Climate Impacts and Resilience in Caribbean Agriculture: Assessing the consequences of climate change on cocoa and tomato production in Trinidad & Tobago and Jamaica (CIRCA)

WP2 – Crop-Climate Suitability Modeling
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WP2 – Crop-Climate Suitability Modeling

• Introduction: CIAT - CCAFS
• Generation of climatological baseline through interpolation of weather station data
• Generation of future climate data
• Impact of climate change in tomato and cocoa crops using crop model Ecocrop
• Conclusions and way forward
CCAFS: the partnership! The largest global coalition of scientists working on developing-country agriculture and climate change

http://ccafs.cgiar.org
1. What is Climate Smart Agriculture?

The CSA Investment Prioritization Framework developed by CCAPs-CIAT helps identify existing and promising CSA practices, calculate and analyze the costs and benefits of these practices, and identify possible barriers to adoption. The Framework aims to contribute to optimized national and sub-national planning, promoting a participatory process for the development of CSA investment portfolios.

Long-Term Adaptation

Climate-smart agriculture combines policies on:

- Adaptation
- Food Security
- Mitigation

Phase 1: Assessment of Practices
- Selection of indicators of interest
- Weighting of pillars
- Assessment of practices based on indicators
- Data collection
- Methods: literature review, surveys, focus groups, interviews

Phase 2: Workshop #1: Identification of Top Options
- Validate objectives and indicators
- Revision of ranked list
- Visualization of tradeoffs
- Document barriers and constraints to implementing practices and ability to overcome barriers

Phase 3: Calculation of Costs and Benefits of CSA practices
- Data collection on costs/benefits
- Calculate C/B or C/E effectiveness of each option
- Identify synergies between practices

Phase 4: Workshop #2: CSA Portfolio Development
- Review results of costs/benefit analyses of practices
- Visualize & discuss CSA rankings - examination of trade-offs
- Selection of portfolio options
- Calculation of aggregated benefits

Output: Ranked long list of priority practices

Results
- Output: Short list of priority CSA practices and ranked list of practices based on CBA.

Portfolios of Prioritized CSA practices

Results
- Portfolios identified
- Constraints, barriers, and adoption strategies identified for an appropriate design of CSA Investment
Why is CSA important? – Food Security

Climate drives yield variation: our systems are sensitive to climate, not resilient to it.
CIRCA project: Methods & results
Interpolation of climate baseline

• The database of weather stations provided by the CIRCA project and quality control.
• The database STRM elevation of 30 arc-second resolution.
• Generate interpolated climate surfaces using ANUSPLIN-SPLINA with weather station data following methodology as described by Hijmans et al (2005)
What is WorldClim?

Stations by variable:
- 47,554 precipitation
- 24,542 tmean
- 14,835 tmax y tmin

Sources:
- GHCN
- FAOCLIM
- WMO
- CIAT
- R-Hydronet
- Redes nacionales
Station data received from UWI and cross-validation of interpolated monthly climate surfaces for monthly accumulated rainfall and maximum and minimum temperature.

Table 2. Exploratory analysis of maximum and minimum temperature data respectively for Trinidad and Tobago

| Station | Centeno | Crow Point | Piarco | St. Aug.
<table>
<thead>
<tr>
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<td>627.00</td>
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<td>29.07</td>
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<td>31.38</td>
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<tr>
<td>Q3</td>
<td>30.94</td>
<td>31.05</td>
<td>32.05</td>
<td>31.97</td>
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<td>0.99</td>
<td>0.76</td>
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<td>Median</td>
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<td>31.35</td>
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| Station | Centeno | Crow Point | Piarco | St. Aug.
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<td>627.00</td>
<td>504.00</td>
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<td>Median</td>
<td>21.71</td>
<td>23.94</td>
<td>22.82</td>
<td>21.98</td>
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Table 4. Exploratory analysis of maximum temperature data in Jamaica

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<tr>
<th>ID_Station</th>
<th>JAM01</th>
<th>JAM02</th>
<th>JAM03</th>
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<th>JAM05</th>
<th>JAM06</th>
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<th>JAM08</th>
<th>JAM09</th>
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<tr>
<td>Min</td>
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<td>26.90</td>
<td>27.50</td>
<td>28.20</td>
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<td>31.10</td>
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<td>30.60</td>
</tr>
<tr>
<td>Std. Desv</td>
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<td>1.24</td>
<td>1.32</td>
<td>1.39</td>
<td>1.12</td>
<td>1.10</td>
<td>1.26</td>
<td>1.32</td>
<td>0.92</td>
<td>1.53</td>
<td>1.34</td>
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<tr>
<td>Median</td>
<td>31.90</td>
<td>30.30</td>
<td>30.10</td>
<td>31.40</td>
<td>30.40</td>
<td>32.00</td>
<td>30.80</td>
<td>27.30</td>
<td>31.00</td>
<td>29.00</td>
<td>29.80</td>
</tr>
<tr>
<td>% NA</td>
<td>27.92</td>
<td>60.00</td>
<td>23.33</td>
<td>19.50</td>
<td>60.03</td>
<td>44.17</td>
<td>61.33</td>
<td>56.67</td>
<td>26.42</td>
<td>61.33</td>
<td>10.83</td>
</tr>
</tbody>
</table>
**Result:** monthly climate baseline

