



Intelligently driven performance management: an enabler of real-time research forecasting for innovative commercial agriculture

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Received: 8 September 2021 / Accepted: 5 August 2022 / Published online: 22 August 2022
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Abstract

Research in commercial agriculture is instrumental to achieve the targets set under the second Sustainable Development Goal (SDG), i.e., ‘Zero Hunger by 2030.’ Execution of research for the success of commercial agriculture becomes a tedious task and research organizations have been long struggling to assess their performance unequivocally in the face of COVID-19. Any evacuation plan in place to improve the performance, monitoring, and evaluation of a research institute must guarantee that the institute is on the right momentum and let it evades metrics-obsessed research drives during this pandemic. A survey was conducted through the participation of the topmost administrators attached to key research institutes working on agriculture in Sri Lanka to explore the current performance management practices deeply. The conclusions derived from a thematic analysis of the survey data were used to propose a set of solutions that facilitate a well-thought research agenda in a digitally transformed performance management system. The solutions imply that intelligently driven key performance measurements worked by artificial intelligence and big data could be used with policy innovations to support research integrity and assessment security within the coexistence of humans and machines for the well-being of research development in the commercial agriculture sector.

Keywords Artificial intelligence · Commercial agriculture · Digital transformation · KPI · Performance management · Research institutes

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Introduction

Zero Hunger by 2030, the second Sustainable Development Goal (SDG) is a universally recognized and accepted directive (Bhavani and Rampal 2020; Gassner et al. 2019; Guenette 2019; Sunderland et al. 2019; UNCTAD 2017) that could be well strategized to achieve food security, especially by developing commercial agriculture sector. World statistics reveal that agriculture accounted for 4% of global gross domestic product (GDP) in 2018, and in some least developing countries, it could account for more than 25% of GDP (WB 2022).

However, despite this initiative has been directed at agriculture development, nearly half of the world's population is still living below the poverty line and more than 11% of people are living in extreme poverty depending on earnings of less than \$1.90 per day leading to hunger and malnutrition. This situation has been further worsened by the socioeconomic impacts of COVID-19 having more than 97 million additional people pushed into extreme poverty in 2020 (UN 2022; UNDESA 2021). Meanwhile, a 60% increase in global food demand is expected to occur by 2050 compared to 2006 due to population increases and changes to food patterns (Gunaratne et al. 2021). To satisfy all of these expectations while addressing the challenges of poverty, the world has set targets under fifteen different initiatives that have links with many other SDGs (FAO 2019) to harness the power of agriculture in reducing food insecurity and enhancing economic and household income. In this context, research development that targets the commercial agriculture sector is supposed to make a direct impact on four such initiatives with expedited contributions to respective SDGs as mentioned in Table 1.

The dynamics of the above initiatives could be considered as a function of productivity-driven success in the commercial agriculture sector. Productivity at a large scale would not be achieved without ever-changing strategical innovations introduced into the commercial agriculture sector. In this context, the product and process innovations conceived from a well-managed research development process are supposed to act as stimulants in increasing the productivity of commercial agriculture development.

The SDG target 12.3 highlights the importance of halving capita global food waste at the retail and consumer levels and reducing food losses along production and supply chains, including post-harvest losses by 2030 in achieving food security (Caldeira et al. 2018; Vos 2019). As pointed out in SDG target '2.A,' agricultural research and extension services and technology development among others could be promoted to enhance agricultural productivity in developing countries, in particular, least developed countries (SDSN 2015). Therefore, sustainable research outputs from such initiatives are supposed to provide solutions, especially for issues mentioned in SDG target 12.3, and be expedient in creating the expected force in achieving food security by 2030.

However, present efforts of research to reap the maximum benefits from the commercial agriculture sector seem behind the targets in ensuring access to safe, nutritious, and sufficient food for all people all year round, and eradicating all forms of malnutrition (FAO et al. 2020); two of the most prominent SDG

Table 1 Some initiatives for Zero Hunger 2030 linked with research contribution and associated SDGs

Initiatives for SDG2		Other supportive SDGs	Research contribution
1	Sustainably manage forests, oceans, water, land, and soil—and promote an ecosystem approach to extract greater agricultural yield with fewer inputs	2, 6, 13, 14, 15	Environmental friendly agriculture products and innovations through research
2	Make food systems more efficient, inclusive, and resilient	2, 12, 17	Research to improve food systems
3	Adopt holistic approaches, such as agro-ecology, agroforestry, climate-smart, and conservation agriculture	2, 13, 17	Research for achieving climate-smart, and conservation agriculture
4	Establish best practices in preventing diseases and anti-microbial resistance that threaten plant and animal production, public health, and trade	2, 3, 8, 17	Research for product and process innovations for plant health and public health

indicators supposed to be improved by developments in commercial agriculture. Thus, the task of research institutes that work for agriculture becomes extremely challenging with the additional threat of the COVID-19 pandemic (Department of Economic and Social Affairs 2020; Yasmi et al. 2020) to food systems and food security, both in national and regional levels.

The pandemic has caused many issues in research development processes adopted by research institutes within their organizational design and research culture in the context of commercial agriculture development. In such pandemic situations, the technical issues and challenges could be observed flaring up with new shapes along with psychological consequences in human behavior.

Against the backdrop of such issues and challenges, we argue that the low productivity of commercial agriculture could be well addressed by a well-thought research development process directed toward producing outputs that satisfy the requirements of its users, particularly the agriculture community while keeping that process on track by using key performance indicators. Further, in a previous study conducted over 60 pieces articles, 'Commercialization,' 'Technology Transfer,' 'Research Collaboration,' and 'Research for Society' were identified as the four most important key performance indicators that could make an impact on commercial agriculture research (Abeyesiriwardana & Jayasinghe-Mudalige 2022).

Considering all of the above facts, this research was grounded on several specific objectives that were derived from the broad objective of studying the impact of digital agriculture on a research institute, on managing its research development process, and ultimately on the commercial agriculture industry in the post-COVID-19. First, this study was set to propose an integrated performance management strategy that assists the research development process to be dependent on data-driven decisions rather than on ad-hoc decisions. Second, through such a performance management system, it was expected to find ways of integrating all research systems into one platform and proposed means of minimizing human bias in decision-making and providing real-time advice on critical aspects such as optimum resource sharing, avoiding research duplications, etc. on the research development process. Third, it was expected to discuss how such a system could further facilitate a research culture that promotes exchanging decisive information on digital agriculture through collaboration among researchers, industries, and academia even amidst the difficulties caused by a pandemic. The selected area that could be developed and linked with a strategy to make the research live in a new normal specifically covers the management of key performance drives that are supposed to collect information-rich data from the research development process to make intelligent decisions for better research in the commercial agriculture sector. Thus, this paper focuses on the core research management strategy that is key performance management of research rather than on the routine administrative and financial activities, which are inevitably required for the success of large-scale research development.

To initiate a study on performance management through key performance drives, a survey was conducted with the leaders of research institutes to understand their views on managing the performance of the research development process in the context of producing highly productive research outputs for the commercial agriculture sector. First, it was expected to identify the present status of existing performance

management systems at the limits of the organizational design of a research institute in achieving the mission of research development for the commercial agriculture sector. Second, the opinions of leaders were investigated on how they would understand and recommend the exploitation of digital interventions in shaping performance management systems (PMS) into their ultimate success.

Based on the findings of the survey and extant literature, the authors of this research paper expect to propose a framework for an integrated PMS characterized by features that support maximum resource sharing and avoid research duplications. The sustainability of the proposed PMS framework in research culture is expected to be facilitated by suggested policy recommendations in directing research work efficiently and effectively toward the innovative commercial agriculture industry, especially in developing countries like Sri Lanka. Thus, this exercise would further contribute to the performance management literature by providing a detailed discussion on how to formulate a conceptual framework for a PMS that could provide extra provisions for acquiring intelligent data from automated labs that are supposed to thrive in pandemic situations in the context of research development on the commercial agriculture sector.

