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ROLE OF KEY PERFORMANCE INDICATORS TARGETING THE RESEARCH ON BUSINESS INNOVATION IN THE COMMERCIAL AGRI-FOOD SECTOR

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ABSTRACT

The theme of research and development (R&D) lies at the heart of any industry that attempts to increase its productivity, and there is no difference concerning those industries cataloged under the commercial agri-food sector. Key performance indicators (KPIs) are recognized as one of the key tools that are heavily used to measure these efforts in research management, through which the right direction of the research agenda of a research institute is evaluated. The dynamics of KPIs in place are, however, slackly deliberated and remain poorly understood, and perhaps, those set up to work toward achieving Sustainable Development Goal (SDG 2) - "Zero Hunger" are not well explored. This study, on this shed of light, aimed to synthesize the literature build-up on performance management of research that was put into a business perspective. A systematic review of the literature was followed in Phase One to identify, collate, and summarize empirical evidence from the extant literature on performance management systems (PMSs) and KPIs. Thirty-two (32) research administrators and practitioners affiliated with prominent research institutes operating in Sri Lanka directing research for commercial agriculture development were approached in Phase Two via in-person in-depth interviews aided by an interview guide comprising 15 probing questions. To assess the perspectives of those officers in the upper echelon, the Thematic Qualitative Models produced by MAXQDA 2022 software were employed. The outcome of the thematic analysis converged those perspectives into five themes: (1) Research commercialization, (2) Research collaboration, (3) Research for society, (4) Institutional management, and (5) Technology-integrated systems. It underscored the organizational benefits gained from well-thought-out PMSs comprised of smart KPIs. Some analysis techniques such as Code-Frequency-Tables, Code-Maps, etc., provided by the software were systematically used to build some frameworks on KPI-key performance drivers (KPD) relationships that facilitate real-time data-driven PMS in driving research business innovations on commercial agriculture.

Keywords: Commercial agriculture, KPIs, Performance management, Research business

1. Introduction

Hunger afflicted approximately 800 million individuals globally in 2020, and more than 30% of the world's population (approximately 2.4 billion people) was moderately or severely insecure in consistently accessing enough food to live an active, healthy life (FAO, 2021). Although this goal is still far from being achieved for a variety of reasons, including disruptions (e.g., the COVID-19 pandemic), the collective effort put forth by all United Nations Member States in 2015 in line with the second Sustainable Development Goal (SDG) - "end hunger by 2030" - remains in momentum. Target 2.3 of SDG 2 specifically calls for doubling agricultural output by 2030 while the world population exponentially approaches nine billion by 2050 (Arora & Mishra, 2022; FAO, 2018). This puts existing food systems under pressure. It requires food systems to boost productivity in both quantity and quality to change the status quo. In the context of a successful transformation of agriculture from the subsistence level to the commercial level, research and development (R&D) in a country plays a significant role in making food more abundant, secure, and affordable. Furthermore, food production has both environmental and social consequences. For example, the global food production system is a significant source of greenhouse gas emissions. Therefore, to avoid future resource depletion, researchers must investigate alternative food sources as well as remedies for detrimental effects of the R&D production process, such as how to save energy in R&D. These challenges have forced research leaders to revise their research management strategies towards more innovative commercial agricultural (CA) sector based on data-driven decision making.

1.1. Research scope and objectives

Little is known about how key performance indicators (KPIs) are institutionalized, developed, and managed at research institutions to create an environment in which performance metrics are developed and linked to the true research needs of the CA through data-driven decision-making. The current condition of the KPIs utilized in research institutes appears to be neither known to the research community nor adequately recorded for future processing. This opens the possibility of making a theoretical as well as a practical scholarly contribution that supports how KPI should be institutionalized, transformed, and managed at research institutes to ensure the success of R&D for CA development.

Therefore, the lack of scholarly literature that aids in understanding the role of KPIs in performance management systems (PMSs) and the lack of guidelines and measurement frameworks in establishing KPIs for research management towards innovative CA can be identified as issues (problem statement) that cause the above research gap. Based on the research gap and problem statement, the following research questions have been formulated:

1. What is the role of KPIs in the research institutes working on R&D in the CA sectors in Sri Lanka?
2. What are the Critical Success Factors (CSFs) and Key Performance Drivers (KPDs) that drive research toward innovative CA?

