

Original article

Evaluating the Adoption of Good Leaf Quality Standards (GLQS) Practices on Reducing Post-Harvest Damage in the Green Tea Leaf Supply Chain: Challenges and Strategies for Enhanced Adoption in Badulla District

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Abstract

This study examines the adoption of Green Leaf Quality Standard (GLQS) practices to reduce post-harvest damage in the green tea leaf supply chain in the Badulla district, emphasizing the importance of leaf quality in tea production. The study also identified the level of post-harvest damages at different stages and addressed challenges in their adoption. Employing both quantitative and qualitative methods, the cross-sectional study collected data from observations, interviews, and surveys across 30 tea factories, targeting pluckers, smallholders, dealers, and factory officers through multistage stratified sampling. Results indicate that the highest adoption of GLQS practices occurs among factory officers (22.84%) and smallholders (22.77%), while dealers and pluckers demonstrated moderate to lower levels at 21.57% and 20.75%, respectively. The results confirmed that the percentage of leaf damage (below the best percentage) remained consistent across the points measured: it was 2.16% from the first to the second point, 22.68% from the second to the third point, and 4.9% from the third to the fourth point. Key barriers to GLQS adoption were identified as a lack of awareness, resistance to change, compliance costs, and limited resources. The multiple regression model revealed strong relationships between level of adoption GLQS and measured independent variables (demographic factors, attitude, exposure to extension services and training programs, supportive policies and regulations, and access to resources) with R-squared values of 0.881 for pluckers, 0.798 for smallholders, 0.968 for dealers, and 0.898 for factory officers. In conclusion, while factory officers lead in GLQS adoption, significant post-harvest losses persist, particularly during transportation. Recommendations include utilizing better-equipped transport, enhancing extension services, and implementing education and training programs to incentivize GLQS compliance and minimize post-harvest damage, thereby improving sustainability in the tea industry.

Keywords: Adoption, Green Leaf Quality Standard (GLQS), Post-harvest Damage, Green Leaf Supply Chain, The Quality of Green Leaves

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INTRODUCTION

Tea (*Camellia sinensis*) is one of the world's most widely consumed beverages, second only to water, and its final quality is critically determined by the condition of raw green leaves at the point of harvest (Wang et al., 2022; Aaqil et al., 2023). Sri Lanka, historically recognised as 'Ceylon Tea', remains one of the world's leading tea exporters and the industry constitutes a vital pillar of the national economy, contributing substantially to export earnings and rural employment (Hilal, 2019; Sri Lanka Tea Board, 2022). Within the Sri Lankan context, the Badulla district is among the most productive highland tea-growing regions; however, it has consistently ranked among the lowest-performing districts in terms of green leaf quality, making it a site of particular policy and research concern (Sri Lanka Tea Board, B60 Project).

Post-harvest losses in the tea leaf supply chain represent a persistent challenge. These losses manifest in several forms: physical leaf damage through bruising and compression, biochemical deterioration through premature oxidation and fermentation, and moisture induced spoilage, all of which reduce the proportion of 'best leaf' reaching the factory withering troughs and, consequently, depress the yield of premium-grade finished tea (Yu et al., 2020; Krahe et al., 2021). Research has demonstrated that the economic consequences of poor post-harvest handling are substantial, raising the proportion of off-grade and refuse tea and reducing overall factory profitability (Kumar & Kalita, 2017).

To address these challenges, the Sri Lanka Tea Board (SLTB) developed and promulgated the Good Leaf Quality Standards (GLQS), a codified set of practices governing the handling, packaging, transportation, and receipt of green tea leaves at every node of the supply chain. The GLQS specifies requirements for approved container types (plastic crates and authorised bags), maximum load weights (18–20 kg per bag), permissible transport distances (not exceeding 25 km), vehicle specifications (covered transport with adequate protection), and time restrictions on delivery (no arrivals after 20:30 hours), among other provisions (FAO, 2016). Despite these regulations, empirical evidence on the extent to which different supply-chain actors comply with GLQS and the factors that either facilitate or impede adoption remains limited.

The adoption of agricultural quality standards is a well-established research area internationally (Parasar et al., 2020; Saikia & Bhattacharyya, 2022; Li et al., 2024). Behavioural and attitudinal factors, access to knowledge through extension services, and institutional support through policy frameworks have consistently been identified as key drivers of compliance across diverse agricultural contexts (Xie et al., 2022; Mathuabirami et al., 2024). Studies in the Sri Lankan tea sector have similarly highlighted the importance of extension services and training in improving smallholder practices (Amarathunga et al., 2023), yet the specific dynamics of GLQS adoption across the multi-stakeholder supply chain in Badulla have not been systematically examined.

This study seeks to fill this gap by providing a comprehensive empirical account of GLQS adoption across four key stakeholder groups, quantifying the distribution of post-harvest damage at each supply chain stage, and identifying the demographic, attitudinal, and institutional factors that predict adoption levels. The findings are intended to inform policy and programmatic interventions by the SLTB, Regional Plantation Companies (RPCs), and development partners aimed at improving leaf quality standards and reducing post-harvest losses in the Sri Lankan tea industry.

Objectives of Study

This research assesses post-harvest damage at various stages, explores how tea leaf supply chain stakeholders adopt Good Leaf Quality Standards (GLQS) to mitigate this damage, and proposes solutions for ensuring sustainable green leaf quality and final tea products.

The specific objectives of this study are as follows:

- To quantify the level of post-harvest damage occurring at each stage of the green tea leaf supply chain from plucking to factory withering in the Badulla district.
- To assess the extent to which different stakeholder groups pluckers, tea smallholders, bought-leaf collecting dealers, and factory officers, adopt GLQS practices.
- To identify the key barriers preventing full compliance with GLQS across stakeholder groups.
- To determine the demographic, attitudinal, and institutional factors that significantly predict GLQS adoption among each stakeholder group using multiple linear regression analysis.
- To recommend evidence-based strategies to enhance GLQS adoption and reduce post-harvest losses in the tea leaf supply chain.

