Developing an Index to Capture Triple Bottom Line Outcomes Achieved by Farmers in a Developing Country: An Empirical Study Involving Sri Lankan Dairy Farmers

Sustainability in agriculture in developing countries has emerged as a critical area of study at least for two interrelated reasons. Firstly, for the vast majority of people in these counties, agriculture serves as the backbone of their livelihood through farming activities (Acar et al., 2019; Sun et al., 2020). Due to poverty, many farmers focus mainly on the economic aspect of farming, overlooking the broader importance and impact of sustainability. Secondly, particularly with the UN's recent announcement of sustainable development goals (SDGs), sustainability (more specifically, sustainable development) has received a more balanced definition, where poverty and related aspects such as a good standard of living remain only one aspect of sustainability (Chand et al., 2015; Zanin et al., 2020). Concerns for the environment resulting from economic activities (in this study, farming) also receive significant importance in the UN's SDGs. Thus, there is a need to evaluate the overall achievement of sustainability from farming activities for farmer development, farming recognition, and policy purposes. Within agriculture, dairy farming remains a vital economic activity in many developing economies (Bhat et al., 2022; Damunupola et al., 2022; Darwai et al., 2024), and the dairy sector in these countries come under increased scrutiny for its sustainability practices, because dairy farming is an activity that can significantly (negatively) impact the environment (Chand et al., 2015; Razzaq et al., 2024; Zanin et al., 2020). This study uses the Triple Bottom Line (TBL) framework (Chofreh & Goni, 2017; Elkington, 1994; Janker & Mann, 2020; Zanin et al., 2020) as the framework to capture the achievement of *overall sustainability* by a dairy farmer through farming activities.

Despite the growing body of literature on measuring sustainability, there remains a significant gap in the availability of measurement tools to capture a more balanced snapshot of sustainability attainment of farmers in a developing country (Chand et al., 2015; De Olde et al., 2016; Janker & Mann, 2020; van Calker et al., 2006). Since there are several thousands or millions of farmers in a developing country (depending on its geographic size and population), any tool that becomes available to measure overall sustainability must not only be empirically valid but also easy to apply by parties interested in farmer development and policymaking. Currently available tools (some details follow) are either too biased towards capturing only one or two facets of TBL of sustainability but not all three (Chofreh & Goni, 2017; Janker & Mann, 2020; Orou Sannou et al., 2023; van Calker et al., 2006), or, when a tool captures all three facets of TBL sustainability, either it would not be suitable for farming in a developing economy (details follow) or it would be unclear as to how the three sustainability facets should be summed to get a valid overall score on sustainability that interested parties could use efficiently to develop, motivate, or recognize farmers (Chand et al., 2015; Chofreh & Goni, 2017; De Olde et al., 2016; Munyaneza et al., 2019).

One of the challenges in Sri Lanka (which could be generalized across some developing countries) that impacts dairy farming sustainability is either low milk productivity (kg milk/cow) or phenomenally high operating costs (Damunupola et al., 2022; Razzaq et al., 2024; Vyas et al., 2020; Wijethilaka et al., 2018). Many farmers in Sri Lanka rear native cows—these cows are inherently low milk yielding but can easily survive the harsh tropical climate. The farmers who rear native cows in Sri Lanka use extensive farming due to the availability of land, resulting in low operating costs. However, farmers who rear exotic cows and crossbreeds—which are inherently high milk yielding—face limited land availability and associated high operating costs (e.g., cost of cow feed, veterinary costs). This is because the land in the up-country region of the country that favours the rearing of exotic cows is used for tea plantations (Korale-Gedara et al., 2023; Prasanna & Shiratake, 2014; Wickrama et al., 2020; Wijethilaka et al., 2018). This dynamic gives rise to the need to develop a sustainability measurement system that fits the country's context well, both conceptually and empirically (statistically). Thus, *the primary objective of this paper* is to develop and empirically validate an index that provides a valid score on the overall sustainability attainment of a farmer in a developing country such as Sri Lanka.