3. What would be possible recommendations for the enhanced performance of an institute working on R&D in CA in Sri Lanka with special reference to digital transformations?

1.2. Performance management and KPI on R&D

Many studies investigating performance management in the context of different organization types, the research sector in general and the agriculture sector in general, have been published (Aramyan, 2007; Chiesa & Frattini, 2007; Kamble et al., 2020; Yawson & Sutherland, 2010), including studies of KPIs in the performance management of research institutes (Agostino, et al., 2012; Bican & Brem, 2020; Dziallas & Blind, 2019). All these attempts give a strong indication of the importance of institutionalizing strong indicators in the calibre of KPIs in performance measurement and management, especially in view of establishing a productive CA sector.

The government organization's structure of Sri Lanka, in general, is bureaucratic and runs on a chain of command within an administrative system (Priyantha et al., 2019). These systems and processes could be considered in even more immature status when performance measurement is expected to strategize the improved sectorial performance perspectives such as the development of CA and organic-only agriculture in a country through R&D. Because the performance of research appears to be measured in general without focusing on a specific specialized area and without identifying the true KPDs, KPIs related to the performance of research institutes' work on CA may not be visible through normal analysis (KPIMS, 2016), which is only capable of understanding noncomplex, impotent patterns and trends. Therefore, KPI data must be systematically available in sufficient quantities to aid decision-making through predictions and visualization. To that purpose, customized ICT tools in a PMS would be a sustainable solution. Data processed through digital channels might be useful and crucial in anticipating what is likely to happen in real-time in the research business related to the CA industry (Abeysiriwardana, Jayasinghe-Mudalige, & Kodituwakku, 2022).

1.3. Methodology in brief

The study was set in two phases, namely, Phases One and Two. In Phase One, a systemic literature review was conducted on published papers/ documents concerning the aspects of performance management. Phase Two consists of three stages. In stage one, a qualitative study was carried out with 10 leaders who manage R&D work for the CA sector in Sri Lanka. In stage two, several frameworks, and models to establish KPIs in PMSs of R&D in CA were proposed (Abeysiriwardana, Jayasinghe-Mudalige, Kodituwakku, et al., 2022; Abeysiriwardana & Jayasinghe-Mudalige, 2022b). In stage 3, the qualitative study was completed by analysing the perspectives of the rest of the 22 leaders of the population of research institutes.

1.4. Overview of the main results

This research study was able to provide the following contribution to the scholarly literature on performance management of R&D based on the qualitative studies carried out with the research leaders.

1. The role of KPIs in R&D in the CA sectors in Sri Lanka was explored, extracted, and determined.
2. The strengths and weaknesses associated with those KPIs and systems that established them were assessed.
3. A model PMS consisting of a set of SMART KPIs, considering the 1 and 2 above, to judge the performance of research conducted in those institutes was proposed.
4. A set of recommendations on R&D performance management in CA in Sri Lanka was made, with a specific emphasis on the use of digital transformations to improve it.

2. Literature Review

A quarter of the population in Sri Lanka depends on agriculture for a living, although its contribution to the country's GDP in the first quarter of 2020 was only approximately 7.3% (DCS, 2020). The elimination of rural poverty in Sri Lanka was significantly aided by higher agricultural revenues, which rose by an average of approximately 5% annually from 2013 to 2022 (Ref: Figure 1).

