 Likert scale)

Authors:	**Country:**	**Industry:**	**Dimensions of Lean Practice**	**Range of Mean Values:**	
				Low	**High:**
Marodin et al. (2016)	Brazil	Automotive	11	4.34	5.32
Dora et al. (2014)	Europe	Food Processing	8	3.46	5.83
Ghosh (2012)	India	Manufacturing	7	5.04	6.02
Sezen et al. (2012)	Turkey	Automotive	10	6.3	6.58
Taj and Morosini (2011)	China	Manufacturing	8	2.66	5.32
* *All values converted to 1 to 7 Likert Scale.*					

Table 7: Comparison of lean practices between clusters

Cluster Comparison:				
	High Lean Practice Cluster		Low Lean Practice Cluster	
	(n1 = 44)		(n2 = 88)	
LP Practices:	Mean:	Std. Dev:	Mean:	Std. Dev:
LP1. Supplier Feedback	5.56	0.64	4.64	0.73
LP2. Developed Suppliers	5.17	0.78	3.73	0.64
LP3. Involved Customers	5.21	0.58	4.36	0.76
LP4. Pull	5.64	0.66	3.80	0.68
LP5. Flow	5.06	0.75	4.20	0.77
LP6. Setup Time Reduction	5.83	0.51	4.77	0.61
LP7. Statistical Process Control	5.82	0.71	4.51	0.79
LP8. Total Preventative Maintenance	5.23	1.14	4.30	0.80
LP9. Involved Employees	5.73	0.77	4.95	0.68
LP10. Signaling (Kanban)	4.16	1.08	2.95	0.71

Table 8: Summary of the MANCOVA results

MANCOVA Results:		
Main Effects:	**High LP vs Low LP Cluster**	**Farm Size:**
LP01 TO LP10	0.000 ***	0.006 **
Between Subjects Effects:		
LP1. Supplier Feedback	0.000 ***	0.065 **.**
LP2. Developed Suppliers	0.000 ***	0.393
LP3. Involved Customers	0.000 ***	0.082 **.**
LP4. Pull	0.000 ***	0.038 *
LP5. Flow	0.000 ***	0.025 *
LP6. Setup Time Reduction	0.000 ***	0.115
LP7. Statistical Process Control	0.000 ***	0.018 *
LP8. Total Preventative Maintenance	0.001 **	0.058 **.**
LP9. Involved Employees	0.000 ***	0.032 *
LP10. Signaling (Kanban)	0.000 ***	0.011 *
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1		

Table 9: Results of the Two-Way ANOVA

ANOVA Results			
Dependent Variable: Sustainable Performance			
Independent Variables		**F**	**Sig.**
LP Clusters	(High LP vs Low LP)	46.205	< 0.001
Farm Size	(Small, Medium, Large)	7.97	0.001
LP Clusters x Farm Size	(Interaction Variable)	0.985	0.376
a. R Squared = .620 (Adjusted R Squared = .605)			

Table 10: Post hoc comparison of sustainable performance scores between categories of farm size.

Post-Hoc Comparison				
Independent Variable: Sustainable Performance		Mean Difference:	Standard Error:	Significance:
Large Farms	Medium Farms	0.299	0.106	0.016***
Large Farms	Small Farms	0.665	0.191	0.002**
Medium Farms	Small Farms	0.365	0.192	0.177
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Table 11: Basic descriptive statistics illustrating sustainable performance scores for each factorial grouping.

Descriptive Statistics				
Dependent Variable: Sustainable Performance		Mean:	Std. Dev.:	N:
High Lean Adoption Cluster	Small Farms	4.500	0.240	2
	Medium Farms	5.118	0.486	17
	Large Farms	5.426	0.414	25
Low Lean Adoption Cluster	Small Farms	3.913	0.448	42
	Medium Farms	4.025	0.599	27
	Large Farms	4.315	0.491	19

CRediT Author Statement:

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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