Review of the current practice of research management, challenges, and key performance drives

Research is carried out by academicians in universities, researchers in research institutes, employees in labs of the research unit of commercial product/ service development organizations, and students or scholars either in any of the above institutes. These researches should be well managed to increase the impact of the research outcomes and provide value-added knowledge to their intended recipients (Zikos et al. 2012). In commercial agriculture, many stakeholders such as farmers, business stakeholders, environmentalists, policymakers, and finally society are expected to act as intended recipients of research outputs.

In the context of agriculture research in Sri Lanka, the Sri Lanka Council for Agricultural Research Policy (SLCARP) operates as the umbrella organization that oversees overall agricultural research management and coordination work in all disciplines of agricultural research of 29 national agricultural research institutes (NARIs) including research institutes and sub institutions under Department of Agriculture (DOA) of the Ministry of Agriculture (Girihagama et al. 2012; SLCARP 2018). In addition, there are ten government universities and affiliated institutes with dedicated agriculture faculties to conduct agriculture research in Sri Lanka (UGC 2022). The research and Innovation sector is attached to several Ministries such as “Technology” and “Science and Technology” (the representative names are provided for the Ministries, as they are continuously reformed at present with the political changes of the country) and administers a few research institutes involved with the agriculture sector, such as National Institutes of Fundamental Studies (NIFS), National Science Foundation (NSF), National Research Council (NRC), Industrial Technology Institute (ITI), and Sri Lanka Institute of Nanotechnology (SLINTEC). All together these research institutes represent the profile of the public government

and semi-government research institutes that work on agriculture research in Sri Lanka. Although the country is practicing commercial agriculture throughout the country from South to North and East to West, with an average land extent of 45% for agriculture (WB 2018), this sector is devoid of a proper integrated plan to share and manage the performance of research development, due to lack of research data management system that is supposed to be originated from an integrated PMS. This makes low productivity, low returns, and high risks in agriculture research, causing the government as well as the private sector reluctant to invest in the research in the agriculture sector. As a result, the research development agenda is dominated by low investment research and viciously gets into a low productivity trap.

The current practice of research management

Three types of research could be observed specifically in the context of the COVID-19 pandemic.

- (1) The standard research work—is aligned with the objectives set by the vision and mission of the research institute.
- (2) The COVID-19 only research—deals with the COVID-19 issues by deviating from the institute's normal research agenda.
- (3) The adapted research – normal research is adapted to coexist with studies on COVID-19.

All of these research have some common management strategies unique to the research practice and culture. Common research management involves all administrative and operational functions such as pre-and post-award management, contractual arrangements, Intellectual Property (IP), business development, technology transfer, commercialization, etc. However, some specific strategies may be needed to incorporate the management processes to achieve research outputs in extraordinary circumstances when time, budget, and priority constraints are deterministically enforced due to some reasons such as lifesaving priority obligated by COVID-19 research on vaccines (Hanney et al. 2020).

In such cases, some common strategies such as maintaining commercialization viability and IP optimization of research may be completely overlooked or adjusted to achieve certain goals as in the case of rapid research developments toward research on the COVID-19 vaccine. This type of rapid research development evolved in a certain area of research may cause disequilibrium in maintaining healthy research agenda for a country, especially in developing countries like Sri Lanka. In such instances, priority for agriculture research might be rollbacked causing unintended socio-economy disruptions. In Sri Lanka, around 26.1 percent of the total labor force is engaged in agriculture (DCS 2022a) and the contribution of the agricultural sector to the Gross Domestic Product (GDP) is 9.0 percent in the fourth quarter of 2021 (DCS 2022b). Therefore, research on agriculture products is thought to be highly significant in increasing productivity in the commercial agriculture

sector in a country like Sri Lanka and supposed to be highly affected by pandemics like COVID-19.

Challenges for research institutes in a lockdown

Certain challenges or issues in practicing research could be split into two categories—technical and psychological—as depicted in Fig. 1.

These issues and challenges would be sharpened, and research development would be worsened in the agriculture sector when the priority for research on COVID-19 goes high on the list. According to a survey (Walker et al. 2020), researchers felt that their confidence was undermined in applying for grants that were not focused on COVID-19 as they were concerned that the extreme focus on the pandemic would mean less funding and attention for some of the other major challenges humanity faces. Thus, commercial agriculture research is supposed to be badly competing for attention, resources such as human resources, equipment and chemicals, and funding that are supposed to be maximally utilized for COVID-19 research (Sohrabi et al. 2021).

COVID-19 lockdown forced researchers to adopt remote working for their research. They were almost completely restricted to long distant interactions, especially when they worked and lived away from their research stations. Travel restrictions enforced by governments badly affected much on the transportation needs such as frequent field visits that involved hand on experimentation on strict schedules and much-needed collaborations in agriculture research (Woolston 2021). In some cases, poor online communication increased the amount of time taken to prepare material and required more material to achieve similar tasks possibly demanding more labor than anticipated and budgeted. Some types of research were impossible or needed to be changed to conduct remotely due to their nature. Almost every researcher faced many problems when they were requested to follow the procedures in adherence to the safety processes relevant to COVID-19 (Gewin 2020; Makoni 2020).

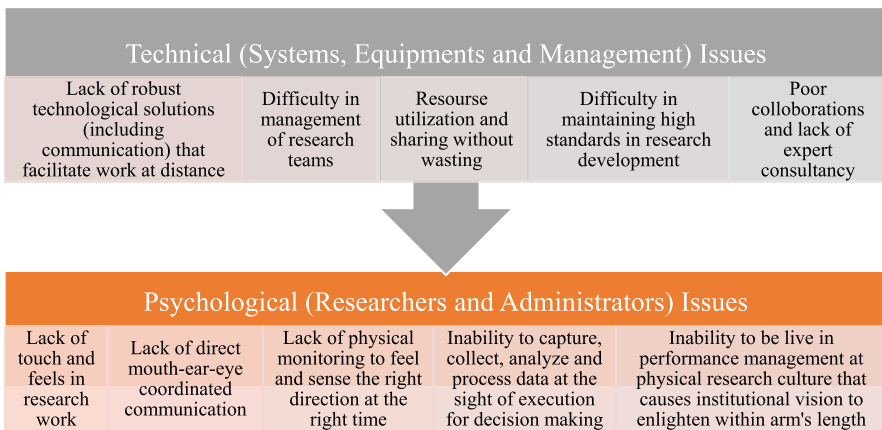


Fig. 1 Technical and psychological barriers for researchers in new normal

In commercial agriculture research, some initial stages, such as developing breeding lines, must be kept going on and should be continuously monitored. Many of these were unique and could not be regenerated. The lifetime of some materials was time bounded and could not be stored for long periods until researchers were allowed to access the labs which were not operated round the clock due to affected staff. Stages of some procurements were critical and interconnected so could not be allowed to wait until clearance of time and distance-bound obstacles. However, the stages of research in commercial agriculture integrated with databases and data analysis were easier to conduct remotely with the group members than the stages that involved data collections in the field that required alternative technologies, perhaps innovative methodologies to monitor and collect phenotypic, morphological, and agronomical data.

Shifting to online working made researchers disconnected from their working environment, physical lab attendance, short distance real-time attendance on lab work, and uni-directional physical coordination that might be enough to carry out research lively. Adding more woe to this, in-house commitments were automatically imposed on the employee, and childcare became the number one contributor in this scenario.

These difficulties and challenges are repeatedly mentioned in the extant research and they do not seem to be addressed with proper solutions. Existing long-practiced management strategies do not seem to fit with the requirements of the post-COVID-19 PMS of a research institute. This has made research institutes explore alternative strategies that could be employed in managing the research development process even in a period like COVID-19.

This paper was written in early 2021 when social distancing requirements in many countries have greatly accelerated a nascent move toward greater digital solutions devoid of human interventions, especially in the context of agriculture development. This could be easily observed by comparing the impact of digital technology on agriculture before the COVID-19 pandemic and after the COVID-19 pandemic as mentioned in Table 2.