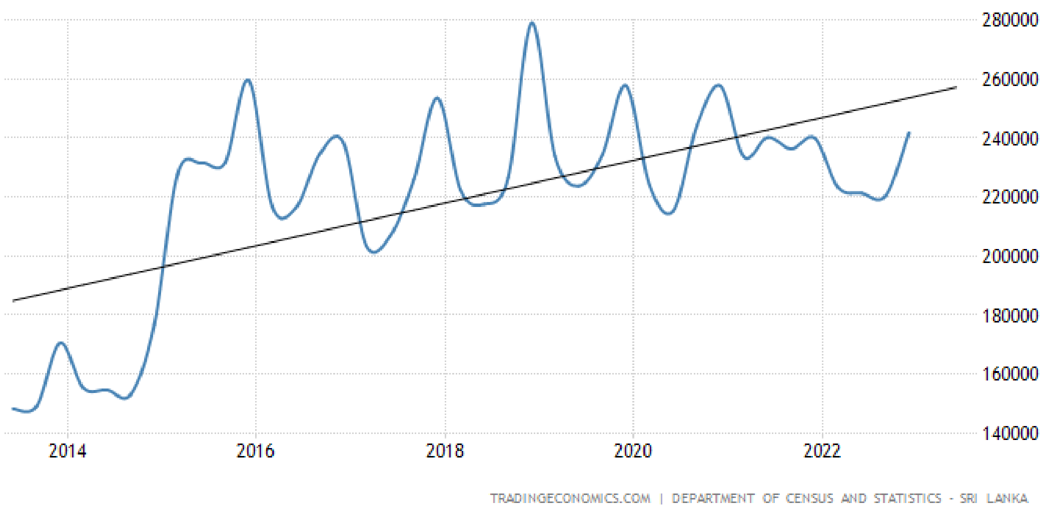

Figure 1. GDP from agriculture (Sri Lanka, 2014-2022) in LKR Mn. vs. quarter of a year.
(Source: Produced with Tools Available in tradingeconomics.com)

Even though agriculture is an important and crucial sector of the Sri Lankan economy, obstacles such as low productivity, low profitability, and natural disasters (e.g., the COVID-19 pandemic) have hindered its growth (Roshana & Hassan, 2020; Thibbotuwawa & Hirimuthugodage, 2015). Therefore, it is important to focus on these agricultural challenges and propose strategies to overcome them, as described in Table 1.

Only research, technology, and innovation through integrating research approaches can

Table 1. Strategies to overcome agricultural issues and challenges.

No.	Requirement	Strategies
1	Increase food production	Increase productivity of food production and introduce quality foods.
2	Reduce food waste	Introducing better management practices in food processing and producing quality food products.
3	Provide better jobs for farmers	Introduce efficient profit-earning farm practices
4	Apply environmentally friendly agriculture processes and agriculture inputs to the field	Produce technologically improved safer agriculture inputs and processes.
5	Environmentally friendly agriculture outputs/ products	Produce agriculture outputs/ products through environmentally friendly practices and inputs

increase livestock and crop yields, reduce loss due to disease and insects, develop more efficient equipment, and increase overall food quality (Chavez-Dulanto et al., 2020). When the worldwide R&D expenditure pattern is examined, it is clear that developed or large-economy nations have made far more progress toward ensuring food security through R&D than developing or small-economy nations (National Academies of Sciences, Engineering, and Medicine, 2023). Approximately $700 billion was spent on R&D worldwide in 2000, and in 2022, that sum tripled and exceeded $2 trillion within a short period of 20 years. A substantial portion of that expansion is taking place in developed or large economy countries, as those countries have realized the significance of R&D in long-term success (National Center for Science and Engineering Statistics, 2022). However, a country should have an effective research management system, as shown in advanced nations, to secure sufficient spending on R&D. The goal of Korea's specialized evaluation and planning unit for science and technology, KISTEP (Korea Institute of S&T Evaluation and Planning), is to improve science and technology (S&T) planning and evaluation to increase the effectiveness of R&D expenditure (CICP-KISTEP, 2021). The government is said to have supported Korea's excellent strategic investment plan, and one of its key strategies is to "strengthen the strategy research," which necessitates the establishment of a proper PMS. China comes in second place to the United States in terms of the quantity of R&D funding. Approximately 1.5 trillion Yuan was spent on R&D in 2016 (250 bln US dollars) with approximately 2% of GDP (Dai, et al., 2020), and become 3 trillion Yuan with approximately 2.5% of GDP by 2022 (SC-PRC, 2023). In 1993, the Chinese Academy of Sciences (CAS) started the research institution assessment process. After 2011, qualitative opinions were taken into consideration to compare an institute's performance to its 5-year targets. Notably, the outcomes of the performance assessments have a direct impact on S&T's decision-making on the distribution of incentive resources based on performance (Xu & Li, 2016).

