Introduction and Focus

Sri Lanka has become the second in the Climate Risk Index 2018.

Greenhouse gas $\rightarrow$ Global warming

- Concentrations of CO$_2$ : The highest peak in 61 years recorded in May 2019

- Temperature

- Rainfall pattern

- Climate Change (CC) influences many sectors of the Sri Lankan economy including plantation agriculture

$\rightarrow$ Extreme weather events.

- Heavy Rainfall
- Severe drought

Take place when least expected
2nd Place in Global Climate Risk Index

Calculated annually

Based on the most reliable data sets

Direct impacts of extreme weather related events:
- storms
- floods
- heat waves etc

& associated socio-economic data

Global atmospheric carbon dioxide concentrations spike every April or May. In 2019 the spike was bigger than usual. Dashed red = monthly mean values; Black line shows the same data after the seasonal effects have been averaged out.

Credit: NOAA.

<table>
<thead>
<tr>
<th>Period</th>
<th>Average increase of CO₂ per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early 1980s</td>
<td>0.6 ± 0.1 ppm</td>
</tr>
<tr>
<td>Last 10 years</td>
<td>2.3 ± 0.6 ppm</td>
</tr>
<tr>
<td>2015 - 2016</td>
<td>3.5 ± 0.1 ppm</td>
</tr>
</tbody>
</table>
Sri Lanka recorded the hottest weather in April 2019
Apr 12, 2019 ColomboPage
News Desk, Sri Lanka.

COLOMBO (News 1st):
The water bodies located around the hydro-power plants recorded the lowest water level in 29 years.
13 Jul, 2019

COLOMBO (News 1st):
Severe drought in some areas; livestock deaths reported
02 Jun, 2019

Colombo (News1st) –
Prevailing windy conditions over the country and surrounding sea areas and showery condition over the island are likely to continue today.
19 Jul, 2019

Daily news
Landslides in Ginigathhena
19 July 2019
➢ Being a rain-fed plantation crop, grown in different elevations & terrains, tea is highly vulnerable to CC.

➢ Impacts of CC vary in different tea growing regions.

➢ Soil quality/fertility can be further deteriorated under CC due to increased soil erosion and burning of soil carbon etc.

→ Other environmental problems eg. Eutrophication

➢ CC affects on the quality of tea in different tea growing regions.

➢ Levels of pest and disease infestations may vary in different regions & new pests/diseases out-breaks are possible under CC.

Sri Lankan tea industry is at a risk
Effects of Rainfall on tea yield

<table>
<thead>
<tr>
<th>Agro Ecological Region</th>
<th>Optimum Rainfall (mm/month)</th>
<th>Loss of tea yield (kg/ha/month/100 mm RF deficit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>350±20</td>
<td>29±3</td>
</tr>
<tr>
<td>WM</td>
<td>417±49</td>
<td>36±6</td>
</tr>
<tr>
<td>WU</td>
<td>223±38</td>
<td>55±7</td>
</tr>
<tr>
<td>IM</td>
<td>227±10</td>
<td>81±11</td>
</tr>
<tr>
<td>IU</td>
<td>303±34</td>
<td>39±3</td>
</tr>
</tbody>
</table>

± Standard Error of mean (Wijeratne et al., 2007)

Optimum rainfall vary from 223-417 mm/month

The drought impacts are in the range of 29-81 kg/ha/month/100mm RF deficit

Predictions related to tea plantations

<table>
<thead>
<tr>
<th>Baseline &amp; GCMs</th>
<th>Yield Projections for the year 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratnapura(WL)</td>
</tr>
<tr>
<td></td>
<td>Low Grown</td>
</tr>
<tr>
<td>Baseline</td>
<td>2489</td>
</tr>
<tr>
<td>HadCM3-A1F1</td>
<td>2348</td>
</tr>
<tr>
<td>HadCM-B1</td>
<td>2419</td>
</tr>
<tr>
<td>CGCM-A1F1</td>
<td>2314</td>
</tr>
<tr>
<td>CGCM-B1</td>
<td>2380</td>
</tr>
<tr>
<td>CSIRO-A1F1</td>
<td>2401</td>
</tr>
<tr>
<td>CSIRO-B1</td>
<td>2472</td>
</tr>
</tbody>
</table>

(Wijeratne et al., 2007)