Conceptual Framework of the Study

This study is grounded in the Diffusion of Innovations (DOI) theory proposed by Rogers (2003), which provides a foundation for understanding why and how agricultural stakeholders adopt or resist new standards and practices. According to the DOI framework, an innovation's adoption rate is influenced by its perceived attributes (relative advantage, compatibility, complexity, trialability, and observability), the characteristics of the adopter, and the social system in which adoption occurs. In the context of GLQS, the relative advantage of compliant handling practices (premium prices, reduced rejection rates) and the compatibility of standards with existing labour routines are expected to influence adoption differently across the four stakeholder groups studied.

Building on the DOI framework, this study also draws on the Technology Acceptance Model (TAM) and its agricultural adaptations, which emphasise perceived usefulness and ease of use as determinants of technology and practice adoption (Xie et al., 2022). In particular, a positive attitude toward quality standards, as a proxy for perceived usefulness and intrinsic motivation, has been

identified as a consistent predictor of adoption in comparable agricultural settings (Saikia & Bhattacharyya, 2022; Li et al., 2024).

The conceptual framework constructed for this study (Figure 1) organises the independent variables into three broad categories: socio-demographic factors, human (attitudinal and labour-type) factors, and awareness and enabling-environment factors. These categories together are hypothesised to influence the dependent variable, namely the level of adoption of GLQS practices, as measured by a composite adoption index.

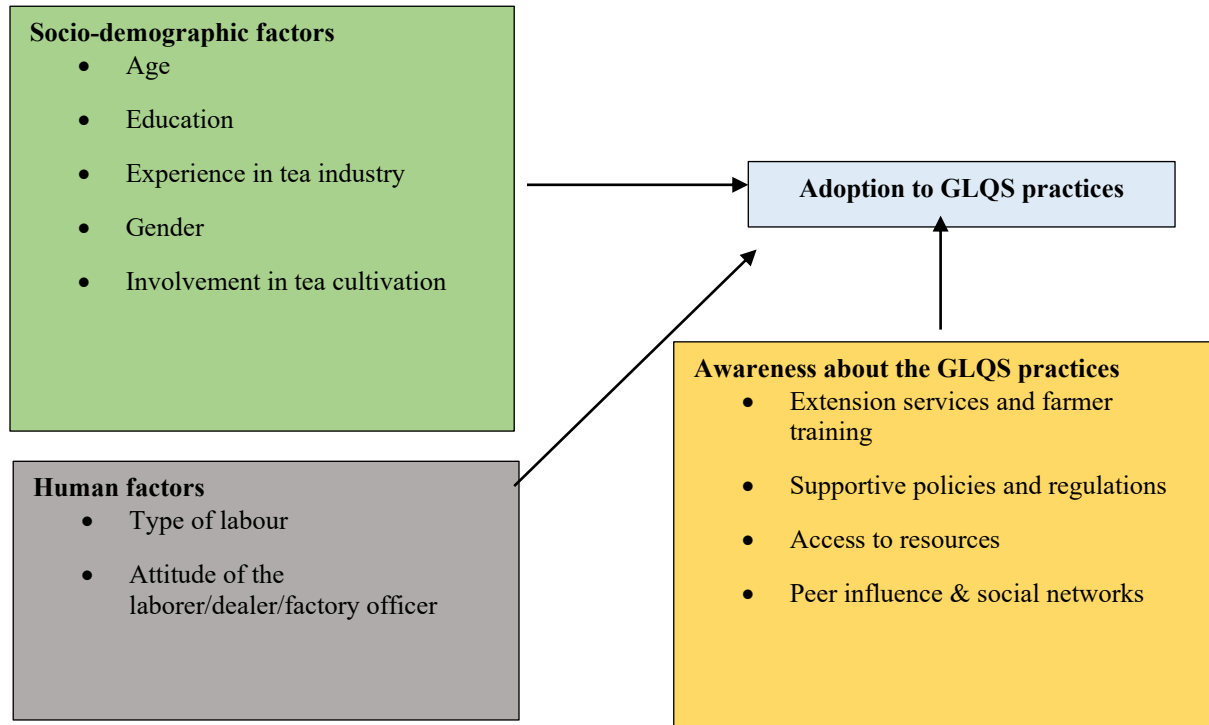


Figure 1. Conceptual framework of the study

Socio-demographic variables include age, education level, years of experience in the tea sector, gender, and degree of involvement in tea cultivation (full-time or part-time). These variables capture structural characteristics of respondents that are expected to shape exposure to information, capacity to adopt new practices, and susceptibility to institutional incentives.

Human factors include the type of labour (hired versus family labour in the case of smallholders) and the attitude of the respondent toward GLQS adoption, measured as an index score derived from a validated Likert-scale instrument. Attitudinal disposition is posited as a proximal predictor of behavioural adoption, mediating the influence of more distal socio-demographic and institutional variables.

Awareness and enabling-environment factors capture the role of the broader institutional context: access to extension services and farmer training programmes, the presence of supportive policies and

regulations, access to physical and financial resources, and the influence of peer networks and social norms. These factors reflect the supply-side of adoption support the degree to which the agricultural system equips stakeholders with the knowledge, incentives, and materials to comply with GLQS.

Together, these three domains encompass the primary determinants identified in the international literature on agricultural standards adoption and are expected to explain a meaningful proportion of variance in GLQS adoption across the four stakeholder groups in Badulla.

METHODOLOGY

Research Design

This study employed a Quantitative method, cross-sectional research design. The quantitative strand involved structured questionnaire surveys and objective physical measurement of leaf quality at four supply chain points. A cross-sectional design was selected because the study sought to document current levels of adoption and post-harvest damage at a single point in time, rather than to track change over a longitudinal period.