It is essential to be more vigilant on research metadata to make the research business more profitable, goal-oriented, and productive towards innovative CA. This requires the measurement of research outputs through a proper set of indicators. While all research in the agricultural sector has the same overarching goal of achieving production of excellence, it also has more focused goals such as knowledge creation and commercialization. These aspects may be well captured and can be monitored and evaluated through a systematic tool such as the KPI. It can be further witnessed by how developed or industrialized nations attempt to systemize KPIs in a proper performance measurement framework to evaluate their research for optimum ROI.

KISTEP, as a government-affiliated research institute under the Ministry of Science and ICT of Korea, pools 100 main science and technology indicators (possible KPIs) under 4 categories and 15 subcategories to be used in evaluating the success of science and technology (KISTEP, 2021). In such an attempt, the Council responsible for National Science and Technology of Korea made use of KPIs to evaluate its R&D programs in the short term every year in various sectors, including agriculture and forestry, where their national plan for improving agriculture and forestry is evaluated (Park et al., 2006). The Science and Technology Policy (STP) Division of the OECD (Organisation for Economic Co-operation and Development) produces the OECD Main Science and Technology Indicators (MSTI) as a statistical publication (Criscuolo & Martin, 2004). It is based primarily on data on the financial and human resources allocated to research and development, as defined in the OECD Frascati Manual, and is supplemented by additional indicators of outputs and potential outcomes of scientific and technological activities, namely, patent data and international trade in R&D-intensive industries (De Marchi, 2019). In an attempt to cover the results' chain in the evaluation of European Research Infrastructure, some KPIs that would be useful in the knowledge creation aspect of research have been proposed based on a survey facilitated by the Association of European-Level Research Infrastructures Facilities (ERF-AISBL) (Kolar et al., 2018).

Thus, KPI is a more powerful tool than previously thought and can be utilized to understand the core business of research institutes and the performance drivers associated with them and then facilitate the decision-making of the research institutes to develop a healthier CA development agenda for a country such as Sri Lanka (Abeysiriwardana & Jayasinghe-Mudalige, 2021). It is expected that the KPI could also emphasize extra strategies that could make research more sustainable in its existence. KPI could enhance the research contributions to a greater quality of life by highlighting the society-friendly characteristics of CA research, such as corporate social responsibility and corporate environmental responsibility (Abeysiriwardana et al., 2022a; Abeysiriwardana & Jayasinghe-Mudalige, 2022c). Thus, the KPIs are supposed to direct and evaluate research with a special focus on society's well-being without compromising its economic sustainability, even in the context of competitive profit earnings. However, these complicated measurements need to be integrated into one platform, perhaps through digital methods, to reap the full benefits of data-driven decision-making.

3. Methodology

Finding interconnected knowledge about theories or the applicability of experience or practice under unique circumstances has been the subject of qualitative studies. Interview methods may be employed to channel that knowledge for further insights. Credibility, transferability, dependability, and confirmability are the four standards provided for determining whether or not the overall findings of qualitative research are trustworthy (Lincoln & Guba, 1994). Considering all the above expectations of a qualitative study, and especially to assure the credibility of the findings and reflexivity, the authors took special care to independently code the data using a pre-agreed code system with the least amount of interviewer intervention with the information obtained from the participants. Furthermore, this research adopts digital methodologies to assist those qualitative methods to make each step more efficient, flexible, and approachable. The thematic analysis methodology used here was based largely on grounded theory and partially on phenomenology and narrative research methodologies (Braun et al., 2023; V. Braun & Clarke, 2006, 2021). The use of KPIs in research institutes was still in need of considering the theoretical aspects of performance measuring systems rather than fine-tuning their practical aspects which led authors to apply grounded theory to establish theoretical performance measurement frameworks based on KPIs. Furthermore, to assist this theory building, the experience of researchers and their attitudes regarding the use of this knowledge-intensive measurement tool (KPIs) were extracted and investigated by following phenomenology and narrative research methodologies.