As the research community was continuously accustomed to these changes, an opportunity for improvement in performance management of research development was perceived by the authors within the boundaries of their research, especially in the context of post-COVID-19 when such performance management was allowed to involve modern digital interventions.

Interventions that support performance improvement in the lockdown

It is not expected that the trends of performance will remain the same as they existed before the new normal in every aspect due to the lasting consequences of the workforce and workplace changes (Herath and Herath 2020; Mahdy 2020). Many general management practices (traditional thrust) in many flavors and intensity had been used frequently and routinely to address performance management before the pandemic situation. However, it could be seen that reengineered practices (transformative thrusts) had surfaced in different momentum to

Table 2 Impact of digital technology on agriculture before and after the COVID-19 pandemic

	Before COVID-19 pandemic	After COVID-19 pandemic	References
1	The use of AI was minimum in labor work related to agriculture and was not used very much in agriculture	With non-availability or lack of sufficient onsite labor, devices that could work without human intervention in the field are increasingly employed and provided with the assistance of AI to reduce labor work. Ex: Tools that optimize management of natural resources, warn of food-security threats, and assist pest control	Sridhar et al. (2022)
2	Remotely managed equipment did not receive much attention and was not used very much in agriculture	Remotely used equipments such as drones, robots, and satellites are frequently used to do field work such as applying fertilizers, providing information about crop systems, etc.	Alexandrova Stefanova et al. (2021), Hafeez et al. (2022)
3	Digital interventions that deal with smooth communication practices and having 360-degree performance evaluations were not sought very much	However, with increased remote communication, workplaces that work around the clock in virtual environments were mushroomed and much depend on smooth communication practices having 360-degree performance evaluations	Abey Siriwardana et al. (2022a)
4	The linking of smart cities and smart villages to remove the digital divide in agricultural communities was discussed comparatively less intensely	Increased attention has been shown to linking smart cities and smart villages to remove the digital divide in agriculture communities to maintain sustainable agriculture for all	Stojanova et al. (2021)

Table 3 Thrust of management practices

Traditional thrust	Transformative thrust
Communication (Close)	Communication (Remote)
Resources for Innovation	Quality and no. of Innovations
Traditional KPI	Digital KPI
Traditional Performance Measurements	Digital Performance Measurements
Performance measurements at fixed time	Real-time performance measurements
Forced Personal focus Performance Measures	Emerging Personal focus Performance Measures

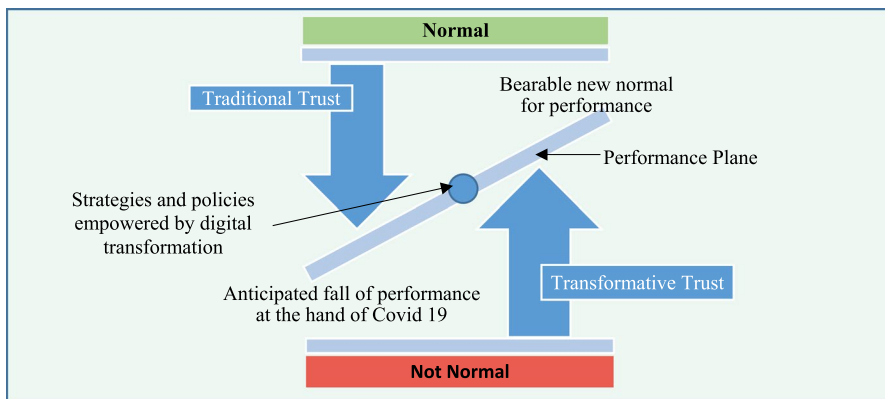


Fig. 2 A conceptual model to understand the performance of research institutes in a pandemic

mediate the imbalance caused by the pandemic by replacing or altering those traditional trusts as mentioned in Table 3.

Figure 2 shows a simple graph to understand how these trusts would behave at the leverage of strategies and policies empowered by digital transformation when COVID-19 has forced the pendulum of a long-observed traditional trust to one extreme.

It is supposed to elevate performance from the anticipated fall caused by the pandemic to a bearable new normal through digital transformation worked out in a PMS along with the strategies and policies highly in favor of such transformations.

The question is how the performance measurements of research institutes could be strategized toward innovative commercial agriculture in such a situation and to what degree that policy changes are required to enable such performance monitoring and evaluation. We argue that it is not enough to use those transformative trusts in isolation, but required all of those transformative trusts to be integrated logically within policy directives through a well-managed PMS to achieve expected output from research development in the commercial agriculture sector.

The necessity of an agile transformation in performance management

All the stakeholders of the economy should be aware of the current performance of agriculture in the pandemic locked down and any trend that may need to be reversed (Kurth et al. 2021; OECD 2020; UNESCAP 2020). It is simply, the amount and quality of the agriculture products and services that research should focus on to improve in converting the commercial agriculture industry into a sustainable business under any condition (Xie et al. 2018).

Therefore, more focus should be on the performance of commercial agriculture research of an institute that works toward the success of the commercial agriculture sector through its shared goals and targets. There is no way that the performance measurement could be ignored or regressed in any situation, even for a temporary period (Knight 2021) as that would exponentially affect the fast recovery process from the pandemic.

In the new normal, the amount and quality should be maintained at a greater elevation with less time and scarce or less amount of inputs caused by the COVID-19 pandemic. In this context, research institutes must put more weight on process-focused innovation instead of product-focused innovation or, as it is better known, business model innovation (BMI) to trade off risk and return of research in this pandemic situation (Devaux et al. 2018; Hasija 2020). The research development process is a useful source of process innovation to enrich the agriculture research ecosystem by introducing new products and services, making improvements to existing products and services, and innovating new technologies in the commercial agriculture sector. Extant research suggests that research institutes could benefit from alternative business models through experimentation, open and disruptive innovations rather than continuous revision in an evolutionary process, adaptation, and fine-tuning of the existing business models (Ramdani et al. 2019). Analysis of so many research data along with associated meta-data in a PMS by intelligent data mining and processing techniques is supposed to facilitate an ideal decision-making process for such experimentations and innovations.

According to the authors' experience and observations, another issue found in research management in Sri Lanka is that many indicators designated as KPIs are not truly associated with actual key performance drives based on critical success factors of the research development process. The authors argue that this issue is caused by frozen benchmarking capacity and debilitated executive expertise in executing decision-making powers against overloaded data that determines the best key performance indicators in a research institute. Therefore, data-driven predictive analytics could be proposed to employ in PMS, along with leadership acumen, to identify and refine key strategic measures or critical success factors for better research development in the commercial agriculture sector (Kiron 2022).

Thus, the measurement of research performance should be strategically managed by considering all of these factors while critical indicators and their targets should be restructured and logically networked by following proper analysis (Abeywardana and Jayasinghe-Mudalige 2021) to facilitate proper information exchange among indicators as well against these requirements.

In this context, a new strategy of performance management vigorously involved in directing research work with optimum impacts in all those circumstances would be an ideal solution when legacy metrics may be misleading and unhelpful in assessing the performance of remotely managed commercial agriculture research (Schrage 2020). Hence, key performance indicators associated with the institute's critical success factors and monitoring agricultural performance need to receive urgent and increasing attention and be processed in real time within a PMS to tackle the funding, time, and location constraints that are imposed on research administration during the pandemic (Walker et al. 2020).

Identification of the research gap

Extant literature was devoid of detailed discussions on performance management practices in the research development process in the commercial agriculture sector, especially in the context of developing countries. Although the literature pinpointed some weaknesses in the research development process and management of it, there was no concrete evidence or background information to be found for possible causes of such weaknesses. In addition, guidelines for a proper PMS that fulfills the requirements of research management, especially in remote management of commercial agriculture research, were not identified and discussed properly. However, the extant literature was rich in detail on technologies that could be strategically integrated into a PMS to make performance management of research development more resilient in producing productive and demand-driven research outputs.

Therefore, based on the extant literature review, the research gap was identified within the scope of this research and detailed in two parts as follows.