Study Area

The study was conducted in the Badulla district of Uva Province, Sri Lanka. Badulla was selected purposively because it has been identified by the Sri Lanka Tea Board's B60 project as one of the districts with the lowest average green leaf quality among major tea-producing regions. The district encompasses a diverse range of tea-growing environments, including Regional Plantation Company (RPC) estates and private smallholder gardens, making it representative of the breadth of the national tea supply chain.

Sampling Strategy

A multistage stratified sampling procedure was employed. In the first stage, the 60 tea factories registered in Badulla district were stratified by Tea Inspection region into four strata: Bandarawela, Welimada, Haliella, and Passara. From each stratum, factories were randomly selected proportional to stratum size, yielding a final sample of 30 factories. This sampling fraction of 50% (30 out of 60) was determined to be sufficient to capture variability across geographic sub-regions and factory types.

In the second stage, respondents were sampled from four stakeholder groups associated with the selected factories: RPC pluckers, tea smallholders supplying those factories, bought-leaf collecting dealers (green leaf collectors), and factory officers. From each group, 40 respondents were selected using systematic random sampling within each factory catchment, producing a total sample of 160 respondents. This sample size was calculated to achieve a margin of error of approximately $\pm 10\%$ at the 95% confidence level for each stakeholder group, consistent with comparable adoption studies in the tea sector (Parasar et al., 2020).

Data Collection

Primary data were collected through five complementary methods:

- Structured questionnaire surveys administered individually to all 160 respondents, covering socio-demographic characteristics, adoption practices, barriers to GLQS compliance, and the independent variable constructs (attitude, access to extension services, supportive policies, resource access, and peer influence).
- Key informant interviews conducted with Tea Inspectors, RPC field supervisors, and factory managers to gather contextual information on implementation challenges and institutional support mechanisms.
- Direct field observations at each supply chain point to verify self-reported compliance and to observe actual handling practices.

Physical leaf quality measurement, in which 100 g samples from the same batch were weighed at four consecutive supply chain points

(1) at the plucking point in the tea field; (2) at the farm gate before loading onto the transport vehicle; (3) after unloading from the vehicle at the factory entrance weighing point; and (4) at the withering trough inside the factory, with the proportion of 'best leaf' and 'below-best leaf' recorded at each point.

All questionnaire instruments were pretested in a pilot survey involving 10 respondents per group and subsequently refined. Internal consistency of all multi-item scales was assessed using Cronbach's Alpha, and instruments were retained only where Alpha values exceeded the threshold of 0.70 (Table 1).

Table 1. Reliability Test for tested parameters in sampled groups

Independent Variables	No. of Items	Cronbach's Alpha RPC-Plucker	Cronbach's Alpha Smallholder	Cronbach's Alpha Leaf Collector	Cronbach's Alpha Factory officer
Attitude of the plucker	20	0.870	0.814	0.909	0.917
Extension services & farmer training	5	0.731	0.756	0.771	0.830
Supportive policies & regulations	6	0.710	0.723	0.867	0.707
Access to resources	3	0.874	0.884	0.845	0.883
Peer influence & social networks	7	0.706	0.765	0.725	0.786
Dependent Variable (Adaptation to GLQS practices)	7	0.811	0.702	0.777	0.718

Note. All Cronbach's alpha values exceed the 0.70 threshold, confirming acceptable internal consistency for all scales across the four stakeholder groups.

Measurement of GLQS Adoption

GLQS adoption was operationalised as a composite index calculated from respondents' self-reported compliance with all relevant GLQS practices specified for their stakeholder role. For each applicable practice, a weighted score was assigned based on observed importance and frequency of application. The adoption index was then computed as:

$$\text{Adoption Index (\%)} = (\text{Grand Total Weighted Score} / \text{Maximum Possible Score}) \times 100$$

A score of 100% would represent full adoption of all GLQS practices applicable to the respondent's role. Scores were then compared across stakeholder groups using descriptive statistics.

Analytical Methods

Quantitative data were entered into Microsoft Excel, cleaned, coded, and subsequently imported into IBM SPSS Statistics (Version 26) for analysis. The following analytical techniques were applied:

Descriptive statistics (means, standard deviations, minimum, and maximum values) were used to characterise the demographic profile of each stakeholder group and to summarise the GLQS adoption index scores.

Physical leaf quality data were tabulated and the percentage of below-best leaves at each supply chain point was calculated from the 100 g sample weights, enabling point-to-point comparison of damage accumulation.

Multiple linear regression analysis was employed to identify the independent variables that significantly predict GLQS adoption within each stakeholder group. For each model, the dependent variable was the GLQS adoption index score, and the twelve independent variables corresponded to the conceptual framework constructs. Model fit was assessed using the R-squared statistic and the F-test; individual predictor significance was assessed at $\alpha = 0.05$.

The empirical regression model was specified as:

$$Y = \beta_0 + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3) + \beta_4(X_4) + \beta_5(X_5) + \beta_6(X_6) + \beta_7(X_7) + \beta_8(X_8) + \beta_9(X_9) + \beta_{10}(X_{10}) + \beta_{11}(X_{11}) + \beta_{12}(X_{12}) + \varepsilon$$

Where Y = Adoption Index score; X_1 = Age; X_2 = Gender; X_3 = Education; X_4 = Experience in tea field; X_5 = Land size; X_6 = Family size; X_7 = Type of labour; X_8 = Attitude; X_9 = Extension services; X_{10} = Supportive policies and regulations; X_{11} = Access to resources; X_{12} = Peer influence and social networks; ε = error term. Note that not all variables were applicable to all stakeholder groups (e.g., land size was only relevant for smallholders; type of labour did not apply to factory officers).

RESULTS and DISCUSSION

Post-Harvest Damage across Supply Chain Stages

Physical leaf quality was assessed using 100 g sample batches weighed at four supply chain points. The proportions of best and below-best leaves at each point, and the corresponding percentage-point changes between points, are reported in Table 2.