3.1. Survey instrument and sampling method

The semi-structured interviews were conducted using an interview guide consisting of 15 probing questions, informed by literature studies and prior knowledge, allowing for a comprehensive understanding of KPIs in developing countries (Abeysiriwardana & Jayasinghe-Mudalige, 2022b). The leaders' attitudes, values, perspectives, and experiences were analysed along with how they were involved with performance management and KPIs in R&D in the CA sector. The sampling method was only applied in Stage 1 of Phase 2 of this research, as mentioned in the Abeysiriwardana, Jayasinghe-Mudalige, Kodituwakku et al. (2022) article. The authors will present the analysis for this research based on the entire population, and the results will be compared with the prior analysis done on a sample of 10 interviewees. The population is made up of Sri Lankan government and semi-government research institutes, which conduct fundamental and applied research and employ between 20 and 300 individuals.

3.2. Data collection

A study invited 60 individuals from 32 Sri Lankan research institutes who showed interest in the development of the CA sector. This covered the whole population of research institutes that were responsible for conducting R&D for the development of the CA sector in Sri Lanka. The top two key positions of those research institutes were called. The next most pertinent key position was chosen when there was only one key position available or when a key position was vacant. Sixty (60) persons were contacted via email or verbal means, and only 35 from 24 institutes responded to consent requests through Google Forms. The research was conducted virtually due to the busy and informal work schedules of the research leaders. To help them feel more at ease with the interview schedule, they were allowed to select any time between 24 hours and 7 days. Interview effective times varied from 28 to 98 minutes. The first round of ten interviews took place between October 29th and November 13th, 2021. The second round of 22 interviews began on November 26th, 2021, and ended on July 13th, 2022. The authors took special care to avoid time-related biases that may associated with the long period of collecting data by employing the same team of trained interviewers and manipulating probing questions strictly within the purpose of the research. Furthermore, interviewees were provided with an introduction/ guideline before starting the interviews and authors were on alert of any substantial changes to their study environment during this period. Only 32 of the 35 consenters participated, with three abstaining owing to personal or medical reasons. Interview transcripts were created from audio files using Otter.ai. (n.d.) transcription software and then corrected for readability and legibility by researchers by inspecting text continuously while listening to relevant audio for errors. The findings were evaluated, and conclusions were reached at predetermined milestones of the study period.

3.3. Data analysis

To create insights for this research study, the authors employed a combination of thematic analysis and content analysis based on utilizing an appropriate mix of data analysis methods (Clarke et al., 2015). The phases of data collection and analysis within a single research project may become circular since revisiting stages may be necessary to achieve better findings (Fossey et al., 2002; Russell & Gregory, 2003). Furthermore, such an approach may easily enable triangulation or crystallization using multiple datasets, methods, theories, etc. (Heale & Forbes, 2013) to achieve a more thorough understanding of the phenomenon under investigation as well as generate frameworks that facilitate R&D management. Using a variety of datasets collected throughout the two time periods and employing different investigation methodologies, the authors used triangulation in their study to address the research questions and increase the validity of the research findings. The MAXQDA program for computer-assisted qualitative data analysis was used to organize the text, evaluate relationships, and show data and findings. Hierarchically, the experts' views on the use of KPIs in organizational dynamics to manage the performance of agriculture research in Sri Lanka were classified into codes, categories, subthemes, and themes.

4. Results and Discussion

This research has two phases to converge the leaders' insights of research institutes in Sri Lanka on the essence of the performance management of research for the development of the CA sector. In phase one, a systematic literature review was conducted to identify major performance drivers of R&D on CA and their relevant KPIs. Phase 2 involved three stages: 1) interviewing 10 Sri Lankan research institute leaders and analysing data using SWOT and thematic analysis (Abeysiriwardana, Jayasinghe-Mudalige, Kodituwakku et al., 2022; Abeysiriwardana & Jayasinghe-Mudalige, 2022b) and 2) proposing frameworks for establishing KPIs in PMSs, integrated virtual PMSs, and performance measurement models (Abeysiriwardana, Jayasinghe-Mudalige, & Kodituwakku, 2022; Abeysiriwardana, Jayasinghe-Mudalige, & Seneviratne, 2022; Abeysiriwardana, Jayasinghe-Mudalige, Kodituwakku et al., 2022; Abeysiriwardana & Jayasinghe-Mudalige, 2022b, 2022c). 3) analysing all 32 in-depth interviews to retrieve further insights on focused subjects. In this research paper, the authors will discuss Stage 3, more or less assisted by the conclusions of previous phases, to look at particular themes and their components with more analytical differences to answer the research questions already elaborated.

