Climate Warming and Natural Rubber Productivity

James Jacob, P. R. Satheesh and D. Ray
Rubber Research Institute of India, Kottayam, Kerala
james@rubberboard.org.in
Session Outline

1. Introduction

2. Has climate changed in the NR belt in the country?

3. How did these changes impact NR productivity in the past?

4. What is in store for future?

5. Geo-informatics and Ecological Niche Modeling

6. Are trees the answer to global warming?
1. Introduction
Emissions $\rightarrow$ climate change: Blame it on economic development

Energy (Fossil fuel)

$E^3$ vicious cycle

CO2 Emissions

Economic Development

Climate Change

Productivity
\[ \text{Profit} = f(\downarrow \text{COP}, \uparrow \text{Market Price}) \]

\[ \downarrow \text{COP} = \frac{\downarrow \text{Cost}}{\uparrow \text{Productivity}} \]
2. Has climate changed in the NR producing regions?
Rainfall during November 2010 at Kottayam (374/212)

\[ y = 0.0814x - 150.53 \]

\[ R^2 = 0.0001 \]
Rainy days/month during November 2010 at Kottayam (22/14)

$y = 0.0249x - 49.129$

$R^2 = 0.0062$
Sunshine hours per day during November 2010 at Kottayam (3.3/6.2)

\[ y = -0.0507x + 100.93 \]

\[ R^2 = 0.3391 \]
Temperature Max.
RRII Met. Observatory (1956-2008)

$y = 0.0471x - 0.931$

$R^2 = 0.64$

Years
Deviation in Temp. (°C)

5 per. Mov. Avg. (Tmax.)
Temperature Min.
RRII Met. Observatory (1956-2008)

\[ y = 0.03x - 0.7798 \]

\[ R^2 = 0.30 \]
Tmin at Kottayam

1957-1961 Mean

2005-2009 Mean
Frequency of warm nights (>24.3 °C) has increased in Kottayam between 1956 and 2007.

\[ y = 0.9791x + 18.226 \]
Frequency of hot days (>32°C) has increased in Kottyam between 1956-2007

\[ y = 2.7762x + 57.527 \]
RRII Annual Rainfall (1971-2008)

Deviation in Rainfall (mm)

Above average 8
Below average 11

Above average 10
Below average 9

\[ y = -3.5x + 6895.7 \]
\[ R^2 = 0.007 \]

\[ y = -42.32x + 84568 \]
\[ R^2 = 0.22 \]
In RRII campus at Kottayam, during the last 50 years:

Tmax. increased by 2.6 °C

Tmin. increased by 1.5 °C

Annual rainfall decreased by 375 mm
## Long term temperature trends

<table>
<thead>
<tr>
<th>STATION</th>
<th>PERIOD</th>
<th>TEMPERATURE</th>
<th>MEAN</th>
<th>RATE/YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TURA (Meghalaya)</td>
<td>1995-2008</td>
<td>Tmax</td>
<td>29.3</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tmin</td>
<td>16.9</td>
<td>0.05</td>
</tr>
<tr>
<td>AGARTHALA (Tripura)</td>
<td>1984-2007</td>
<td>Tmax</td>
<td>30.6</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tmin</td>
<td>19.9</td>
<td>0.06</td>
</tr>
<tr>
<td>PADIYOOR (Kannur, Kerala)</td>
<td>1998-2009</td>
<td>Tmax</td>
<td>32.8</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tmin</td>
<td>21.8</td>
<td>0.11</td>
</tr>
<tr>
<td>DAPCHARI (Thane, Maha.)</td>
<td>1986-2009</td>
<td>Tmax</td>
<td>33.2</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tmin</td>
<td>20.6</td>
<td>0.03</td>
</tr>
<tr>
<td>KOTTAYAM (Kerala)</td>
<td>1956-2009</td>
<td>Tmax</td>
<td>31.2</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tmin</td>
<td>22.7</td>
<td>0.03</td>
</tr>
</tbody>
</table>
3. How did these changes impact NR productivity in the past?
Associated changes in weather