Table 2. Leaf Quality Measurements at Four Supply Chain Points (100 g Sample Batches)

Supply Chain Point	Best Leaf (g)	Below-Best (g)	Best Leaf (%)	Below-Best (%)	Change in Below-Best (pp)
1st — Plucking point (tea field)	60.87	12.44	83.03%	16.97%	—
2nd — Farm gate (before loading)	57.12	13.51	80.87%	19.13%	+2.16 pp
3rd — Factory entrance (after transport)	30.02	21.57	58.19%	41.81%	+22.68 pp
4th — Withering trough (factory)	26.68	23.38	53.29%	46.71%	+4.90 pp

pp = percentage points. The change in below-best percentage is calculated as the absolute difference in the below-best proportion between consecutive points.

The data in Table 2 reveal a clear and pronounced escalation in leaf damage between the farm-gate loading point (2nd point) and the factory entrance unloading point (3rd point). At the farm gate, 19.13% of the sampled leaves were classified as below-best; by the time the same batch arrived at the factory entrance after transportation, this proportion had risen to 41.81% — an increase of 22.68 percentage points. This finding identifies the transportation phase as by far the most damaging stage in the supply chain, consistent with the role of dealer transport practices in compressing and heating leaves during transit.

By contrast, the changes occurring at other stages were considerably smaller: a 2.16 percentage-point increase in below-best leaves between the plucking point and the farm gate (attributable to handling and short-term storage at the smallholding), and a 4.90 percentage-point increase between the factory entrance and the withering trough (associated with internal factory handling). These findings suggest that while all stages contribute to quality degradation, interventions targeting transport vehicles, packaging, and loading practices are likely to yield the greatest returns in terms of damage reduction.

GLQS Adoption Rates by Stakeholder Group

The mean GLQS adoption index scores for each stakeholder group are presented in Figure 3. Overall, adoption rates were critically low across all groups, ranging from 20.75% for RPC pluckers to 22.84% for factory officers. The full ranking from lowest to highest adoption is: RPC pluckers (20.75%) < bought-leaf collecting dealers (21.57%) < smallholders (22.77%) < factory officers (22.84%).

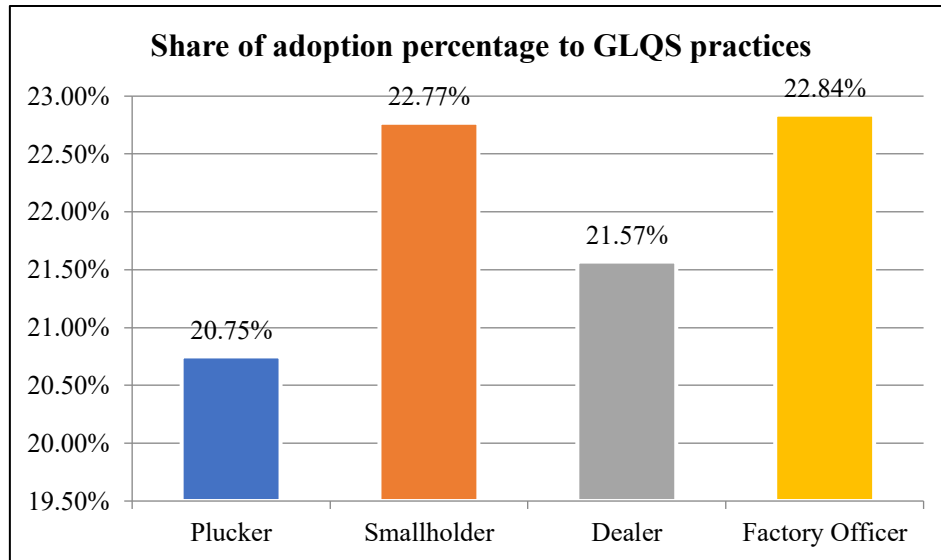


Figure 2. Mean GLQS adoption index (%) by Stakeholder group

It is critical to contextualize these percentages within the broader adoption literature. In standard technology and practice adoption research, adoption rates below 25% are generally regarded as indicative of an early or stalled adoption phase, signaling critical implementation failures rather than successful uptake (Rogers, 2003). The finding that even factory officers the group with the greatest institutional incentive and oversight to comply achieve only 22.84% adoption signals a systemic rather than individual-level failure, suggesting that structural barriers such as inadequate resources, transport infrastructure, and institutional enforcement mechanisms must be addressed alongside individual-level attitude and training interventions.

Factory officers achieved the highest adoption (22.84%), most plausibly because of their position within formal factory structures, which provide greater access to institutional oversight, accountability mechanisms, and quality management training. Smallholders achieved the second-highest adoption (22.77%), possibly reflecting their direct financial incentive to supply premium-quality leaves and earn higher factory gate prices. Dealers' moderate adoption (21.57%) is consistent with their intermediary role and logistical constraints. RPC pluckers' lowest adoption (20.75%) may reflect the piece-rate payment structure prevalent in estate plucking, which incentivises quantity over quality, as well as limited personalized extension contact.

GLQS Practices by Stakeholder Group

Pluckers

GLQS requirements applicable to pluckers centre on preventing physical damage and heat accumulation in harvested leaves. Key standards include using approved nylon plucking bags, limiting bag loads to 18–20 kg to prevent compression, using minimal hand contact during plucking, refraining from compressing leaves within bags, transporting leaves to the weighing shade as promptly as possible

after plucking, refraining from wetting leaves in bags, and using only approved plastic crates or bags for onward transport. The low adoption rate among pluckers (20.75%) suggests that most of these practices are not being consistently followed, and that financial incentives (piece-rate pay structures) and limited supervisory enforcement are primary contributing factors.