- (1) The lack of knowledge and understanding of research management strategies that optimize performance drivers of the research development process within a robust mechanism.
- (2) The absence of deliberations on how those strategies could be applied in networking all stakeholders of the research development process and make them contribute to socially accepted research that works on the principle of sustainable commercial agriculture.

Following the research gap, and on the assumption that research institutes in developing countries like Sri Lanka are not flexible enough to address the challenges of mobilizing public resources in research development through proper data-driven decisions making which could only be achieved through key performance drives, the research problem was articulated as follows.

What are the critical components and characteristics of a performance management system that might be improved to showcase the real values and benefits of agriculture research and what are the potential changes that can be incorporated into a PMS, especially in post-COVID-19 conditions, to execute an enhanced strategy on performance management to realize the research needs and facilitate better decision making and policy formulation?

Based on the above research problem, the following research questions were formulated.

- (1) How do the key performance drives and KPIs manage and drive the research development process toward sustainable commercial agriculture within the institutional framework and research culture of the institute?
- (2) How do the technology-enabled integrated KPI systems improve the performance evaluation of the research development process toward innovative commercial agriculture?

Methodology

The methodology was set in two parts as follows.

1. A survey was carried out to expose the leaders' perspectives on the core values of existing performance management systems that work on research development for the commercial agriculture sector.
2. Then, based on the following three motivations, a framework for an integrated virtual PMS was proposed here and described in the result section of this research paper. The first motivation was provided by the results of the analysis done on perceptions of the leaders of the research institutes. Second, the trends and patterns of the research development process in the literature. It warranted a better PMS with an intelligent setup in post-COVID-19. Third, what authors experienced with existing research management, and how they would like to envisage a PMS in the future for developing better research for the commercial agriculture sector.

To find the answers to the two research questions mentioned at the end of the literature review, ten interviews were conducted with the leaders at the highest position of the research institute in Sri Lanka. They were requested to answer fifteen open-ended questions to understand and explore their views and perseverance on the subject of managing research development toward better performance management in commercial agriculture. The following procedure was adopted in conducting the survey.

Samples and procedures

The target population comprised all research institutes in the government and semi-government sectors (except universities as they belong to a special category of the government sector with a special focus on higher education) that had a mandate in conducting agriculture research ($n = 30$). Depending upon the categorical definition, research institutes under the Department of Agriculture, Ministry of Agriculture, and Ministries that were involved with the subjects of Science, Research, Innovation, and Technology, and mentioned agriculture research as one of the functions of their research agenda in their website/ mandate/

gazette/ annual reports were selected as the sampling frame/inclusion criteria ($n=30$). The sample size of the respective population was determined by the concept of data saturation (Lowe et al. 2018). Data saturation is achieved when no new information arises from subsequent data collection efforts and could be operationalized in a way that is consistent with the research question(s), and the theoretical position and analytic framework adopted (Saunders et al. 2018). The more recent studies indicate that no new themes or concepts could be generally extracted after around ten interviews (Muellmann et al. 2021).

Based on the above facts and the authors' observations that research institutes in the government sector of Sri Lanka were not very much matured in performance management to expose subtle differences, ten key informants were selected from the pool of well-known leaders of the research institutes that worked for commercial agriculture development. Thus, a sample of ten interviewees was assumed to be sufficient to obtain a set of saturated data for the analysis and it represented 33% of the target population within the sampling frame.

Purposive sampling combined more or less with snowball sampling was used in this survey to select key informants as justified by the following reasons.

1. In the sample, individuals were selected from a pool of leaders who were in the upper echelon. According to the claims by Palinkas et al. (2015), they were qualified to be selected by purposive sampling as they were supposed to possess the knowledge and experience with the phenomenon of interest, that is performance management of research development. Further, these key informants were more or less influential in KPI formulation and making informed decisions in the research development toward innovative commercial agriculture.

2. In addition to knowledge and experience, they were the individuals who were available on the first attempt and expressed their willingness to participate. Further, their ability to communicate their experiences and opinions in an articulate, expressive, and reflective manner was moreover taken as a positive factor (Jamalimoghadam et al. 2019; Willig 2007).

The sample was well represented by government and semi-government research institutes of Sri Lanka by providing a heterogeneous sample, based on researching basic and applied research, staffing ranging from 20 to 300 persons, and covering all the fields related to commercial agriculture. First, the highest two (2) key positions of the institute were selected. When there was only one key position or a key position was vacant, the next most relevant key position was selected. In case of a failure to find an appropriate second key position based on the criteria of selection, it was satisfied only with one key position of the research institute. Thus, the decision-makers on organizations' research work covering the commercial agriculture sector of Sri Lanka ($n=10$) were selected by their consent on a first come first serve basis when the request was sent to 60 individuals of 30 research institutes. Further, the selection of an expert on the recommendation of another expert leader was sometimes practiced to provide additional justification to the selection criteria at the discretion of snowball sampling.

Data collection

Data were collected through semi-structured online interviews comprising open-ended questions in an interview guide. Interviews were ranging from 30 to 60 min of effective time durations (the time was calculated after removing informal introductions, preparatory explanations, and afterword discussions of the interviews). Participants were allowed to expand their views on areas of interest beyond the interview structure with some probing questions. All interviews were conducted in the period from 29 October 2021 to 13 November 2021.

Survey instrument

As there was no standard questionnaire or interview guide available to be used in covering all aspects of using KPIs in research institutes for commercial agriculture development specifically in the context of research institutes of a developing country, the entire interview guide was informed by the prior knowledge gained from the previous literature study conducted by the authors (Abeyesiriwardana and Jayasinghe-Mudalige 2022). The sample questions of the interview guide used to structure the discussion are provided in Appendix 1. Literature was referred to justify each question, and then, six (6) member expert panel validated the interview guide. The most prominent inputs from the expert panel consisted of some concerns that cover the facts on the importance of environmental aspects to be included in performance management, the use of simple KPIs against complex KPIs, and the readiness of using digital interventions in the context of performance management of a research institute.

The 15 questions questionnaire covered all aspects concerning KPI formulation, establishing, measuring, reporting, and making decisions based on the measured data of KPI in research development toward innovative commercial agriculture as they were frequently referred to by literature as important areas to be considered in performance management of research institutes (Kolar et al. 2022).

Data analysis

The data were analyzed using the thematic analysis method, one of the most standardized analysis methods established over the past 15 years in qualitative research. It is a widely accepted method used to identify, analyze, and interpret patterns or relationships within qualitative data and leads to recurring ideas, or themes that provide evidence base insights into a particular domain of interest (Clarke et al. 2015). The following Braun and Clarke (2006) six steps analysis process was adopted to extract semantic (or descriptive) and latent (or interpretative) codes (Terry et al., 2017) that ultimately reveal answers to the research questions.

- (1) Getting familiar with the data to explore the phenomenon by reading and re-reading all the interview transcripts and data from the other sources
- (2) Generating initial codes by organizing the data into meaningful and systematic ways and condensing the amount of data into smaller pieces of meaning
- (3) Searching for themes by examining how the codes combined to form overarching themes in the data
- (4) Reviewing the themes and modifying and developing the preliminary themes
- (5) Defining the final themes after refining them
- (6) Writing the report by selecting the themes that contribute meaningfully to answering the research questions

MAXQDA, a computer-assisted qualitative data analysis software program, was used to organize the text, derive relationships, and visualize the data and results. Coding was done to reduce the amount of raw data to a set of succinct data which was relevant to the research questions, break the data down into manageable sections, and take raw data to higher-level insights or abstractions to develop the themes. Thus, the attitudinal statements of the experts regarding the utilization of KPIs in the organization dynamics to manage the performance of agriculture research in Sri Lanka were transformed into codes, categories, sub-themes, and themes in a hierarchical order to find answers to the research questions.

A proposed framework for a virtual PMS

Further, to provide a solution that addresses the weaknesses found in the current practice of performance management of research institutes in developing research for commercial agriculture, a framework for a virtual PMS in a cloud environment driven by AI and big data was proposed as detailed in the latter part of result section of this paper. It is further deliberated in the discussion section along with relevant policy measures.