The paper now reviews currently available sustainability measurement tools very briefly to justify the research gap. de Olde et al. (2017) assert that sustainability assessment tools may vary widely from one another due to differences in scope (geographical and sector), target group (e.g. farmers versus policymakers), selection of indicators, aggregation and weighing methods, and execution time. In a study conducted by Janker and Mann (2020), it was found that there exists about 125 sustainability assessment tools in the literature. These tools were found to adopt different terminologies to capture different aspects of dairy farm sustainability, for example, Life Cycle Assessment (LCA) by Weiler et al. (2014), Global Reporting Initiative (GRI) standards by Feil et al. (2023), Sustainability Assessment of Food and Agriculture Systems (SAFA) by Cammarata et al. (2021), Carbon footprint Analysis by Galloway et al. (2024), Response-Inducing Sustainability Evaluation (RISE) by Hani et al. (2003), and the

TBL framework by Chand et al. (2015). It is important to note that some of these tools (e.g. RISE) are different derivatives of the TBL framework. Weiler et al. (2014) examined how multi-functionality within the LCA method can be incorporated in the context of smallholder dairy in Kenya. Cammarata et al. (2021) used SAFA to assess strength and weaknesses of organic dairy farming in mountain area of Sicily, Italy. A sustainability tool comparative study conducted by De Olde et al. (2016) for Denmark dairy farms concluded that RISE is the most relevant tool for Denmark dairy farms compared to SAFA and other similar frameworks. Feil et al. (2023), used GRI guidelines to select appropriate sustainability indicators for small and medium sized dairy farmers in Brazil.

Of the above tools, the RISE tool suggested by De Olde et al. (2016) for Denmark as well as the SAFA tool suggested by Cammarata et al. (2021) for Italy do not seem to fit the developing economies because these tools have been originally developed in a developed country context. Factors such as high involvement of small-scale farmers, socio-economic and environmental conditions, limited resource availability (e.g. funding, expertise, and technology), low level of stakeholder involvement (e.g. government and development authorities) and policy environment will limit the application of the above mentioned two tools for developed countries. Tools such as the GRI, LCA, or carbon footprint analysis seem difficult to adopt at the smallholder farmer level in developing countries due to their complexity, resource constraints (financial, technology and time related), lack of institutional support and economic priorities (e.g. small-holder farmers in developing countries may prioritize immediate economic survival and profitability over long term sustainability goals). In addition, these tools only look at environmental sustainability while a wider scope needed to be considered. Furthermore, the sustainability indicators suggested by Chand et al. (2015) for the Indian context, such as measures of empowerment of women, physical labour such as carrying heavy weights, and lack of sharing the work burden of female family members with male family members, are not very relevant, at least in the Sri Lankan dairy farming context.

The development of the overall sustainability index consisted of three parts. The first part was identifying what to measure under each of the three TBL sustainability domains. The second part was the mathematical formulation of the overall sustainability index. The third and final part was quantitative data collection to validate the mathematical model using quantitative data collected from a large sample of dairy farmers in Sri Lanka (n = 348). One can view the mathematical model also as a statistical model, but the authors prefer the term “mathematical model” because the mathematical model was specified in such a way that the data would fit the mathematical model perfectly (R^2 = 100%). Each of the three parts of the methodology are described in turn.

Identification of the indicators of sustainability in each of the TBL sustainability domains was accomplished thorough review of existing sustainability measurement frameworks and identification of best practices and prescribed indicators (e.g., Bánkuti et al., 2020; Chand et al., 2015; De Silva et al., 2023; Orou Sannou et al., 2023; Zanin et al., 2020). Subsequently, these indicators were trimmed down to an optimal set of indicates through field research interviewing farmers (*n* = 11), milk processors (*n* = 4) and dairy experts (*n* = 4) who were knowledgeable about the Sri Lankan context. Two requirements sought was sufficient coverage of teach TBL domain and parsimony in the measurement system as over-populated/ complicated measurement systems would have limited practical value. The outcome was three indicators for each TBL sustainability domain (nine indicators altogether as shown in Appendix 1).