CC - Multifactorial phenomenon
Model predictions of the SDGVM according to A1F1 scenario:

(Wijeratne et al., 2011)
Impacts of climate change on the long-term tea yields during the 21st century

How to overcome the challenges of CC

Good Agricultural Practices

introduced by the TRI for improving soil and micro-climate in tea plantations to minimize adverse impacts & sustain productivity of tea lands

Mitigation Measures

Adaptation Measures
Adaptation Measures

1. Proper land selection and utilization

2. Proper cultivar selection
   - Drought/Heat/Flood/Pest/Disease tolerant cultivars
   - Poly- or bi- clonal seedling tea for drought prone areas
   - Graft combinations

3. Management Options
   a) Drought management package
      (Anandacoomaraswamy, 1997)
   b) Experiments are in progress to increase the climate resilience of tea cultivars

   c) Improvement of Arial Environment
      Proper establishment and management of shade trees
d) Irrigation

e) Mulching/cover crops

Use of artificial mulch for soil moisture retention

(Bandara et al., 2016)

f) Rain water harvesting

4. Improvement of soil

- Increasing soil organic matter content
- Soil & moisture conservation
- Site specific fertilizer recommendation
- Slow release fertilizer
- Biofilm biofertilizer for nursery: 50 % reduction of fertilizer usage (De Silva et al., 2014)
- Beneficial microbial inoculants: reduce the use of fertilizer by one-third (Tennakoon et al., 2016)
CC vulnerability map for tea in Sri Lanka

Vulnerability indices were developed using Rainfall, Temperature and soil data

**Highly Vulnerable areas:**
WL1a, WL1b, WL2a, WM2a, WM2b, WM3a, IM2b, IM3a and IM3c

**Vulnerable areas:**
WM1a, WM1b, WM3b, IM1a, IM2a, IU3a, IU3d and IU3e

Proper adaptation and mitigation practices to minimize the possible negative impacts

(Wijeratne and Chandrapala, 2014)

Growing tea only in most suitable lands

Extent of Tea Plantation by District

National Level

Tea Research Institute of Sri Lanka
Diversification of marginal lands to other uses

- Intercropping
- Mixed cropping
- Timber plantations
- Energy plantations
- Infilling vacancies
- Thatch banks

Drought Susceptibility Index DSI

Using the physiological parameters such as net photosynthesis rate and relative water content with known cultivars DSI was developed and tested successfully \((\text{Damayanthi et al., 2010})\)

Facilitates early detection of drought susceptible/tolerant cultivars \((\text{Damayanthi et al., 2017})\)
**Use of climate resilient cultivars**

Based on C & N stocks and drought tolerance ability accession 199, cultivar TRI2025 and DN can be recommended for future tropical climates such as Uva upon fulfilment of other factors such biotic stress tolerance and better quality etc.

*(Wijeratne et al., 2018)*

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**• Development of graft combinations**

Successful graft combinations for drought (Cultivar/Cultivar)

- TRI 2023 on CY 9
- TRI 2026 on DN
- TRI 4046 on DN
- TRI 4052 on DN

Evaluation of cultivar/seedling combinations (Cultivar/Seedling)

- TRI 4053 on Sapumalkanda seedlings

**• Development of by- and poly-clonal seedling tea for drought prone areas**

- Development of new tea cultivars through controlled hybridization for biotic and abiotic stress tolerance is in progress

*(Anon, 2017)*
Soil conservation & improvements

Soil conservation

Soil improvement
(Burying of pruning, green manure & compost applications etc)

CC Mitigation: C sequestration & C balance

• Preliminary investigations showed a negative C balance in Sri Lankan tea industry (De Costa et al., 2008)

<table>
<thead>
<tr>
<th>Region</th>
<th>C absorption (Mg/yr)</th>
<th>C emission (Mg/yr)</th>
<th>C balance (Mg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Grown</td>
<td>1.426</td>
<td>0.677</td>
<td>-0.749</td>
</tr>
<tr>
<td>Mid Grown</td>
<td>1.278</td>
<td>0.334</td>
<td>-0.944</td>
</tr>
<tr>
<td>High Grown</td>
<td>0.874</td>
<td>0.430</td>
<td>-0.444</td>
</tr>
</tbody>
</table>

Based on assumptions

This finding created detailed investigations of CO₂ sequestration & emission studies on tea plantations in Sri Lanka