Results

Lessons learned: indication for the imminent need for an intelligent PMS

At the forefront, all the 10 leaders of the research institutes in Sri Lanka who were leading research development for the commercial agriculture field unanimously agreed that the research development should have a prime performance management system consisting of KPIs to concentrate on meaningful research for the commercial agriculture sector. The fact that the word KPIs was prominently highlighted by its size and thickness compared to other words like “performance,” “research,” and “agriculture” in the word cloud of Fig. 3 demonstrated how it was emphasized in the interview and its important role in performance management.

The thematic analysis evolved with 5 themes along with 12 sub-themes, 32 categories, and 119 codes to explain and describe the answers to the research questions.

Table 4 Code system integration and their frequencies on the subjects related to research management

No.	Code System (4 or more mentions in code integration)	Frequency
1	Full code	287
2	Institutional management\role of intercommunication\decision-making\inter connection between divisions	9
3	Research collaboration\visibility of vitality and structure\institutional collaboration\transparency of KPIs	9
4	Technology integrated systems\KPI implementation \institutional policies\changes in KPIs	9
5	Research for society\best strategy for best-fit set of KPIs\monitor aspects\3P's	8
6	Research for society\environmental aspects in KPIs\business environment analysis\SWOT analysis	8
7	Technology integrated systems\KPI implementation \institutional policies\situational changes	7
8	Research collaboration\contribution from external parties\stakeholder contribution\government contribution	7
9	Technology integrated systems\KPI implementation \current status\division specifications	7
10	Technology integrated systems\KPI implementation \current status\current number of KPIs	7
11	Research for society\best strategy for best-fit set of kpis\monitor aspects\complex structured KPIs	7
12	Research collaboration\contribution from external parties\stakeholder contribution\fundng organizations	6
13	Technology integrated systems\KPI implementation \institutional policies\complement with the overall KPIs	6
14	Technology Integrated Systems\KPI Implementation \Performance Evaluation\Institute's performance based on KPIs	5

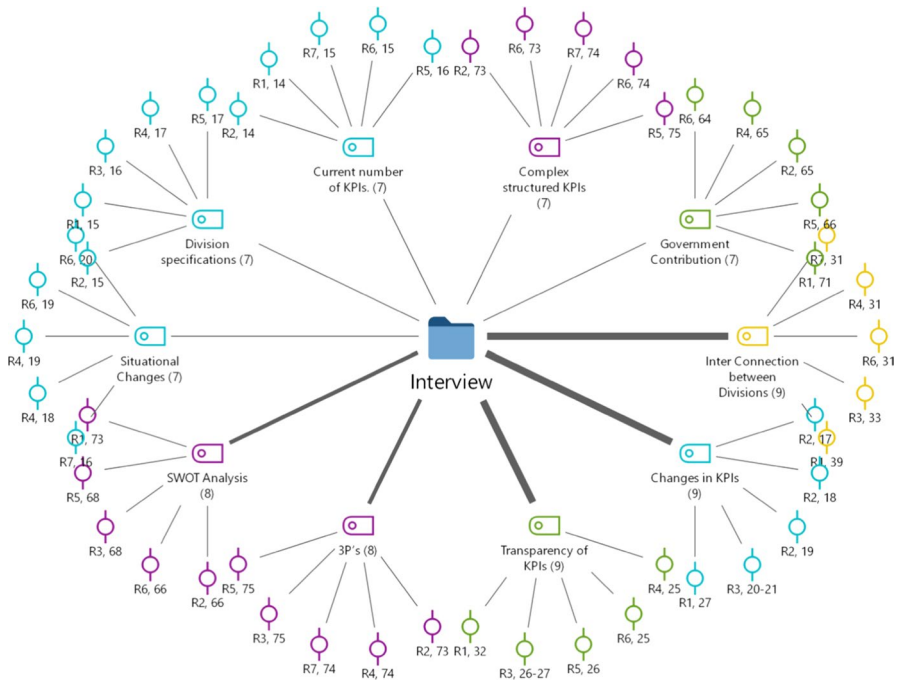


Fig. 4 Single-case-model: interview document at the center of the analysis

KPIs,” “Changes in KPIs,” and “Interconnection between Divisions.” “Research for Society” and “Technology Integrated Systems” have 3 codes each and other themes have 2 codes each except for the “Research Commercialization” with no code associated with it according to details on this Single-Case Model.

The internal arrangement of the code system and 10 interview documents (for ten interviewees) could be further studied with the code matrix browser in Fig. 5. The code matrix browser for the code system of the theme “Technology Integrated Systems” is depicted here with the theme at the top of the code system. The theme, sub-themes, and categories have zero values as these terms were not directly mentioned by the interviewees in this research. In the context of digital interventions, the most frequently mentioned codes referred to the theme “Technology Integrated Systems” were “Division Specifications,” “Current number of KPIs,” “Changes in KPIs,” and “Complement with the overall KPIs” with the number of codes 7, 7, 6, and 6, respectively.

In the Code Map, selected codes are displayed on a map. The more two codes co-occur, i.e., the more similar they are in terms of their use in the data, the closer they are placed together on the map. Each circle symbolizes a code, and the thickness of the connection lines represents the coincidences between codes. Only the number of codes that existed in a particular area of the grid was mentioned when substantial relationships could not be demonstrated among the codes. The size of the symbol and the font size on the map illustrated the frequency of codes. According to the code map depicted in Fig. 6, codes of institutional management had some

Code System	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	SUM
Institute policy changes											1
Negative impressions											2
Technology Integrated Systems											0
KPI Implementation											0
Institutional Policies											0
Situational Changes											5
Changes in KPIs											6
Complement with the overall KPIs.											6
Mandated KPIs											2
Nature of the Institute											2
Communication within the staff											1
Performance Evaluation											0
Objectives of the Institute											4
Institute's performance based on KPIs											4
Current Status											0
Stakeholder benefits											1
Division specifications											7
Sector specific KPIs											1
Current number of KPIs.											7
Psychological and Technical Barriers											0
Internal difficulties											0
Doubts about Performances Measurem											1
Problems in identifying right and optim											1
Issues in configuring and identifying KPI											2
Lack of Multi stakeholder involvement											0
Lack of Understanding among staff											1
Scientists Preference											1
Soft issues											1
Institutional Capacity											0
Sufficient Knowledge on KPIs											3
Mandate and structure											1
Barrier elimination through discussions											1
Digitally Enabled KPI System											0
Monitoring Performances											0
Continuous Measurement of KPIs											2
Transparency											2
Proper Evaluation of expected Outputs											1
Financial Feasibility											0

Fig. 5 The code-matrix-browser for the code system of the theme “technology integrated systems”

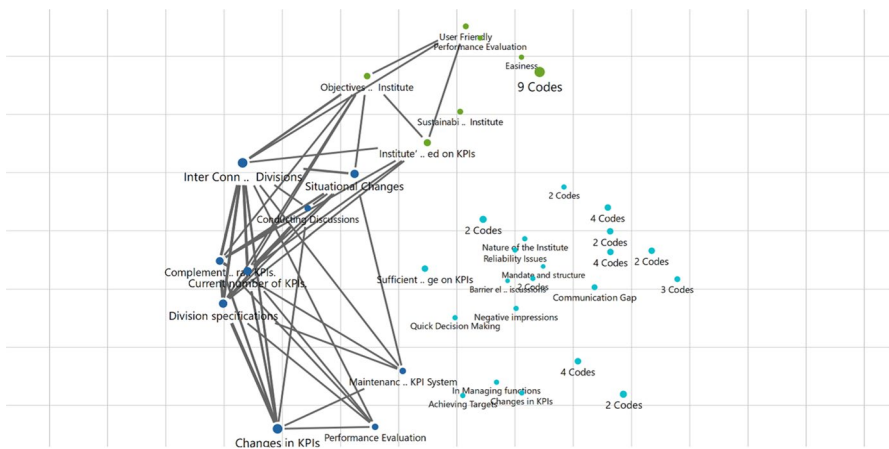


Fig. 6 Code map: relationship between institutional management and technology integrated system

co-occurrence with codes of Technology Integrated System such as user-friendly performance evaluation, Institute’s performance based on KPIs, and Situational Changes.