The mathematical basis for formulation of the overall sustainability index is explained as follows. Let TOT, ECN, SOC, and ENV represent the overall sustainability, economic, social, and environmental sustainability respectively; also let X_{1ECN}, X_{2ECN}, and X_{3ECN} represent the three economic sustainability indicators; X_{1SOC}, X_{2SOC}, and X_{3SOC} represent the three social sustainability indicators; and X_{1ENV}, X_{2EENV}, and X_{3ENV} represent the three environment sustainability indicators. Then following equations can be specified:

$$TOT = \lambda*ECN + \kappa*SOC + \mu*ENV \quad (1)$$

$$ECN = w_1*X_{1ECN} + w_1*X_{2ECN} + w_3*X_{3ECN} \quad (2)$$

$$SOC = w_4*X_{1SOC} + w_5*X_{2SOC} + w_6*X_{3SOC} \quad (3)$$

$$ENV = w_7*X_{1ENV} + w_8*X_{2ENV} + w_9*X_{3ENV} \quad (4)$$

Where λ, κ, μ, w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, and w_9 remain unknown parameters that would be empirically determined using a model fitting approach using a specific structural equation model (SEM) known as a second order, formative-formative model (Hair Jr et al., 2022). Smart PLS version 4 (Ringle et al., 2024) was used as the SEM software in the study.

The data to estimate the model parameters was obtained through a questionnaire administered to 324 dairy farmers, of whom 169 were from the Kurunegala district of Sri Lanka and 155 were from the Nuwara Elia district of Sri Lanka. Both districts are dairy-intensive districts of the country. It is important to note that the survey included questionnaire items that are related to several other theoretical constructs (not just the three TBL sustainability domains) and questions on farmer demographics as this paper is one of the many papers related to a comprehensive doctoral research project covering farmer development, using Sri Lanka as the context. Since there are nine indicators of sustainability (equations 2-4) there were nine statements (one on each indicator) for which the agreement was sought in a Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). Interestingly, of the 155 Nuwara Eliya dairy farmers participated in the study, 149 (96%) were found to be adopting intensive farming (more precisely, farming reliant on limited land and hence high operating cost per cow) using exotic cows that suit the colder climate in this district. This was not the case among the 169 farmers in the hot and humid Kurunegala district (23 farmers were found to be adopting intensive farming, 73 farmers were found to be adopting semi-intensive farming, and 72 farmers were found to be adopting extensive farming).

Finally, in order to demonstrate the practical usage of the TBL sustainability index, four sets of multiple regression models were run taking economic sustainability, social sustainability, environmental sustainability, and overall sustainability as the dependent variables. Price being paid per kg of milk (this is assumed to be a proxy for milk quality), farming experience, education, herd size, location (Kurunegala district vs Nuwara Eliya district), special, processor-led training (being selected vs not selected) were treated as the independent variables. The analysis was conducted using Minitab 21 software.

The data analysis revealed that of the 12 model parameters estimated (equations 1 to 4)—including the 9 indicator weights—were statistically significant at 0.05 significance level. The results also fulfilled the other criteria required for validity of the measurement system, such as the absence of multicollinearity (for details see Hair et al., 2022). The estimated indicator weights were as follows: $w_1 = 0.293$; $w_2 = 0.374$; $w_3 = 0.333$; $w_4 = 0.410$; $w_5 = 0.336$; $w_6 = 0.254$; $w_7 = 0.256$; $w_8 = 0.320$; and $w_9 = 0.424$. In addition, the parameters λ, κ, and μ (the unstandardized regression coefficients) were found to be 0.291, 0.381, and 0.328 respectively. It is important to note that the above parameter estimates are valid only when the 1-5 measurement scale is being used for the nine sustainability indicators. Based on the said scale, a farmer who is performing dismally in overall sustainability would secure a score of 1, while a farmer who is performing maximally in overall sustainability would secure a score of 5 (the theoretical extremes). Since this scale does not have a sufficient resolution for practical applications (e.g. understanding what farmers achieve for themselves for their efforts), the 1-5 scale was converted to a 0-1000 scale for overall sustainability using arithmetic manipulation. Appendix 1 depicts how the nine sustainability indicators should be weighted in the 0-1000 scale.

The descriptive statistics of overall sustainability (in the 1-5 scale) was as follows: Mean = 3.5904; median (50th percentile) = 3.7400; standard deviation = 0.7505; 25th percentile = 3.0332; 75th percentile = 4.0918; minimum = 1.5537; and maximum = 5.0000. The farmers were graded based on their overall sustainable performance. Farmers who score above 4.0918 (75th percentile) were classified as excellent performers, farmers who score between 3.0332 and 4.0918 (the 25th percentile and 75th percentile) were considered as average performers, and farmers who score less than 3.0332 were considered as poor performers. Based on this classification, of the 324 farmers, 81 (25%) were found to be poor performers, 162 (50%) were found to be average performers, and the remaining 81 (25%) were found to be excellent performers.