4.1. Role of KPIs in contemporary research performance management

The thematic analysis of 32 interviews (2nd analysis) revealed the same 5 themes, 12 subthemes, and 32 categories as observed similarly in 10 interview analyses described in Abeysiriwardana, Jayasinghe-Mudalige, Kodituwakku et al. (2022).

1. Research Commercialization
2. Research Collaboration
3. Research for Society
4. Institutional Management
5. Technology Integrated Systems

However, in addition to 119 codes in the 1st set of 10 interviews, another 33 codes were added, making the whole code set containing 152 codes in the second analysis consisting of 1854 code segments. As per Figure 2., in Word Clouds of the 10 and 32 interview sets, the term "kpis" was clearly emphasized to show how important it is to the performance management of research institutes.

Figure 2. Word cloud of 10 (L) and 32 (R) interviews.

With KPIs in hand, research leaders described the role of KPIs based on the above five themes, which highlight "research commercialization," "research collaboration," and "research for society" as CSFs of R&D. Therefore, these CSFs were elected as major candidates for establishing complement KPDs/ KPIs for CA research development. With this set of results in hand, the authors tried to compare research leaders' expectations with the actual situation of performance management of CA research in Sri Lanka. Many research institutes use KPIs to measure the performance of research, as shown in Table 2. Here, the KPI data of seven research institutes (institutes involved with science, technology, and research) that were continuously contained within the same ministry for 7 years and addressed the subject of science and technology from 2016 to 2022 were analysed according to the published annual reports and other available progress reports in the ministry. The most prominently used 12 KPIs are listed below. "0" means that a particular KPI is not recorded for any research institute for a particular year. "7" means that the particular KPI is used by all seven (7) research institutes.

In actual situations, many research institutes have focused more on "popularizing SIT" rather than how to engage more in the "research commercialization," "research collaboration" and "research for society" aspects of research. This lack of focus creates serious concerns about the effectiveness of those KPIs that were not assessed against

Table 2. Heatmap of KPIs in some research institutes in Sri Lanka (SIT – Science, Innovation, and Technology).

No.	KPI (As a number)	Year (2016 – 2022)						
		'16	'17	'18	'19	'20	'21	'22
1	Research grants awarded	3	3	3	4	3	3	3
2	Established joint research/ research-industry collaborations	3	3	4	4	3	4	5
3	Research papers published	5	5	5	5	5	5	5
4	Local/ international recognitions obtained	2	2	3	3	2	3	3
5	Local/ international patents obtained	3	6	4	4	5	5	5
6-I	Programs conducted to popularize SIT	6	7	7	7	7	7	7
6-II	Participants in programs aimed at popularizing SIT	6	6	6	6	6	6	6
7	Publications related to the field of SIT published	4	4	5	5	5	5	5
8	Local/ internationally signed technology transfer agreements	3	4	3	3	3	2	3
9	Research products commercialized locally/ internationally	5	5	5	5	5	4	4
10	Inventions that are financially supported for commercialization	3	3	3	3	3	3	3
11	Local/ internationally signed SIT collaborations	3	4	4	3	3	3	3
12	Successfully completed SIT collaborations	0	0	2	2	2	2	3

their potentiality in generating insights for the decision-making process of R&D that focuses on national requirements.

4.2. Recommendations for enhanced performance of R&D in the CA sector

In a developing country, a major question arises regarding how to balance the performance of theoretical research of low potential ROI (fill the knowledge gap of applied research) with applied research (having high potential of commercial value). In a developed country, resources are saturated, so there is no obligation to use resources for theory building in advancing commercial research in many ways. In developing countries, research is a burden to the economy, as it revolves around a vicious cycle of inefficiency in many contexts in addition to a lack of resources for its very existence. Table 3. summarizes the findings of code maps on interactions of several themes which are essential parts of good research culture in any country. Although codes within themes co-occurred, codes between themes did not, according to these maps. The lack of coherence between all these themes provides a good indicator of why research outputs are not strong enough to launch business innovation in the CA industry.