However, some of the most prominent codes of Technology Integrated System were not co-occurred with the codes of Institutional Management such as Quick Decision-Making with Achieving Targets.

Virtual PMS in a cloud environment driven by AI and big data

The output of the above analysis of leaders’ perspectives served as a basis to derive a framework for virtual PMS in a cloud environment as in Fig. 7, where the activities mentioned inside are supposed to be integrated into a single PMS system.

The framework is consisting of three layers namely, the Outer layer, the Middle layer, and the Inner layer, and data are supposed to be interchanged among all three layers. A PMS that works on this type of framework facilitates transformative thrusts proposed in the digitally driven research environment. Thus, these thrusts are secured and measured within a PMS that follows the proposed framework for optimum results toward research institutes’ goals and visions.

In this framework, intelligent KPIs are expected to collect data from the middle layer and feed it to AI-enabled PMS to perform organizational learning through continuous experimentation (Yunus et al. 2010). Data in the middle layer are supposed to be first-hand data that come through new actions or derived data from the actions that originate at the outer layer. For example, according to work schedule changes, relocation of research facilities will take place causing new data on research facilities. To enable continuous experimentation, these new data could be used to derive a new set of experimental data for optimum research facilities against different schedules. Data analytics on these data are supposed to challenge and question the existing policies, rules, and assumptions more consistently and facilitate imagining new ways of organizational business to develop new business models for research

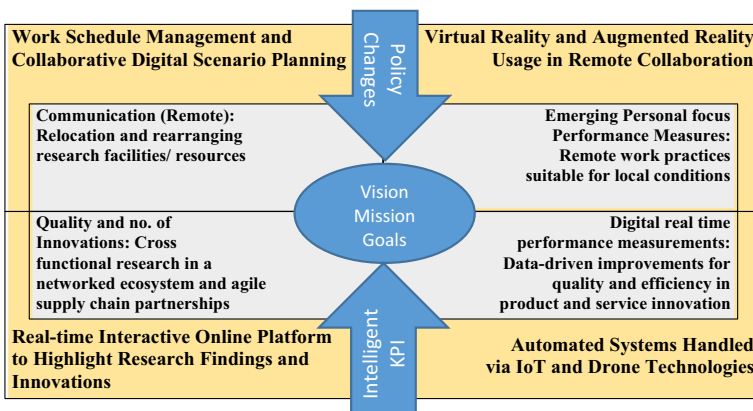


Fig. 7 Framework of intelligently driven PMS for research development in agriculture

development. The inner layer would typically interact with the middle layer to keep the research institute in line with its mission and vision.

Outer layer

The outer layer of the framework consists of four activities that are supposed to be monitored with the assistance of AI-driven performance management applications in the PMS. A plethora of data and meta-data regarding research practices are expected to be generated due to transactions performed in this layer.

Work schedule management and collaborative digital scenario planning Research schedules are very important in implementing research projects effectively. These schedules contain different human resource/ labor involvements along with instrument allocation for the research project. Further, these schedules are linked to the store levels, training, customer interaction, outsourcing, etc. which impact management decisions and finally stakeholder expectations.

To exercise an extreme form of social distancing, a new form of work schedule should be prepared and guidelines must be developed on how research activities should be carried out safely with machine-level interventions and real-time data mining. Workforce management facilitated by AI-enabled hundreds of learning models could be used to address these issues in conducting research. With so many variables such as historical data on associate skillset, experience, performance, and other key metrics affecting the accuracy of human resource and instrument scheduling, the intelligent solution will analyze all of this information in real time to optimize employee and instrument schedules. Scheduling needs to fluctuate resources of the research domain between hibernate stages and peak periods of the research by calculating the amount of required efficient human resources and instrument allocations. These scheduling can be made more precious and accurate by using predictive analytics performed on the data related to the multi-skilled capacity of researchers and the multifunction capacity of instruments. Here, supervised learning algorithms facilitated by other AI components could be used to understand the positive and negative efficiencies when using multi-skilled employees (Jagare and NICE 2020).

Then, collaborative scenario planning based on data from new types of sensors, e-marketing platforms, food traceability systems, remote sensing, earth observation services, and social media, and analyze these data using advanced analytic tools and artificial intelligence techniques to explore alternative research methods would improve an organization's core processes for creating supply chain uninteruptedly at a rapid pace (Joglekar and Phadnis 2020).

Although the connected research workflow proposed here is very beneficial, some issues should be handled with care in practicing it in the research development process. This is due to the complexity of different perspectives of research implementation and many resources associated with it, including digital assets, that are required to be shared and optimized on the FAIR principle (Ogryczak et al. 2014; Zhao et al. 2020).

A real-time interactive online platform to highlight research findings and innovations A real-time interactive online platform would facilitate more transactions and trades for promoting research findings while establishing control over the remote practices in the research culture. This would act as a dashboard for self-evaluation of researchers and all other stakeholders responsible for research development toward innovative commercial agriculture. Further, it will expose how society responds to such research products and services while emphasizing national priorities to be addressed along with expectations of the society from research development.

Virtual reality and augmented reality in remote collaboration This would make research continuous through the provision of inputs by principle researchers to a series of next-level researchers (Yu et al. 2010) through artificially made physical presence. Here, the conducting of research is supposed to be managed through local unspecialized third parties readily available in isolated areas in the absence of principal researchers who might be confined to locked-down areas.

Automated systems handled via IoT and drone technologies The best-of-breed IoT platform seamlessly connects a wide range of assets and delivers real-time performance data. These data could be used to generate real-time decision-making to prevent maintenance issues and ensure continuous improvements in digital infrastructure (PTC 2020).

Middle layer

The middle layer is composed of four components as follows.

Communication (remote): relocation and rearranging of research facilities Many researchers in thousands of labs in a variety of research fields are reconsidering their planned studies and inertly recognized that not all projects could be easily put on freeze (Servick et al. 2020). Transfer of research from one place to another place where the conditions are good for that particular research would be a useful option in these situations. This will ensure researchers' ability to access alternative similar resources, which have not been significantly affected by the lockdown.

Emerging personal focus performance measures: remote work practices suitable for local conditions It is important to introduce remote work practices suitable for local conditions after understanding the impact of the pandemic lockdown on the researcher to make them feel that it has opened up more opportunities to spend their time on research (Ali Al-Atwi 2019). Performance management strategies may be used here to create new human resource policies and maintain the balance of the assessment and the safe side of new skills and capabilities through strategies of upskilling workers amid increasing automation. This would make a change of attitude of the researcher toward the need of the country and world instead of gaining academic credit. Meanwhile, policies should be refurbished to ensure health inclu-

siveness in the research agenda based on impartial, intelligent decisions worked out with ever-changing data.

Quality and amount of innovations: cross-functional research in a networked ecosystem and agile supply chain partnerships It would be beneficial to society if research institutes and their work could be interlinked with community networks, which could play a significant role in connecting and empowering rural and underprivileged populations and enable a regulatory and policy environment that is required for the mass adoption of community networks. A policy change there would induce more localizations and local productions to be used in research work rather than researchers opting for imported productions and services for their research work. To make all of these tasks fall in line with research expectations, a plethora of data produced within the processes needs to be analyzed through well-set logical algorithms possibly endorsed by deep learning studies.

Digital real-time performance measurements: data-driven improvements for quality and efficiency in product and service innovation Research institutes get involved with many stakeholders to ensure their research businesses and generate more data through the measurement of various indicators than ever before. However, for many research institutes, using that data effectively in a PMS through a digital transformation remains challenging. The other issue is that although there are many indicators of agricultural performance in the literature (Olubode-Awosola et al. 2008), these indicators may not be exact indicators to provide information on whether each research institute and the country as a whole are on right track executing research in commercial agriculture in this pandemic situation. So the complexity of using many KPIs should be solved by either eliminating unnecessary KPIs or integrating many KPIs into composite KPIs through data-driven decision-making.