The measurement system developed has several practical applications, but it is recommended that in awarding points for each sustainability indicator, the situational factors need to be considered. In agriculture, the sustainable performance of a farmer can be affected significantly due to weather (drought years affect the milk output significantly), a country's economic climate, and unstable government policy, plus other situational factors (Darwai et al., 2024; Wijethilaka et al., 2018). While the 1-5 Likert scale used in the study for data collection is suitable for large surveys (such a survey can be used to shortlist farmers or group farmers into categories), for applications such as recognition, it is recommended that the assessment should be made by agribusiness experts who can assess sustainable performance more objectively, using tighter marking rubrics (the 0-1000 scoring system shown in Appendix 1 is recommended). The measurement system reported in this paper is useful for policy makers to examine the sensitivity of policy decisions and adverse/ uncontrollable events such as poor weather. The measurement system is also useful for key actors in the dairy value chain such as the milk processors to demonstrate that they are monitoring farmer sustainability as a part of their corporate social responsibility.

The regression results indicated that among the significant predictors, location emerges as the most influential factor, with Kurunegala farmers surpassing Nuwara Eliya farmers by a significant margin. Interestingly, the herd size was *not* found to have a significant effect on any of the dimensions of sustainability including the overall sustainability. The remaining independent variables were found be significant (the absolute value of the T statistic of regression coefficients was used as a proxy to compare the relative sizes of their effects). One surprising finding was that farmers selected for a special training program implemented by the milk processor performed poorly compared to their counterparts who are not in the program. This discrepancy could be attributed to the relative newness of the special training programme (this was introduced just six months before data collection, which may not be a sufficient elapsed time for the learning curve effects to kick-in) higher expectations of the farmers, which did not eventuate. Another possibility could be that the special training programme did work from the processor's standpoint (e.g. increased volume of milk supply, better milk hygiene).

The significance of this study lies in its potential to advance the sustainability of dairy farming in developing countries in three key aspects. Firstly, the study employs a holistic approach by developing a comprehensive scoring system grounded in the TBL framework. This approach provides a robust tool for evaluating sustainability in dairy farming, offering a more balanced and thorough assessment compared to existing methods. Secondly, the study suggests a set of context-specific indicators that have been empirically validated. This localization makes the scoring system more relevant, effective, and user-friendly for the target context, addressing the specific needs and constraints faced by these farmers. Furthermore, this approach shows potential to contribute to global sustainability efforts by meeting SDGs. Thirdly, study explained the context specific predictor variables and their significance. Finally, the study contributes to the academic discourse on sustainability in agriculture, particularly in the context of developing countries. By filling gaps in existing research and providing a novel, context-specific tool, it adds valuable insights and methodologies to the field. Additionally, the study supports practitioners by enhancing policy decision-making and initiating more tailored development initiatives. However, applying the findings to contexts that are very different to that in Sri Lanka is not recommended. While limited generalizability of the finding is a weakness of the study, as a methodology, the study has very wide analytical generalizability. Finally, in keeping with the systems and process thinking in operations management, the overall sustainability index developed in this paper is not recommended to be used as a metric to reward farmers (for recognition it is alright) because the farmers should be rewarded for both the processes that they put in place (farm practices) as well as the outcomes they achieve for themselves. The overall sustainability is presented in this paper is heavily biased towards the latter (only three farming practices are covered in this paper, and all of them pertain to environmental sustainability).

Key words: dairy farmers, sustainability scoring system, Developing country.

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Appendix 1

Table A: The Resulting Scoring System

Number	Indicator	Points
1. **Economic Sustainability (291 points)**		
1.1 ECNSUS1	Gross income received from dairy farming	85 points
1.2 ECNSUS2	Net farming income to meet household needs	109 points
1.3 ECNSUS3	Profitability of the farming business	97 points
2. **Social Sustainability (381 points)**		
2.1 SOCSUS1	Quality of life resulting from farming	156 points
2.2 SOCSUS2	The quality of education given to the children	128 points
2.3 SOCSUS3	Recognition received from the community	97 points
3. **Environmental Sustainability (328 points)**		
3.1 ENVSUS1	Practices related to proper disposal of effluents	84 points
3.2 ENVSUS2	Practices related to use of solid waste for agriculture activities	105 points
3.3 ENVSUS3	Practices related to action to reduce air pollution	139 points
	TOTAL (Overall Sustainability)	**1000 points**