**Figure 4.** Climatic characteristics for wet (a) and dry (b) areas in Trinidad and Tobago respect to variables of precipitation (mm) and mean temperature (°C)

**Figure 6.** Climatic characteristics for wet (a) and dry (b) areas in Jamaica respect to variables of precipitation (mm) and mean temperature (°C)
Generation of future climate data: Circulation models from IPCC AR5

Delta method to downscale

Ramirez-Villegas J, Jarvis A (2010)
Downscaling Global Circulation Model Outputs: The Delta Method

Observe climate

Model climate
Suitability modeling with Ecocrop

EcoCrop, originally by Hijman et al. (2001), was further developed, providing calibration and evaluation procedures (Ramirez-Villegas et al. 2011).

How does it work?

It evaluates on monthly basis if there are adequate climatic conditions within a growing season for temperature and precipitation...

...and calculates the climatic suitability of the resulting interaction between rainfall and temperature...
For temperature suitability
Ktmp: absolute temperature that will kill the plant
Tmin: minimum average temperature at which the plant will grow
Topmin: minimum average temperature at which the plant will grow optimally
Topmax: maximum average temperature at which the plant will grow optimally
Tmax: maximum average temperature at which the plant will cease to grow

For rainfall suitability
Rmin: minimum rainfall (mm) during the growing season
Ropmin: optimal minimum rainfall (mm) during the growing season
Ropmax: optimal maximum rainfall (mm) during the growing season
Rmax: maximum rainfall (mm) during the growing season

Length of the growing season
Gmin: minimum days of growing season
Gmax: maximum days of growing season

\[ T_{\text{kill}} = 4 + T_{\text{kill}}(\text{initial}) \]

\[ T_{\text{suit}} = 100 \]

\[ \frac{T(T) - T_{\text{min}}}{T_{\text{opmin}} - T_{\text{min}}} = T_{\text{suit}} \]

\[ 1 - \frac{T(T) - T_{\text{opmax}}}{T_{\text{max}} - T_{\text{opmax}}} = T_{\text{suit}} \]

\[ T_{\text{suit}} = 0 \]
The results can be seen through the maps:

**TSUIT = suitability by temperature (0-100)**

**GSTMEAN = Better growing season (0:12)**, the number indicating that the start of growing season in that month provides the best conditions respect to temperature.

In the example:

TSUIT = 0.6 (60%) and GSTMEAN = 2

How it works??

**Temperature:**

The suitability for each month is calculated according to the mean temperature value of the pixel.

Select the lowest suitability for each of the 12 potential growing seasons, according to the length of the growing season of the crop (months).

The final temperature suitability is the maximum value of all growing seasons.

The results can be seen through the maps:

The image shows a circular diagram with months arranged in a clockwise manner, each month's suitability value is indicated. The diagram illustrates how the suitability values are calculated for each month.
How it works??

**Precipitation:**

The evaluation for rainfall is similar as for temperature, except that there is one evaluation for the total growing season through the total cumulative rain of the growing season of the crop (months) and not for each month.

The final rainfall suitability is the maximum value of all growing seasons.

The results can be seen through the maps:

**RSUIT** = suitability by rainfall (0-100) %

**GSRAIN** = Better growing season (0:12), the number indicating that the start of growing season in that month provides the best conditions respect to rainfall.