(De Costa et al., 2015)
Tea Plantation Community + Soil = Tea Ecosystem

- High Shade
- Medium Shade
- Tea plants
- Soil

Ecosystem

Detailed investigations on C sequestration potential of tea plantations
C sequestration potential at community level considering tea, HS and MS biomass C stocks all three tea growing regions both seedling and VP tea

Summary findings of the project

• C Sequestration potential
   Seedling tea > VP tea
   Substantially increase with the compliance of TRI recommendations →
    incorporation of shade trees, proper spacing, better management etc
   Varies in million Mg/yr of CO\textsubscript{2} equivalents as →

\[
\begin{array}{ccc}
\text{High Grown} & \text{Mid Grown} & \text{Low Grown} \\
0.37 & < & 1.03 < 2.81 \\
\end{array}
\]

(Wijeratne et al., 2014a)

Carbon sequestration potential of tea plantations

Incorporation of shade trees i.e. High Shade (HS) and Medium Shade (MS), increases the C sequestration potential of the community of tea plantations tremendously

(Wijeratne et al., 2014b)
Detailed investigation on CO₂ emissions

Soil CO₂ emission (soil respiration) was measured using Anderson method (1982).

Data collection over a natural moisture gradient

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Data collection in all major tea growing soil series

1. High Grown: Maskeliya, Mattakelle & Nuwara Eliya
2. Mid Grown: Kandy, Ukuwella
3. Low Grown: Weddagala, Pallegoda & Dodangoda

Soil series selected with the assistance of Head, SPND, TRI

Soil Organic Carbon
Soil Bulk Density
Soil Moisture
Soil Temperature
Soil pH

Expected to quantify the soil CO₂ emissions and develop GHG inventory under the Cropland remaining Cropland for the category of Agriculture Forest and Other Land Use (AFOLU) sector

Tea Research Institute of Sri Lanka
Summary of early findings

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean Soil Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Grown</td>
<td>20.6 ± 0.2</td>
</tr>
<tr>
<td>Mid Grown</td>
<td>23.3 ± 0.1</td>
</tr>
<tr>
<td>Low Grown</td>
<td>29.2 ± 0.3</td>
</tr>
</tbody>
</table>

Correlations of Soil Respiration

Vs Soil Moisture content
Vs Soil Organic Carbon Content

Provisional C budget for tea plantations

CO₂ sequestration data were taken from Wijeratne et al., 2014

C budget = CO₂ (emissions – absorption) from tea ecosystem

<table>
<thead>
<tr>
<th>Tea Growing Region</th>
<th>Soil Series</th>
<th>CO₂ emissions (Mg of CO₂/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Grown</td>
<td>Mattakelle</td>
<td>2.66</td>
</tr>
<tr>
<td>Mid Grown</td>
<td>Kandy</td>
<td>6.79</td>
</tr>
<tr>
<td>Low Grown</td>
<td>Pallegoda</td>
<td>7.17</td>
</tr>
</tbody>
</table>
Incorporation of shade trees i.e. High Shade (HS) and Medium Shade (MS) makes the C budget of the tea plantations more and more negative, i.e. tea plantations become more and more climate positive.

Summary

Tea plantations are highly vulnerable to the negative effects of climate change.

Impacts of climate change will be more and more severe in future.

It is necessary to follow good agricultural practices and take timely precautions to overcome these emerging challenges.

New tea plantations to be initiated only at best suitable lands following proper adaptation practices.

Proper establishment and management of shade trees in tea plantations is a must.

Policy makers should be influenced to explore potentials to tackle new markets such as “Payments for Environmental Services” for the sustainability of the tea industry.
References


To be continued in next slide


Acknowledgement

- Management & staff of:
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  - Courtlodge Estate,
  - Park Estate,
  - Radella Estate,
  - St. Clair Estate,
  - Maussakellei Estate,
  - Hapugastenne Estate (Maskeliya),
  - Laxapana Estate,
  - Craighead Estate,
  - Elkaduwa Estate,
  - Talgaswella Estate,
  - Hapugastenne Estate (Gallalla),
  - Ury Estate,
  - St. Joachim Estate and St. Coombs Estate
- Staff of the TRI regional centres of mid country & low country,
- Staff of the TRI extension centres of Kottawa, Deniyaya and Passara
- Head, SPND, TRI

Thank you