Tea Smallholders

Smallholders face similar handling requirements to pluckers during harvesting, and additionally must manage the storage of harvested leaves on the farm before handover to dealers or direct transport to the factory. Their relatively higher adoption (22.77%) is plausibly linked to the direct economic incentive of obtaining premium prices for high-quality leaf and their involvement in managing their own supply chain from field to handover point. Smallholders who supply directly to factories without dealer intermediation may have a particularly strong motivation to maintain leaf quality throughout.

Bought-Leaf Collecting Dealers

GLQS practices for dealers govern the transport and custody phase of the supply chain and include: transporting leaves only in approved plastic crates or bags; maintaining bag loads within the 18–20 kg limit; not transporting leaves to factories after 20:30 hours; not transporting from collection centres more than 25 km from the factory; using only covered transport vehicles with adequate protective mechanisms; applying minimum-handling practices during loading and unloading; and maintaining accurate records and documentation. The finding that the transport phase between farm gate and factory entrance accounts for the largest single increment of damage (22.68 percentage points) provides strong empirical justification for prioritising dealer compliance with these transport-specific GLQS requirements.

Factory Officers

Factory officers are responsible for enforcing GLQS standards at the point of leaf receipt. Their applicable practices include: accepting leaves only in approved containers; rejecting loads exceeding the 18–20 kg limit; not accepting deliveries after 20:30 hours; not accepting leaves transported from distances exceeding 25 km; accepting only vehicles with approved transport conditions; transferring leaves to withering troughs promptly and with minimum handling; and maintaining systematic records of leaf quality assessments. As the final gatekeepers in the supply chain, factory officers have the capacity to incentivise compliance among other stakeholders by enforcing these receipt requirements rigorously. Their highest adoption rate in this study is therefore not merely descriptively interesting but also has normative implications: strengthening factory officer enforcement is likely to create upstream incentives for higher adoption by dealers and pluckers.

Key Barriers to GLQS Adoption

Across all four stakeholder groups, respondents identified five primary barriers to GLQS adoption (Figure 4). According to the survey, the most significant challenges faced by RPC pluckers include a lack of awareness or education, high compliance costs, limited access to resources, resistance to change, and regulatory complexity, with these challenges collectively accounting for 17.16% of reported barriers. Market fluctuations were recorded as the lowest challenge among pluckers, with only 14.16%. For smallholders, the primary challenges are similarly a lack of awareness or education, high compliance costs, limited access to resources, resistance to change, and regulatory complexity, which together represent 17.31% of reported barriers. Market fluctuations were the least challenging factor for smallholders, recorded at 13.41%. Dealers reported similar prominent challenges — lack of awareness or education, high compliance costs, limited access to resources, and regulatory complexity — which accounted for 20.30% of their reported challenges. Market fluctuations were the least concerning at 9.64% for dealers, while resistance to change was recorded at 9.13%. Factory officers also faced comparable key challenges: lack of awareness or education, high compliance costs, limited access to resources, and regulatory complexity, comprising 20.20% of their reported barriers. Market fluctuations were noted at 9.09% for factory officers, with resistance to change at 10.10%. Despite these challenges, some stakeholders argue that market fluctuations can present opportunities for innovation and adaptation, suggesting that a proactive approach may mitigate some of the identified barriers (Forest et al., 2024; Irawan et al., 2024).

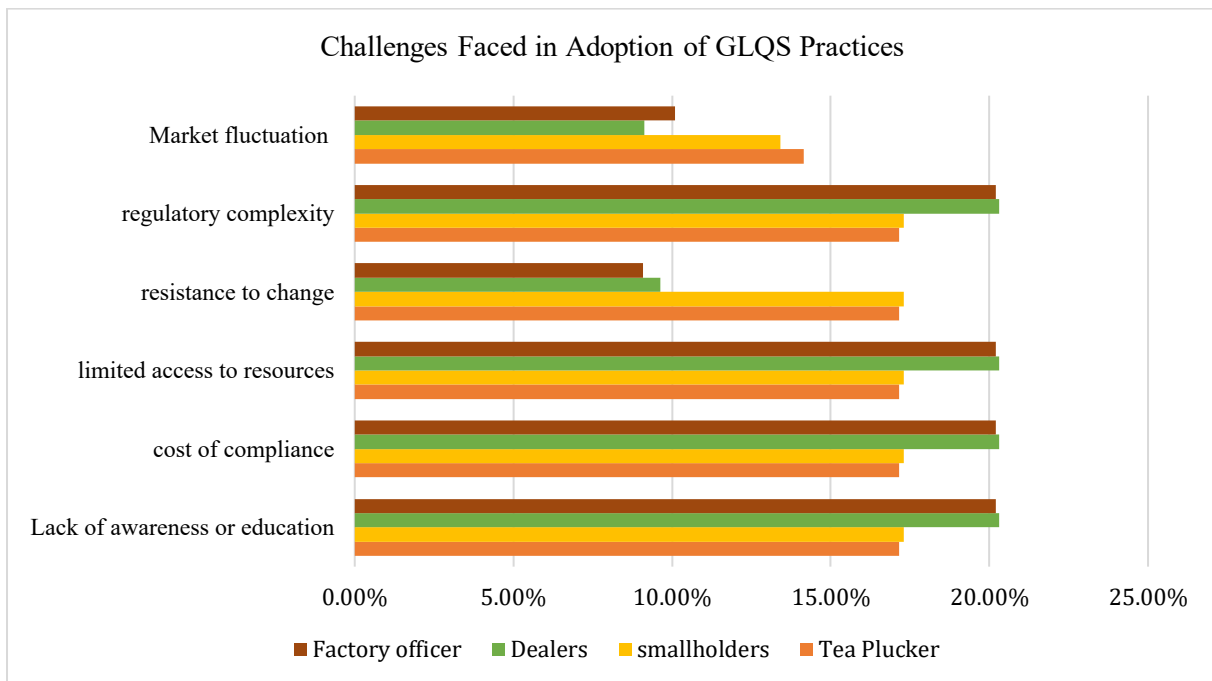


Figure 3. Bar chart - Challenges faced in adoption of GLQS practices by Stakeholder group

These findings are consistent with the international literature on agricultural standards adoption. Awareness and training deficits have been identified as primary barriers to standards compliance in

multiple tea-growing contexts (Parasar et al., 2020; Amarathunga et al., 2023), while financial constraints and resistance to change are well-documented barriers across diverse smallholder agricultural systems (Irawan et al., 2024; Forest et al., 2024). The cross-group consistency of these barriers in the Badulla context suggests that structural and systemic interventions, rather than group-specific targeted approaches, may be appropriate as a first-order response.