In the example:

RSUIT = 0.9 (90%) and GSRain = 12
Finally the interaction (product) is calculated between the suitability of temperature and precipitation for each growing season

\[ T_{1_{SUkur}} * R_{1_{SUkur}}; T_{2_{SUkur}} * R_{2_{SUkur}}; T_{3_{SUkur}} * R_{3_{SUkur}}; ...; T_{12_{SUkur}} * R_{12_{SUkur}} \]

The final suitability will be the best result of the 12 products calculated

<table>
<thead>
<tr>
<th></th>
<th>GS1</th>
<th>GS2</th>
<th>GS3</th>
<th>GS4</th>
<th>GS5</th>
<th>GS6</th>
<th>GS7</th>
<th>GS8</th>
<th>GS9</th>
<th>GS10</th>
<th>GS11</th>
<th>GS12</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSUIT</td>
<td>0.5</td>
<td>0.6</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
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<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>RSUIT</td>
<td>0.8</td>
<td>0.5</td>
<td>0.7</td>
<td>0.4</td>
<td>0.8</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.5</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>SUIT (TSUIT*RSUIT)</td>
<td>0.40</td>
<td>0.30</td>
<td>0.21</td>
<td>0.12</td>
<td>0.24</td>
<td>0.12</td>
<td>0.09</td>
<td>0.09</td>
<td>0.12</td>
<td>0.25</td>
<td>0.35</td>
<td>0.45</td>
</tr>
<tr>
<td>SUIT (%)</td>
<td>40</td>
<td>30</td>
<td>21</td>
<td>12</td>
<td>24</td>
<td>12</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>25</td>
<td>35</td>
<td>45</td>
</tr>
</tbody>
</table>

In the example, GS2 is the best season for temperature (60%) and GS12 for precipitation (90%). For interaction of two variables the better suitability (45%) is obtained also in the growing season 12 (GS_{SUkur} = 12)
Modeling of potential future impacts on crop suitability: Results

- Climate data from UWI climate data group
- Climate parameters from WP 1

**Table 6. Crop parameters to Ecocrop Model**

<table>
<thead>
<tr>
<th>SPECIE</th>
<th>GMIN</th>
<th>GMAX</th>
<th>TILL</th>
<th>TMIN</th>
<th>TOPMIN</th>
<th>TOPMAX</th>
<th>TMAX</th>
<th>RMIN</th>
<th>ROPMIN</th>
<th>ROPMAX</th>
<th>RMAX</th>
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</thead>
<tbody>
<tr>
<td><strong>Cocoa Lower Amazon</strong></td>
<td>180</td>
<td>365</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>27.7</td>
<td>46</td>
<td>1000</td>
<td>1250</td>
<td>2500</td>
<td>2800</td>
</tr>
<tr>
<td><strong>Cocoa Trinidad hybrid</strong></td>
<td>180</td>
<td>365</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>30</td>
<td>43.5</td>
<td>1000</td>
<td>1250</td>
<td>2500</td>
<td>2800</td>
</tr>
<tr>
<td><strong>Cocoa Upper Amazon</strong></td>
<td>180</td>
<td>365</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>34.3</td>
<td>46</td>
<td>1000</td>
<td>1250</td>
<td>2500</td>
<td>2800</td>
</tr>
<tr>
<td><strong>Tomato</strong></td>
<td>90</td>
<td>140</td>
<td>10</td>
<td>15</td>
<td>21</td>
<td>24</td>
<td>30</td>
<td>400</td>
<td>600</td>
<td>1300</td>
<td>1800</td>
</tr>
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</table>
Cocoa: Trinidad Hybrid & Upper Amazon
Cocoa: Lower Amazon
Inter annual variability in Trinidad & Tobago

Figure 16. Behavior of suitability crops during the 1997-2013 time series for five localities in Jamaica. The categories refer to aptitude levels: Very High (VH) >75%, High (H) >50%, Medium (M) >30%, Low (L) <30%.
Cocoa: Lower Amazon
Tomato
Inter annual variability in Trinidad & Tobago

Figure 12. Behavior of suitability crops during the 1990-2010 time series for three climatic stations in Trinidad and Tobago. The categories refer to aptitude levels: Very High (VH) >75%, High (H) >50%, Medium (M) >30%, Low (L) <30%.
Impact of climate change in T&T and Jamaica (Conclusions)

Figure 17. Percentage of loss currently suitable areas in Trinidad & Tobago and Jamaica, respectively. The red line determines the average of suitable areas for current crops and boxes detailing the media, the first and third quartile of the future suitable areas.
Participatory local adaptation plans
Farmers as Scientists!

1. A broad set of varieties is evaluated
2. Each farmer gets a different combination of varieties
3. Environmental data (GPS, sensors) to assess adaptation
4. Farmers test and report back by mobile phone
5. Farmers receive tailored variety recommendations and can order seeds
6. Detect demand for new varieties and traits

Outscaling a citizen science approach to test climate adaptation technologies on farms: Jacob Van Etten, Bioversity International
Use ICT tools for crow sourcing and M&E

- Registering farmer in the system
- Managing data collection of farmers experiments (surveys, spatial information, ...)
- Monitoring CSA implementation projects (activity reports, feedback loops with experts)