Inner layer

The inner layer deals with all the coordination part and completes final decision-making tasks with the help of policies and data that come through KPIs. Intelligently driven key performance indicators will ultimately stimulate discussion on the new policy and investment options. It would further improve the performance of research development and unlock new possibilities to build back better policy options, rules, and regulations that put researchers right on track to achieve the research institute's goals toward commercial agriculture development in any pandemic situation.

Discussion

The themes that emerged within this study disclosed some significant relationships, which provided some insights for further development of knowledge about performance management and thought-provoking ideas on the issues of present

performance management system toward research development for commercial agriculture. As revealed by the code frequency table, single case model, code matrix browser, and code map, the frequently discussed and emphasized topic was “Technology Integrated Systems.” The two other subjects mentioned along with “Technology Integrated Systems” and the “KPI Implementation” were supposed to represent institutional core management concerns such as “Decision Making,” “Communication and Connection,” “Performance Evaluation,” and “Institutional Policies.”

Thus, many participants expressed their views on the use of digital technology in improving present PMS. None of the participants presented an overtly negative perspective of digital interventions on PMS, although numerous challenges and conflicts were identified in implementing such systems. The alignment of digital technologies with the implementation mechanism of PMS was considered imperative for some participants. Two such instances were as follows.

Digitally enabled KPI system would sustain efficiency, equality, as well as transparency for performance management.

Rather than the institute giving them messages, staff will be able to check the KPIs or the institute’s (performance) on a regular basis through a digital system.

However, it was observed that several important co-occurrences were missing within both themes as revealed by the code map. Based on the fact that these relationships were missing in the code map, it could be reasoned that the leaders did not discuss the task of “Quick Decision Making with Achieving Targets” appropriately within a performance management system enabled by a “Technology Integrated System.” This leads to the deliberation that, when subjects of “technology” and “institute management” were discussed together, leaders demonstrated the lack of necessary strategies to interconnect them to reap the full benefits of research performance management. Meanwhile, the frequently mentioned codes of the code matrix browser could be arranged into the following statement to get a useful insight into the existing performance management of research institutes and help in subsequent strategy planning on future PMS: Leaders of the research institutes have a challenge of handling overall “Changes in KPIs” on “Division Specifications” along with the struggle of managing “Current number of KPIs” of Divisions to be “Complement with the overall KPIs.” All of these indications and deliberations revealed the need for a data-driven framework and associated it with a PMS to integrate all divisions, systems, and sectors for better performance management. Thus, a framework was proposed in this research to provide an insight into formulating strategic and policy reforms necessary for an intelligent PMS.

Furthermore, any significant clues were not found to confirm that the thoughts of leaders were there for a visionary change of performance management through digital interventions in the direction of increasing community participation in research development and improved research collaboration. Further, they could not take digitally enabled performance management into a proper discussion within the scope of commercialization and market competitiveness of a research product. However, it was found that they were in the mere view that digitally enabled performance

management could be a useful solution one-way or another in increasing the productivity of a PMS.

All of these observations of the survey signpost the need for a prime performance management system for a research institute that enables data-driven decision-making based on KPI data to monitor and manage key performance drives of commercial agriculture research. This would cause a developing country like Sri Lanka to be well positioned in achieving SDG 2 by making use of its research infrastructure through guided research development in innovative commercial agriculture. Therefore, with post-COVID-19 consequences, it has become an immediate requirement to formulate a framework for establishing a prime key performance management system. Further, such PMS is supposed to guide research in commercial agriculture to be more sustainable toward the needs of the society and finally be able to provide the exact output that is required by that society. In addition, a set of technology transformations and policy interventions are supposed to be associated with the implementation mechanism of such PMS to make a tradeoff between the social benefits and economic gain of research (Abey Siriwardana et al., 2022b).

It needs the simple “work from home” concept transformed into a conducive environment that is enabled by sufficient controlling interventions. These interventions would build a strong interconnected research culture natured with supportive tools and motivational and rewarding practices that supports a post-pandemic virtual research environment. Performance drives identified in that adopted culture could be managed within such intelligent PMS by strategies and policies to provide the foundation necessary to support rapid adaptation, innovation, and resilience in research development toward innovative commercial agriculture.

Accordingly, a well-managed and agile PMS enabled with AI and big data to support a research culture without being disputed by subjective human decision-making was envisaged. In addition, digitally endorsed key performance indicators associated with performance drives with specific AI capacities were recommended to be used in that management environment as set forth by the framework in Fig. 7 in the result section of this research paper.

To follow this proposed framework, research institutes are required to be very well equipped with AI and big data capacities due to many reasons. AI covers many perspectives such as reasoning, knowledge representation, planning, natural language processing, perception, and object manipulation through speech recognition, dexterous manipulation, autonomous navigation, machine vision, pattern recognition, and localization and mapping (Bogue 2014). Big data is an extremely large and diverse data set that could be used in computational analysis to reveal patterns, trends, and associations that lead to data insights for new or better research based on data, which comes through research institutes, researchers, stakeholders, research projects, and research environment. In this context, along with its end-to-end visibility, AI can be effectively used with big data in the decision-making process of a research institute where the results are independent of cognitive bias and only dependent on the vision and goals of the research institute.

Key Performance Indicators (KPIs) innovatively geared by digital accountability will play a major role in the performance measurement of research institutes' works toward commercial agriculture. As researchers are dispersed and distanced,

using KPIs associated with individuals rather than with the team plays an effective and efficient role in performance management and results in more transparency for research performance. This concept could be extended to capture data from every resource in the agriculture network by assigning individual KPIs to respective IoT devices. Research institutes may thus introduce and renovate their data-driven dashboards to capture positive research outcomes and use well-developed methodological assessment through real-time analytic insights to consult all levels of stakeholders and resources appropriately (Schrage 2020).

In addition to resource management, the recent past has seen many advances in Intelligent Agriculture (IA) where applications in Smart Farming (SF) and Precision Agriculture (PA) have shown promising productivity enhancement for the agriculture industry. Smart sensing technologies in SF would help farms become more "intelligent" as more farms become connected through smart agriculture technologies. Meanwhile, PA as a farming management concept would work on observing, measuring, and responding to inter- and intra-field variability in crops through facilities provided by SF. Applications of AI with the help of sensors and other means embedded in robots and drones are significantly used in current agriculture practices of irrigation, weeding, and spraying especially in the countries like America and China (Shi et al. 2018). These applications are supposed to pave way for accumulating big data on yield, use of water, pesticides, herbicides, and maintenance of soil fertility, and possibly associating the same big data for further research in the field (Anami et al. 2020; Talaviya et al. 2020). The PMS proposed here could be easily integrated into such data flow through extra sensors to make intelligent decisions on the effectiveness of the linked research in the field. Thus, it would be able to make decisions on collaboration, commercialization, and technology transfer along with the very important performance drive "research for society" that works on how to develop sustainable research that would have qualities preferred by all of its stakeholders of the commercial agriculture sector.

AI and big data in many applications are being swung between success and failure even with many technological advancements and familiarities in those fields of interest (Kellogg et al. 2022). Therefore, many studies are needed to secure how to use them in performance management through KPI especially in research development for the commercial agriculture sector due to a series of issues starting from demand for extra work (feeding data) to operate AI tools to loss of autonomy (end-user core work). However, we argue that these issues would not affect very much in performance management of research development if developers and implementers could strategically deal with them in the following two ways.

- I. As many of the state-of-the-art sensors are already developed and used in IA, the data feeding burden could be easily transferred to those sensors with extra links made between them and the proposed PMS. It would promote more IoT-based agriculture practices in the field as well as in the organization design of research institutes simultaneously.
- II. Researchers' core work involves the conceptualization of the research project which is acclaimed by the public and peers subsequently. The planning and implementing stages of the research project assisted by AI would relieve

researchers to concentrate more on the conceptualization stage. Therefore, all stakeholders in the research development process would prefer other workflow arrangements that are more or less critical in decision-making to be self-managed within a PMS.