Multiple Linear Regression Analysis

Multiple linear regression models were estimated for each of the four stakeholder groups to identify the significant predictors of GLQS adoption. The results are presented in sequence below, with the model summary followed by the parameter estimates for each group.

Pluckers' level Model

Table 3. Model summary -Pluckers

R	R Square	Adjusted R Square	Std. Error of Estimate
0.939	0.881	0.850	3.829

The Pluckers' level model accounts for 88.1% of the variance in GLQS adoption ($R^2 = 0.881$), with a strong overall correlation ($R = 0.939$) between the predictor set and the adoption index.

Table 4. Parameter estimates - RPC Pluckers' level

Variable	B	Std. Error	Beta (β)	t	Sig. (p)	Significance
Constant	48.874	3.604	—	5.104	0.381	—
Gender	3.166	2.133	0.212	1.484	0.119	ns
Age	-0.398	0.207	-0.587	-1.926	0.236	ns
Education	-0.105	0.223	-0.067	-0.471	0.238	ns
Experience in tea field	0.103	0.190	0.161	0.543	0.017	*
Attitude	0.611	0.261	0.629	2.339	0.013	*
Extension services & training	0.297	0.178	0.524	1.666	0.045	*
Supportive policies & regulations	0.066	0.138	0.120	0.476	0.000	**
Access to resources	-0.268	0.134	-0.648	-2.008	0.000	**
Peer influence & social networks	0.236	0.176	0.407	1.344	0.437	ns

* $p < 0.05$; ** $p < 0.01$; ns = not significant. Derived empirical equation for significant predictors: Adoption (Pluckers) = $48.874 + 0.103(ETF) + 0.611(ATD) + 0.297(ETS) + 0.066(SPR) - 0.268(ACR) + \varepsilon$

The regression analysis revealed that attitude, experience in tea cultivation, extension services, supportive policies, and access to resources significantly influence the adoption of Good Leaf Quality Standards (GLQS) practices among RPC Estate Tea Pluckers. Notably, a positive attitude toward GLQS ($\beta = 0.629$, $p = 0.013$) and access to extension services and training programmes ($\beta = 0.524$, $p = 0.045$) emerged as the two strongest positive predictors of adoption, underscoring the importance of motivation and training in driving GLQS adoption. Experience in tea cultivation also contributed positively ($\beta =$

0.161, $p = 0.017$) and supportive policies ($\beta = 0.120$, $p < 0.001$) also positively contributed, though with smaller effects. Surprisingly, access to resources showed a significant negative effect ($\beta = -0.648$, $p < 0.001$), suggesting potential barriers such as resource mismanagement or misalignment with GLQS requirements, warranting further investigation. These findings highlight the need for targeted interventions that enhance farmers' attitudes, provide robust training, and ensure effective resource utilisation to promote sustainable GLQS adoption. While these findings highlight the importance of positive attitudes and training, it is also crucial to consider that some farmers may resist adopting GLQS due to perceived costs or scepticism about the benefits, suggesting a need for comprehensive outreach and education strategies to address these concerns (Saikia & Bhattacharyya, 2022; Xie et al., 2022).

Tea Smallholders' level Model

Table 5. Model Summary - Tea Smallholders

R	R Square	Adjusted R Square	Std. Error of Estimate
0.884	0.798	0.650	4.829

Table 6. Parameter Estimates - Tea Smallholders

Variable	B	Std. Error	Beta (β)	t	Sig. (p)	Significance
Constant	75.858	14.862	—	5.104	0.000	**
Gender	3.166	2.133	0.212	1.484	0.148	ns
Age	-0.398	0.207	-0.587	-1.926	0.064	ns
Education	-0.105	0.223	-0.067	-0.471	0.641	ns
Experience in tea cultivation	0.103	0.190	0.161	0.543	0.031	*
Attitude	0.611	0.261	0.629	2.339	0.026	*
Extension services & training	0.297	0.178	0.524	1.666	0.006	**
Supportive policies & regulations	0.066	0.138	0.120	0.476	0.637	ns
Access to resources	-0.268	0.134	-0.648	-2.008	0.054	ns
Peer influence & social networks	0.236	0.176	0.407	1.344	0.189	ns

* $p < 0.05$; ** $p < 0.01$; ns = not significant. Derived empirical equation for significant predictors: Adoption (Smallholders) = $75.858 + 0.103(ETF) + 0.611(ATD) + 0.297(ETS) + \varepsilon$

The multiple regression analysis identified key determinants of Good Leaf Quality Standards (GLQS) adoption among smallholder tea farmers, with attitude, access to extension services, and experience in tea cultivation emerging as significant predictors. The smallholder model explains 79.8% of variance in adoption ($R^2 = 0.798$) with a strong overall correlation ($R = 0.884$). Specifically, a positive attitude toward GLQS ($\beta = 0.629$, $p = 0.026$) and access to extension services and training programmes ($\beta = 0.524$, $p = 0.006$) exhibited strong positive effects, highlighting the critical role of motivation and knowledge transfer in promoting GLQS practices. Experience in tea cultivation ($\beta = 0.161$, $p = 0.031$) also significantly enhanced adoption, though with a smaller effect. Conversely, access to resources showed a marginally significant negative effect ($\beta = -0.648$, $p = 0.054$), suggesting potential challenges

in resource utilisation or alignment with GLQS requirements. Non-significant predictors, including gender, age, education, supportive policies, and peer influence, indicate limited influence in this context. The strong role of extension services is consistent with Amarathunga et al. (2023), who demonstrated that farmer field school approaches significantly improve GLQS-relevant practices among Sri Lankan tea smallholders. These findings underscore the importance of targeted interventions to foster positive attitudes, strengthen training programmes, and address resource-related barriers to enhance GLQS adoption among smallholders.