Rising temperature

Girth

Management of plantations

YIELD

Pests & Diseases

Human Health
\( y = f \text{ (weather variables)} \)

- Mean annual yield was estimated as the average g/t/t for 3-13 years from 10 locations in different agro-climatic regions and used as the \( y \) variable.
- Mean weather data, estimated from long term meteorological data (10-53 years) for these different locations were used as independent variables (\( x \)).
- The different independent variables were:
  1. Mean Annual temperature (\( \text{Tann} \))
  2. Mean Annual maximum temperature (\( \text{Tmax} \))
  3. Mean Annual minimum temperature (\( \text{Tmin} \))
  4. Mean annual rainfall (\( \text{RF} \))
  5. Mean number of annual rainy days (\( \text{RFday} \))
Backward Multiple Linear Regression (MLR) was done ((SPSS-Statistical Package for the Social Sciences (now PASW-Predictive Analytics Software) using g/t/t as the y-variable and the five x-variables (Tann, Tmax, Tmin, RF and RFday))
The MLR models obtained for the individual regions for all clones together:

\[ Y = 433.43 - 7.87T_{\text{max}} - 4.83T_{\text{min}} \text{ (CES)} \]

\[ Y = 171.01 - 2.54T_{\text{max}} - 1.71T_{\text{min}} \text{ (Padiyoor)} \]

\[ Y = 204.98 - 1.01T_{\text{max}} - 5.51T_{\text{min}} \text{ (Dapchari)} \]

\[ Y = 41.25 + 0.67T_{\text{max}} - 1.13T_{\text{min}} \text{ (Agarthala)} \]

\[ Y = -24.85 + 3.58T_{\text{max}} - 2.59T_{\text{min}} \text{ (Tura)} \]
<table>
<thead>
<tr>
<th>Location</th>
<th>Year Range</th>
<th>MLR Coeff.</th>
<th>MLR Intercept</th>
<th>R²</th>
<th>% Change (for 1°C rise)</th>
<th>% Change (for next 10 year)</th>
<th>g/t/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>TURA</td>
<td>2003-08</td>
<td>Tx: 3.58</td>
<td>-24.85</td>
<td>0.23</td>
<td>2.72</td>
<td>11.25</td>
<td>35.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tn: -2.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGARTHALA</td>
<td>2003-08</td>
<td>Tx: 0.67</td>
<td>41.25</td>
<td>0.07</td>
<td>-1.17</td>
<td>-1.10</td>
<td>37.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tn: -1.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PADIYOOR</td>
<td>2007-08</td>
<td>Tx: -2.54</td>
<td>171.01</td>
<td>0.19</td>
<td>-8.72</td>
<td>-4.23</td>
<td>48.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tn: -1.71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAPCHARI</td>
<td>2007-08</td>
<td>Tx: -1.01</td>
<td>204.98</td>
<td>0.50</td>
<td>-11.25</td>
<td>-3.70</td>
<td>57.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tn: -5.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CES</td>
<td>2003-08</td>
<td>Tx: -7.87</td>
<td>433.43</td>
<td>0.29</td>
<td>-16.23</td>
<td>-6.90</td>
<td>73.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tn: -4.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Field Productivity (Kg/ha/yr)

<table>
<thead>
<tr>
<th>YEARS AND CLONES</th>
<th>MLR</th>
<th>% Change (for 1°C rise)</th>
<th>y/ha (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>Intercept</td>
<td>R²</td>
</tr>
<tr>
<td>Kottayam 2008-09</td>
<td>Tx</td>
<td>-6.14</td>
<td>999.53</td>
</tr>
<tr>
<td></td>
<td>Tn</td>
<td>-27.68</td>
<td></td>
</tr>
<tr>
<td>Thaliparamba 2008-09</td>
<td>Tx</td>
<td>6.14</td>
<td>-7.30</td>
</tr>
<tr>
<td></td>
<td>Tn</td>
<td>-1.37</td>
<td></td>
</tr>
<tr>
<td>Kanjirapally 2008-09</td>
<td>Tx</td>
<td>-11.33</td>
<td>789.36</td>
</tr>
<tr>
<td></td>
<td>Tn</td>
<td>-12.68</td>
<td></td>
</tr>
</tbody>
</table>
Estimated % reduction in rubber yield for every degree rise in temperature from the present (Direct effect only)
Productivity of RRII 105 (g/t/t) decreased over time under experimental conditions.