Therefore, all of these subtle implementation strategies must go hand in hand with useful policy directives to make them successful in the research development process.

Policy and practical implications

Policy implications

The following five policy directives are implied to be promoted in the proposed PMS framework in executing it as an intelligent PMS to manage the research agenda for innovative commercial agriculture.

Use of modern digital interventions to manage performance in a conducive research culture

The use of more apps that thrive on existing web and internet facilities to support commercial agriculture research may act as an immediate facilitator for performance management tasks. Powerful Work Management Software either open source or proprietary in nature could be integrated with performance management tools that enable high-performance, low-code platforms in the cloud environment and provide facilities to build enterprise-grade scalable and secure cloud apps rapidly that favor remote workforce environment. These capacities have their inherited adhesiveness to be further enhanced and managed through AI interventions in new research culture. Therefore, policy changes in improving the delivery and access to government services (Pencheva et al. 2020) as well as providing an extended network for the rural community to participate in the research development process through government interventions will make the research institute stay top of the performance curve while providing a solution to the high-cost issue associated with implementing such systems. Given the limited ICT infrastructure and generally low ICT skills levels in rural areas, it is important to support rural participants through alternative low-cost facilities such as mobile platforms and prime communication links to link with the research management process.

Facilitate connected research culture through networking automated digital labs

Here, labs are supposed to interconnect in real time and around the clock through communication networks to share equipment, data & information, and human resources. In this research culture, external stakeholders like farmers, and extension workers will be aware of the research output, while feedback from the external entities will be typically on the table of the research community. This setup will

inform the farmer community of new product innovations that could otherwise be unnoticed by the farmer community at rapid change of applications and variations of research innovation. It will moreover create internal pressure to reinvent the wheel of research culture by moving away from the structured way and working into fast-moving product development culture that has frequent product updates and innovations urged by external stakeholders' pressure.

Measure performance across digital platforms supported by AI and automation

The internet and emerging technologies such as data science, digital twins, the IoT, autonomous systems, etc. are collectively put into work on a mass scale for managing different workflows or processes (Acioli et al. 2021; Yang and Gu 2021). AI and big data existing in the cloud environment will be an added enabler in Industry 5.0 to nurture the networked research society (Nahavandi 2019) where traditional performance management reaches its limits. Consistently used intelligently driven performance measurements through all management platforms would collect meaningful insights, understand employee intentions, and create a workflow accordingly enabling improved employee engagement.

Avoiding jurisdictional overlapping and underlapping in research institutions

Some public research institutes are underperformed due to jurisdictional overlapping and underlapping caused by ambiguous acts and mandates (Rahman 2021), especially in developing countries like Sri Lanka. One of the main reasons behind this jurisdictional concern could be identified as the deficiency of policy directives based on data-driven decision-making on performance management of research development for the policymakers. These data are available when a proper performance management system is in place to capture weaknesses such as research duplication, multiple funding, idling resource allocation, etc. in the context of the research development process. Therefore, AI-enabled software solutions in PMS could be recommended to capture those weaknesses in real-time and provide unbiased insights to avoid conflict of interests, poor coordination, and implementation of research development through policy interventions that support delegation of complete and exclusive jurisdiction in an integrated institutional system (Gersen 2006).

Ensure ethics in the use of AI

AI will only be a highly sophisticated enabler when incorporated carefully into PMS (Smith 2021; Walmsley 2021). The technology used in AI can be biased, depending on how algorithms have been fed and trained (Gill 2013). In certain circumstances, this bias can have drastic effects on performance management. Therefore, it is essential to eliminate the sources of bias through digital policy measures so that the algorithms can work fairly in PMS.

Practical implications

This study may enable research institutes to design and adopt an effective PMS based on the proposed framework on “Intelligently Driven PMS” and enhance the likelihood of its acceptance by the research culture to obtain desired results of such PMS. Moreover, the study provides an opportunity for the research management to identify issues and limitations of existing PMS compared to the proposed “Intelligently Driven PMS” and make informed decisions on preference for a new PMS. The results are particularly important for the research institutes that work in the commercial agriculture sector with much stakeholder participation. The policies and management strategies mentioned here such as promoting AI and big data in modern PMS and improving stakeholder participation by facilitated collaborations are common for many research organizations. Therefore, the results are generalizable for all the research institutes and research development processes.

Conclusion

The processes associated with disruptive innovations of research development would be best suited to discover, create and develop ideas to earn profits, increase efficiency, and/or reduce costs in commercial agriculture research in a locked-down situation (Morris 2012). However, such process innovations would not exist without directions from a well-structured PMS. Therefore, it was imperative to investigate current performance management strategies to analyze their strengths and weaknesses in managing research development in the commercial agriculture sector.

The survey on the perspectives of topmost leaders in performance management of research development toward commercial agriculture revealed five themes namely Research Commercialization, Research Collaboration, Research for Society, Institutional Management, and Technology Integrated Systems. In addition, ‘Research Commercialization,’ ‘Research Collaboration,’ and ‘Research for Society’ were among the most prominent KPIs in research development of the commercial agriculture sector as revealed in a previous study conducted by the authors. Therefore, all of these studies agreed on the three key performance drives to be used competitively in research development and measured in an effective decision-making process. However, in practice, these performance drives were not properly managed within the research development process, especially in developing countries like Sri Lanka due to a lack of real-time data-driven decision-making through proper PMS.

Furthermore, the results of the survey revealed that leaders did not explain the performance of research in the relevant context and within the boundaries of a proper PMS assisted by digital interventions. This results that research institutes are stalling from reaping true benefits out of key performance drives when trying to use their research capacities in the research development process.

It was informed through insights of leaders’ perspectives that technology-integrated PMS would provide an ideal solution to enhance all stakeholders’ participation in research development toward innovative commercial agriculture. However, there were no clues that they were equipped with the necessary strategies

and policies for exploiting digital interventions in an intelligent PMS that supports evidence-based decision-making based on KPIs in a timely and unbiased manner.

In this context, we argue that leaders of research institutes in search of reaping the benefits of digital empowerment in the context of commercial agriculture development must carefully scrutinize the landscape of emerging technologies and strategically leverage the strength of innovation that already exists in the organization to transform how their research involves long-term sustainable economic and social impacts. AI and big data is one such technology that could be used to impose a disruptive effect on PMS, although there is still a research gap in the field of study of AI technology adoption in performance management of research institutes toward innovative commercial agriculture development. Given this, the framework proposed here would act as a bridge to facilitate a smooth transition from the present working environment to a more advanced integrated virtual environment through digitally enabled performance management. The advantage of adopting this framework is that it could be used in a systematic step-by-step approach to transforming into a fully functional smart virtual organization design for research institutes. In addition, the relevant policy measures were proposed and discussed with some strategies that facilitate a conducive environment for establishing AI enable SMART PMS that would be willingly embraced by the research community.

Although the proposed framework developed in this paper should be further validated with real data of intelligently driven KPI indices in research institutes, it, in turn, could be used as a versatile tool to understand the required policy measures, technology adoptions, and performance drivers of a research institute toward the development of intelligently driven performance management system for innovative agriculture research.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s43545-022-00484-8>.

Acknowledgements The authors wish to express their sincere gratitude to the all experts who participated in this study by devoting their valuable time to sharing their knowledge and views for this study.

Author contributions The authors would like to present their contributions as follows: PCA contributed to the conception/design of the research, conduct the interviews and analyzed the data, and drafted the work, UKJM and SRK revised it, and KBM fed and analyzed the data. As PCA, I confirm that the manuscript has been read and approved for submission by all the named authors.

Data availability All secondary data analyzed and cited in this article are available in the public domain, while the primary datasets analyzed during the study are not publicly available due to ethical considerations but may be provided upon an appropriate request to the corresponding author.

Declarations

Conflict of interest The authors know of no conflicts of interest associated with this publication, and there has been no outside funding for this work that could have influenced its outcome.

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