Bought-Leaf Collecting Dealers' level Model

Table 7. Model summary - Bought-leaf collecting dealers

R	R Square	Adjusted R Square	Std. Error of Estimate
0.997	0.968	0.450	3.729

Table 8. Parameter estimates - Bought-leaf collecting dealers

Variable	B	Std. Error	Beta (β)	t	Sig. (p)	Significance
Constant	10.156	11.731	—	0.866	0.393	ns
Age	-0.103	0.116	-0.094	-0.882	0.385	ns
Education	-0.195	0.209	-0.090	-0.935	0.357	ns
Experience in bought-leaf handling	0.016	0.089	0.014	0.175	0.012	*
Attitude	0.644	0.230	0.583	2.794	0.009	**
Extension services & training	0.149	0.149	0.179	1.001	0.014	*
Supportive policies & regulations	-0.046	0.173	-0.063	-0.269	0.790	ns
Access to resources	0.064	0.058	0.100	1.104	0.278	ns
Peer influence & social networks	0.181	0.176	0.171	1.026	0.313	ns

* $p < 0.05$; ** $p < 0.01$; ns = not significant. Derived empirical equation for significant predictors: Adoption (Dealers) = $10.156 + 0.016(ETF) + 0.644(ATD) + 0.149(ETS) + \epsilon$

The regression analysis of dealers' influence on Good Leaf Quality Standards (GLQS) adoption revealed that attitude, experience in the tea field, and access to extension services significantly drive their engagement with GLQS practices. A correlation coefficient of 0.997 indicates a very strong positive relationship between independent and dependent variables, while an R^2 of 0.968 indicates that the model nominally explains 96.8% of the variance in the dependent variable; however, the Adjusted R^2 drops sharply to 0.450, indicating significant model overfitting due to the small ratio of observations ($n = 40$) to the number of predictors. Readers should therefore interpret these model-level statistics with caution. At the individual predictor level, a positive attitude ($\beta = 0.583$, $p = 0.009$) emerged as the strongest predictor, underscoring the critical role of dealers' motivation in promoting GLQS standards. The role of experience aligns with findings that emphasise the importance of expertise in agricultural practices (Steyn & Stevens, 2002). Experience in the tea field ($\beta = 0.014$, $p = 0.012$) and access to

extension services and training programmes ($\beta = 0.179$, $p = 0.014$) also significantly enhanced adoption, though with smaller effects, highlighting the importance of knowledge and expertise. Studies show that effective extension services can significantly improve farmers' satisfaction and productivity (Mathuabirami et al., 2024). Other factors, including age, education, supportive policies, access to resources, and peer influence, were not statistically significant predictors ($p > 0.05$), suggesting limited impact in this context. These findings emphasise the need for interventions that foster positive attitudes and provide targeted training to dealers to strengthen their role in advancing GLQS practices within the tea supply chain.

Factory Officers' level Model

Table 9. Model summary - Factory officers

R	R Square	Adjusted R Square	Std. Error of Estimate
0.910	0.898	0.750	4.730

Table 10. Parameter estimates - Factory officers

Variable	B	Std. Error	Beta (β)	t	Sig. (p)	Significance
Constant	96.615	15.709	—	6.150	0.000	**
Gender	-5.215	6.393	-0.136	-0.816	0.421	ns
Age	-0.262	0.332	-0.359	-0.788	0.436	ns
Education	0.149	0.291	0.086	0.513	0.612	ns
Experience in tea manufacturing	0.526	0.324	0.741	1.625	0.014	*
Attitude	0.395	0.193	0.699	2.044	0.030	*
Extension services & training	0.033	0.150	0.038	0.217	0.021	*
Supportive policies & regulations	-0.357	0.188	-0.614	-1.894	0.068	ns
Peer influence & social networks	0.109	0.123	0.167	0.882	0.035	*

* $p < 0.05$; ** $p < 0.01$; ns = not significant. Derived empirical equation for significant predictors: Adoption (Factory Officers) = $96.615 + 0.526(ETF) + 0.395(ATD) + 0.033(ETS) + 0.109(PISN) + \epsilon$

The regression analysis of factory officers' influence on Good Leaf Quality Standards (GLQS) adoption revealed that experience in the tea field, attitude, access to extension services, and peer influence significantly shape their contribution to GLQS practices. The factory officer model explains 89.8% of variance in adoption ($R^2 = 0.898$), with strong overall model fit ($R = 0.910$). Specifically, greater experience in the tea manufacturing process ($\beta = 0.741$, $p = 0.014$) and a positive attitude toward GLQS ($\beta = 0.699$, $p = 0.030$) were strong positive predictors, indicating that seasoned and motivated officers play a pivotal role in promoting GLQS standards (Gamage & Wickramaratne, 2020; Noorain, 2014). Access to extension services and training programmes ($\beta = 0.038$, $p = 0.021$) and peer influence ($\beta = 0.167$, $p = 0.035$) also significantly enhanced GLQS adoption, though with smaller effects. Peer influence is a finding unique to this group, likely reflecting the formal collegial and supervisory

dynamics of factory environments. Supportive policies showed a marginally significant negative effect ($\beta = -0.614$, $p = 0.068$), suggesting potential misalignments or barriers in policy implementation (Hall, n.d.). Non-significant predictors, including gender, age, and educational attainment, had minimal impact. These findings highlight the need for targeted training and peer engagement strategies to leverage experienced and motivated factory officers in advancing GLQS practices.