<table>
<thead>
<tr>
<th>1980s</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;55 to 60</td>
<td>&lt;55</td>
</tr>
</tbody>
</table>

Field productivity of NR increased substantially in the past.
4. What is in store for future?
### Future trends in NR productivity

<table>
<thead>
<tr>
<th>STATION</th>
<th>% Change in next decade</th>
<th>RATE/YEAR (degrees C/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TURA (Meghalaya)</td>
<td>11.3</td>
<td>0.15</td>
</tr>
<tr>
<td>AGARTHALA (Tripura)</td>
<td>-1.1</td>
<td>0.02</td>
</tr>
<tr>
<td>PADIYOOR (Kannur, Kerala)</td>
<td>-4.2</td>
<td>0.01</td>
</tr>
<tr>
<td>DAPCHARI (Thane, Maha.)</td>
<td>-3.7</td>
<td>0.08</td>
</tr>
<tr>
<td>KOTTAYAM (Kerala)</td>
<td>-6.9</td>
<td>0.05</td>
</tr>
</tbody>
</table>
• In the next ten years, NR productivity in India can go down by 5.6% in the traditional regions and by 3.7% in the dry and hot non-traditional regions as a result of warming conditions.

• But in the NE region, which is also a non-traditional region, productivity may go up in the next decade.
NR in NE India 2012
(Maxent model)

NR in NE India 2050
(Maxnet model)
Present NR distribution in South India.

South Kerala appears to be better niche for NR in South India (Mexent model)
NR Distribution in Brazil

Sierra Leone

Cameroon
5. Geo-informatics and Ecological Niche Modeling
Established GIS facility to map rubber distribution for traditional area using remote sensing and bring in all the information related to rubber for meaningful analysis, visualization and interpretation. Red colour indicates all vegetation types (including rubber). Vegetation types are not classified in this picture.
Comparison of satellite based rubber area with ground statistics

<table>
<thead>
<tr>
<th>District</th>
<th>Ground survey statistics ( ha) (2005 - 06)</th>
<th>Satellite based rubber area ( ha)</th>
<th>Variation Compared to ground survey statistics (%)</th>
<th>% of geographical area under rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiruvananthapuram</td>
<td>30 009</td>
<td>27 527.23</td>
<td>-8.27</td>
<td>12.61</td>
</tr>
<tr>
<td>Kollam</td>
<td>35 665</td>
<td>37 271.97</td>
<td>4.50</td>
<td>14.96</td>
</tr>
<tr>
<td>Pathanamthitta</td>
<td>49 551</td>
<td>51 766.25</td>
<td>4.47</td>
<td>20.54</td>
</tr>
<tr>
<td>Alapuzha</td>
<td>3 934</td>
<td>5 770.57</td>
<td>46.68</td>
<td>3.74</td>
</tr>
<tr>
<td>Kottayam</td>
<td>1 11 635</td>
<td>1 06 793.22</td>
<td>-4.33</td>
<td>48.19</td>
</tr>
<tr>
<td>Idukki</td>
<td>38 844</td>
<td>37 103.46</td>
<td>-4.48</td>
<td>7.39</td>
</tr>
<tr>
<td>Ernakulam</td>
<td>58 309</td>
<td>56 654.19</td>
<td>-1.10</td>
<td>23.58</td>
</tr>
<tr>
<td>Trissur</td>
<td>14 058</td>
<td>13 927.41</td>
<td>-0.92</td>
<td>4.59</td>
</tr>
<tr>
<td>Palakkad</td>
<td>31 952</td>
<td>28 420.82</td>
<td>-11.05</td>
<td>6.33</td>
</tr>
<tr>
<td>Malappuram</td>
<td>32 588</td>
<td>36 633.61</td>
<td>12.41</td>
<td>10.30</td>
</tr>
<tr>
<td>Kozhikkode</td>
<td>18 237</td>
<td>18 751.59</td>
<td>2.821</td>
<td>7.96</td>
</tr>
<tr>
<td>Wyanad</td>
<td>7 777</td>
<td>8 976.98</td>
<td>15.42</td>
<td>4.21</td>
</tr>
<tr>
<td>Kannur</td>
<td>38 366</td>
<td>49 477.40</td>
<td>28.96</td>
<td>16.74</td>
</tr>
<tr>
<td>Kasargod</td>
<td>25 374</td>
<td>20 052.69</td>
<td>-20.97</td>
<td>10.08</td>
</tr>
<tr>
<td>Kanniyakumari</td>
<td>18 225</td>
<td>20 781.71</td>
<td>14.02</td>
<td>12.36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5 14 524</strong></td>
<td><strong>5 19 909.10</strong></td>
<td><strong>1.04</strong></td>
<td><strong>12.28</strong></td>
</tr>
</tbody>
</table>
6. Are trees the answer to global warming?
CO₂ sequestration potential of five years old plants calculated from Eddy Covariance System

