Paper I: National Tea Production Decline: Evidence Based Analysis

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A steady and progressive decline in the national tea production has been observed in comparison to that of in other major tea producing countries. The production decline, particularly since 2013 was a common concern of the stakeholder experts and professionals besides, the national target set to be increased from the present level of 299,339 Mn kg (2021) to 360 Mn kg in 2025 with about 61 Mn kg increase in the next five years. In this context, investigations were undertaken by the Tea Research Institute with the objectives of (i) finding out the evidences for the tea national tea production decline since 2013, (ii) to identify possible reasons and (iii) to recommend appropriate interventions to arrest the situation in view of sustaining the industry. Probable factors and relevant data from published documents, records, sample survey, advisory reports and stakeholder views were used in the investigation. Statistical analysis was performed using appropriate statistical tools wherever necessary.

The following key observations have been made as attributed to the national production decline since 2013: Changes of tea production in the Low country more towards national tea production where major fraction of the production was from smallholdings (SH) in the low country region; Continuous production decline observed in the Regional Plantation Companies (RPC) sector since early 2000 and in the smallholding and corporate sectors since 2013; Comparison of tea production between two periods (before and after 2013) in terms of Compound Annual Growth Rate (CAGR) showing a clear decline both in RPC and SH sectors out of which a severe decline being evident in the low country region.

Other major contributory factors were: Aging of tea bushes, bush debilitation, lack of replanting and infilling, worker scarcity, soil degradation, low adoption of important good agricultural practices, erratic weather and policy changes with respect to agriculture inputs. Accordingly, short, medium and long term recommendations are made in order to arrest the national tea production decline. The short term interventions include awareness and training, mechanization, adoption of GAPs & monitoring and evaluation while medium and long term interventions proposed are restoration of soil fertility, planting shade and green manure, infilling and consolidation, precision tea farming, irrigation, alternative worker deployment models, analyze and reorganize the supply chain and replant with appropriate tea cultivars.

Paper II: Soil Conservation in Tea Lands Affected by Water - Induced Erosion

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Declining tea production is one of the emerging issues in Sri Lanka tea industry at present where several contributory factors have been identified. Declining soil fertility due to soil erosion has been identified as one of the factors as soil erosion leads to the loss of top soil with costly plant nutrients that are largely externally supplied. The situation has been aggravated since the recent past as a result of climate change. Implementation of soil conservation measures is a prerequisite for improving soil fertility arresting soil erosion. In this context, effectiveness of different soil conservation measures on soil erosion and land productivity under present climatic conditions is of timely requirement. Therefore, a field experiment was conducted to quantify reduction of soil and nutrient losses by soil conservation practices and to recommend most appropriate soil conservation practices for tea lands.

As experiment was conducted at Kenilworth Estate, Ginigathena at mid elevation during October 2020 November 2021 covering 2 Monsoon and 2 Inter Monsoon seasons, with five treatments viz. terrace, terrace with vetiver grass, terrace wall, tea land (without conservation) and bare land (without vegetation and conservation) and two slope levels i.e. high (60% - 72% slope) and low (20% - 30 slope). The results indicated that, out of the soil conservation measures tested, terrace with vetiver grass (TV) and terrace wall (TW) have significantly reduced runoff, soil loss and nutrient loss compared with tea without conservation measures. Runoff reduction was found to be 80% and 68% in TV and TW respectively. These soil conservation practices also reduced soil losses by 78% and 68% respectively indicating that saving nutrients in tea lands is more beneficial to reduce fertilizer cost. The results also showed that more than half of the quantity of plant nutrients lost by runoff water can be retained in soil if appropriate soil conservation measures are properly adopted. Establishment of terrace with vetiver grass was found to be the best conservation practice. Results further emphasized the importance of covering the vacant patches in tea field with grasses or cover crop species to avoid direct exposure of the land to rainfall with a view to minimize soil erosion.

Paper III: Carbon Mineralization Dynamics of Organic Materials and Their Usage in Restoration of Degraded Tea Soils

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Soil restoration has become a mandatory practice in tropical agricultural soils, particularly in hilly rainfed areas frequently cultivated with tea. Understanding carbon mineralization dynamics of organic amendments is essential to implement soil restoration measures at a low cost. This study was conducted focusing on the restoration potentials of tea growing soils using organic materials available in tea growing ecosystems *viz.* Gliricidia leaves, tea waste, biochar using tea waste, charged biochar and compost. Two soils with different organic carbon levels were incubated with the organic materials at 0.5 g carbon (C)/100 g rate under warm tropical conditions and released carbon dioxide (CO_2) was measured in elapsed time. Two kinetic models were applied to depict the mineralization process. Microbial biomass carbon and nitrogen, dehydrogenase and catalase activities were measured. The parallel first-order kinetic model fitted well for C mineralization kinetics for all the amendments showing 2 distinct mineralization stages.

Gliricidia leaves markedly enhanced the net cumulative CO_2 emission in both high carbon and low carbon soils showing a rapid decomposition amounting to 15,807 and 12,305 mg kg^{-1} soil, respectively. Biochar showed minimal C mineralization of 3198 and 1505 mg kg^{-1} respectively in high carbon and low carbon soils also not significantly different from the untreated soil. Considering first-order kinetics, decomposition rates varied in the order of Gliricidia leaves> tea waste> charged biochar> compost> biochar for high carbon soil however for low carbon soil, the highest was tea waste followed by Gliricidia leaves. Charged biochar, tea waste and Gliricidia leaves improved the soil microbial biomass C by 83, 79 and 84% in high carbon soil and 93, 82 and 93% in low carbon soil respectively and over 70% increment in microbial biomass nitrogen in both soils.

Soil microbial quotient was increased by 53-92% in both soils. Dehydrogenase activity was significantly accelerated in compost, charged biochar and tea waste by 158, 130, 59% in high carbon soil and by 213, 264, 476% in low carbon soil compared to the untreated soils. The addition of charged biochar remarkably increased the soil catalase activity by 141% over the

untreated soils. Nitrogen mineralization was greater in Gliricidia leaves amended tea soil amounting to 94% of added N therein particularly in low carbon soil. Results suggest that the Gliricidia leaves amendment has short-term effects on soil C improvement due to its faster mineralization. Biochar alone poorly contributed to improve soil health for a shorter period therefore, enrichment of biochar with nutrients is required. Charged biochar has benefits in terms of C sequestration and restoration of degraded tea growing lands.