CONCLUSIONS

Post-harvest leaf damage progressively increased across all tested supply-chain stages, with below-best leaves rising from 16.97% at the plucking point to 19.13% at the farm gate, 41.81% at the factory entrance, and 46.71% at the withering trough. The largest increase occurred during transportation from the farm gate to the factory entrance (+22.68 percentage points), identifying transport as the most damaging stage. Therefore, priority interventions should improve transport vehicles, packaging, loading, ventilation, and delivery time, alongside better field and factory handling practices.

GLQS adoption was critically low across all stakeholder groups, with RPC pluckers recording the lowest level (20.75%), followed by green-leaf collecting dealers (21.57%), smallholders (22.77%), and factory officers (22.84%). As all scores remained below 25%, the findings indicate a systemic implementation failure rather than isolated individual shortcomings. Therefore, future interventions should combine stakeholder-specific education and training with improved resource access, transport facilities, financial incentives, regulatory enforcement, and institutional support. Particular attention should be given to RPC pluckers by aligning payment systems with leaf quality, strengthening personalised extension services, and promoting quality-based rewards throughout the tea supply chain.

The findings indicate that GLQS adoption among RPC estate tea pluckers is strongly associated with positive attitudes and access to extension services and training. Experience in tea cultivation and supportive policies also contribute significantly. However, the negative relationship between resource access and adoption suggests possible inefficiencies or mismatches requiring further investigation. Strengthening extension programmes, fostering favourable attitudes, ensuring supportive policies, and improving the effective use of resources are therefore essential for sustainable GLQS adoption practices.

The findings demonstrate that GLQS adoption among smallholder farmers is primarily driven by positive attitudes, extension services, training, and cultivation experience. However, the negative association with resource access indicates potential inefficiencies in resource allocation and utilisation. Therefore, strengthening targeted extension programmes, improving stakeholder motivation, and aligning resources with GLQS requirements are essential for enhancing adoption and ensuring sustainable production of high-quality green tea leaves.

At the dealer level, GLQS adoption is primarily determined by positive attitudes, tea-sector experience, and access to extension and training services. Therefore, targeted capacity-building and motivational interventions are essential to strengthen dealers' engagement in promoting leaf quality

throughout the tea supply chain. However, these findings should be interpreted cautiously due to potential model overfitting.

At the factory-officer level, GLQS adoption is primarily driven by tea manufacturing experience and positive attitudes, supported by access to extension services, training, and peer influence. Therefore, targeted capacity-building, peer-learning, and motivational strategies should prioritise experienced factory officers, while policy implementation barriers should be addressed to strengthen their role in advancing GLQS practices.

Across stakeholder groups of studied, inadequate awareness and education, high compliance costs, limited resources, regulatory complexity, and resistance to change are the key barriers to GLQS adoption. Therefore, implementation strategies should prioritise stakeholder education, affordable compliance mechanisms, improved resource access, simplified regulations, and change-management support. Addressing these interconnected barriers through stakeholder-specific interventions is essential for strengthening sustainable GLQS adoption across the tea supply chain.

Major Findings at Glance

GLQS adoption remains critically low across the tea supply chain, ranging from 20.75% among RPC pluckers to 22.84% among factory officers. This indicates a systemic implementation failure rather than weaknesses within a single stakeholder group. Adoption is primarily influenced by stakeholder attitudes, experience, extension and training access, peer support, and effective resource utilisation. Inadequate awareness, high compliance costs, limited resources, regulatory complexity, and resistance to change further restrict adoption. Post-harvest damage also increases from 16.97% at plucking to 46.71% at the withering trough, with transportation causing the greatest deterioration. Therefore, GLQS improvement requires an integrated policy approach covering production, collection, transportation, and factory handling.

Implications for Policy and Practice

Establish a coordinated national GLQS implementation framework covering all supply-chain stakeholders.

Introduce quality-based payment and incentive systems, particularly for RPC pluckers and smallholders.

Strengthen stakeholder-specific extension,

The findings of this study carry several practical implications for the Sri Lanka Tea Board, Regional Plantation Companies, tea factory management, and development sector actors engaged in supporting the Sri Lankan tea industry.

For the Sri Lanka Tea Board, the most actionable implication concerns the redesign and intensification of the extension service delivery model. Given that access to extension services is a

significant predictor of adoption across all four stakeholder groups, scaling the reach and quality of training programmes - particularly for RPC pluckers who have the least access to individualised extension contact - should be a first-order policy priority. Programmes modelled on farmer field school methodologies, which have been shown to be effective in the Sri Lankan tea smallholder context (Amarathunga et al., 2023), offer a proven starting point.

For Regional Plantation Companies, the finding that pluckers' adoption rates are lowest despite their operating within a formal and regulated employment structure suggests that the piece-rate payment system creates a structural disincentive to quality compliance. Exploring incentive structures that reward quality alongside quantity (e.g., premium bonuses for verified GLQS-compliant plucking) could substantially shift attitudinal orientation among this group.

For dealers, the critical role of the transport phase in damage accumulation suggests that investment in approved transport vehicles potentially through subsidised financing arrangements or cooperative procurement would have the highest impact on post-harvest damage reduction. The Sri Lanka Tea Board, in collaboration with factory owners and financial institutions, should explore mechanisms to make such investment economically accessible to small and medium-scale dealers.

For factory officers and factory management, the finding that peer influence is a significant predictor of factory officer adoption suggests that structured quality management circles or peer-mentoring arrangements within factories could enhance adoption and internal accountability for GLQS compliance. Strengthening factory officer empowerment to enforce incoming-leaf standards rigorously backed by clear institutional support from factory management would additionally create upstream incentives for dealer and smallholder compliance.

Additional Declarations

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