CO₂ Flux (March 2009 - March 2010)

3350 gm/m²/year = 33.5 ton CO₂/ha/year
Atmospheric CO$_2$ Concentration (ppm)

$y = 2.0956x - 3822.1$

$R^2 = 0.9976$
Taking a modest rate of $25 \text{ T CO}_2 / \text{ ha / year}$, world’s 10.5 m ha of natural rubber plantations help to offset the current rate of build up of CO$_2$ in the atmosphere to the tune of 1.6%.

*Natural rubber provide invaluable ecosystem services to humanity that should not go unappreciated.*
NR plantations in India sequester about 20 million ton CO$_2$ every year which is roughly 1.3% of the annual emissions from fossil fuels in the country!
<table>
<thead>
<tr>
<th>(Gt C/yr)</th>
<th>1980s</th>
<th>1990s</th>
<th>2000-2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission</td>
<td>5.4</td>
<td>6.4</td>
<td>7.2</td>
</tr>
<tr>
<td>Ocean fixation</td>
<td>1.8</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Land fixation</td>
<td>0.3</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Net addition to atmosphere</td>
<td>3.3</td>
<td>3.2</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Total terrestrial vegetation area: 15000 m ha
Current fixation: 3303 m MT CO2
Fixation rate: $220 \times 10^{-9}$ m MT CO2/ha/yr
Net addition to atmosphere: 10151 m MT CO2
Required (additional) rate to offset this: 3.07 T CO/ha/yr
($0.9 + 3.07 = 3.97$ T CO2/ha/yr)
At the present rate of emission and rate of fixation by terrestrial vegetation, we need an additional land area of around 46141.0 m ha for planting trees so as to fully offset the current rate of increase in atmospheric CO2 concentration (1.30 ppm per year).

This is equal to the terrestrial vegetation area of three planets.
• Even if we take the sequestration capacity of the land and ocean together, we will still require one more additional planet to keep the atmospheric CO2 concentration stabilized at the present level.

• Further rise in concentration can be avoided by deliberate reduction in the amount of anthropogenic CO2 emission into the atmosphere and not by increasing sequestration alone.
Emission

Removal
In conclusion:

Warming conditions seem to have adversely affected NR productivity in the past and may mess up the shape of things to come.

NR productivity will be adversely affected in some places and stimulated in other places as climate warms in future.

Existing areas may become less congenial and new areas may become more favorable for NR cultivation as climate warms.

Geoinformatics and Ecological Niche Modeling help to predict how NR landscape may change as climate warms.

Further rise in atmospheric CO2 concentration can be avoided by deliberate reduction in the amount of anthropogenic CO2 emission into the atmosphere and not by increasing its removal by planting trees.
THANK YOU

james@rubberboard.org.in