In CA R&D, indicators responsible for measuring commercial results are given more weight and may consist of the number of new products, product success rate, sales volume, market share, cost-saving ratio, and general aspects of employability and food security. However, these indicators become weak candidates for KPDs if interactions among the themes found in this study occur with less frequency. These themes can be converged to provide the following insight in this regard: *Impactful research is a product of good "institutional management" that is assisted by robust KPDs/ KPIs such as "research commercialization," "research collaborations," and "research for society" through a data-driven "technology integrated system" incorporated into a PMS.*

Table 3. Code similarity check between themes according to code maps.

No.	Theme 1	Theme 2	Similarity
	Technology Integrated System	**Institutional management**	
1	User-friendly	Achieving Targets	Low
2	Situational Changes	Interconnection between Divisions	
3	Lack of Understanding among staff	Performance Evaluation	
4	Quick Decision Making		
	Research for Society	**Research Collaboration**	
1	Complex structured KPIs	Transparency of KPIs	Medium
2	3P's	Availability of KPDs	Medium
3	Discuss and set KPI	Government Contribution	Low
4	Environment aspects in KPI	Farmers Contribution	Low
5	Stakeholders		Low
	Research Commercialization	**Research Collaboration**	
1	Research Value Preservation	Transparency of KPIs	Medium
2	Market Identification	Availability of KPDs	Medium
3	Research Value Communication	Government Contribution	Low
4	Demand-driven Research	Farmers Contribution	Low
5	KPI on commercialization		Low
	Research for Society	**Technology Integrated System**	
1	Complex structured KPIs	User-friendly	Medium
2	3P's	Situational Changes	Medium
3	Discuss and set KPI	Lack of Understanding among staff	Low
4	Environment aspects in KPI	Quick Decision Making	Low
5	Stakeholders		Low

4.3. Digitization and digitalization of performance measurements

Given the investment needed to implement a digital transformation, some research organizations are unsure of precisely how these solutions can assist them in improving decision-making. This is partially due to the difficulty some early adopter research organizations have had in quantifying the financial benefits of their investments in digitally transformed PMSs. Seriously, non-financial benefits such as non-biased decisions, improvement of trust among employees, etc., are not taken that much into those calculations (Westerman et al., 2014). Additionally, performance measurement is a data-intensive process, and shifting less important data management tasks to digital systems would greatly benefit the research institute by reducing the overall time spent on those tasks and making complex data into simple information for quick decision-making (Nudurupati et al., 2016). However, it should be noted that the digitalization of performance management involves more than just the adoption of modern technology; rather, it involves a fundamental shift in the "organizational performance measurement strategy" that has a major impact on organizational knowledge and the entire socio-technical organizational system.

4.4. Performance measurement framework as an organizational strategy

If a PMS could be implemented in a balanced manner by establishing a robust performance measurement framework that facilitates the existence of SMART KPDs/KPIs, it could significantly contribute to the long-term sustainability of research implementation in the innovative CA sector (Kaplan & Norton, 2005). Thus, a PMF that facilitates establishing valid and reliable KPIs along with digital interventions to make it a real-time and data-driven decision-making system is proposed in Figure 3.

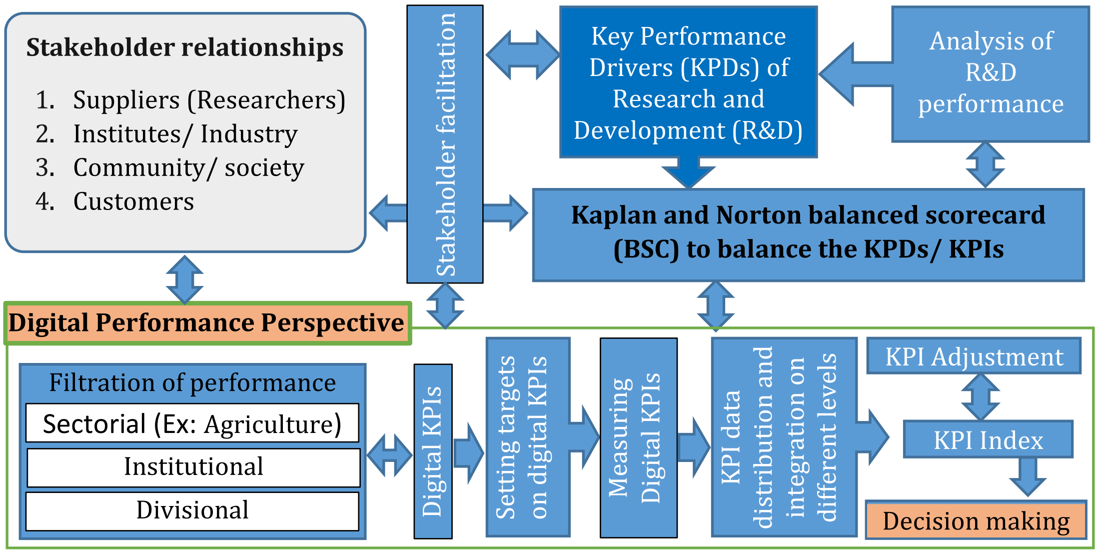

Figure 3. Digitally transformed performance measurement framework.

The above framework is found on the balance performance measurement strategy and facilitates digital information processing of KPIs while ensuring stakeholder interactions are not overlooked during the measurement establishment process.

4.5. Policy interventions for effective PMS

The most delicate aspects of research success in CA, such as the social responsibility and environmental friendliness of agriculture research along with its economic sustainability, have not been put into a structure and effectively practiced, despite the fact that the more sophisticated systems are available to measure the performance of such research aspects and have been in use for quite a long time. This might be brought on by a lack of policies, regulations, and clearly defined methods and resources included in an appropriate PMS. Policy measures in research performance management may facilitate a robust decision-making system in implementing sustainable research for the CA sector as follows.

1. To increase government funding for research on national and social issues
2. To facilitate sizable increases in applied/ commercialized research of an institute
3. To help the government prioritize novel technologies that competitors focus on
4. To identify the requirements to pursue basic science

Therefore, the following policy measures are proposed to coexist with the performance measurements of CA research to make PMS sustainable throughout its lifecycle.

1. Critical Set of KPIs: Less number is preferred based on institutional, national, and global analysis
2. Integration of all performance measurements including international requirements in a single performance measurement and reporting approach
3. Adopting the "Research for Society" approach at the Research Institute through PMS
4. Measure performance across digital platforms supported by AI and automation

5. Conclusion and Implications

If the performance of the research process in the CA sector is carefully facilitated and managed, research would have a more significant impact on the economy of a developing country such as Sri Lanka, even in circumstances such as low investment. In such a context, manoeuvring KPIs as a powerful tool for managing the performance of research could lead to a strategic shift in the development plan of research organizations. However, it has been observed that research institutes have followed ineffective (the selection and establishment of KPDs/KPIs) and inefficient (the implementation mechanism) systems for the performance measurement of research in the CA sector. The insights of leaders that were obtained from in-depth interviews shed light on how those KPDs/ KPIs should be institutionalized and behaved in an R&D process to reap the maximum benefits. This research study further contributed by proposing a model PMS consisting of a set of SMART KPIs to judge the research performance of those institutes. Furthermore, a set of policy recommendations on R&D performance management in CA in Sri Lanka was proposed with a special reference to the use of digital transformations in optimizing it. Thus, this research covered its objective of exploring, extracting, and determining the role of KPIs in R&D in the commercial agricultural (CA) sectors in Sri Lanka while identifying the strengths and weaknesses associated with certain KPIs and systems. The results provided additional evidence to achieve the objective of proposing a model PMS consisting of a set of SMART KPIs. The authors found a few limitations in their study including data restrictions to the domain of a specific country and sector, both of which could have been validated with the availability of more diverse data. It is imperative to carry out additional research in domains such as performance evaluations, in compliance with the competitiveness performance framework. These studies are intended to explore competitiveness links that could potentially facilitate the transition of established research institutions into emerging ones. Furthermore, the results of such kind of study would provide a strong foundation for creating a widely accepted methodology to identify and evaluate research competitiveness in relation to fields such as CA.

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