Within the “Mazorquero Cacao” Project:

A novel method for estimating cocoa crop losses related to pest and diseases in the Peruvian Amazonia

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Cocoa Production in San Martin

Most productive cocoa zone of Peru

Cocoa crops have social, environmental and economic importance

90% of the cocoa varieties are CCN-51

P&Ds pose severe constraints

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Análisis Integral de la Logística en el Perú 2016

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P&Ds Complex in San Martin

Up to 60% incidence of the most damaging P&Ds

Recent emergence of *Carmenta Foraseminis* (American Pod Borer “Mazorquero”)

Impact of these P&Ds is not necessarily additive

The Sanitary Harvest is a common practice

Available Markets differ in terms of the seed quality they purchase
Cocoa Markets in San Martin

Local Conventional & Organic Markets

Local “Black” Market

As affected seeds are still exploitable, estimating the damage can help in decision making
Research Question & Objectives

How can we estimate yield loss & crop loss related to P&D incidence?

- Incidence to track presence of P&Ds
- Severity not available
- No integrative indicator

Develop a mathematical model to estimate yield loss related to cocoa pods P&Ds

Establish a yield loss due to individual and combined P&D incidence

Fit model for identified markets to estimate crop losses
**Materials & Methods - Data Collection**

a. **P&Ds Combinations per pod**

- 30 Pods per Combination, different cocoa plots

![Pods combinations](image)

- Black Pod
- Frosty Pod Rot
- American Pod Borer
- Black Pod + American Pod Borer

b. **Pod’s Phenological Stage for Harvest**

- On P&Ds symptoms appearance
- Pods close to maturation

![Pods close to maturation](image)

c. **Seed Damage Classes**

- Affected Seeds (AS)
- Destroyed Seeds (DS)
- Healthy Seeds (HS)
Materials & Methods - Data Analysis and Methodology Development

d. Seed’s Damage Ratio per Pod (SDR) for each P&Ds Combination:

\[ SDR_i = \text{Seed Damage Ratio for each P&D combination} \]
\[ SDR_i = ASR_i + DSR_i \]

\[ ASR_i = \frac{\sum_{i=1}^{n} (AS_i)}{S_i} \times 100 \]

\[ DSR_i = \frac{\sum_{i=1}^{n} (DS_i)}{S_i} \times 100 \]

AS\(_i\) = Total number of affected seeds in evaluated pod
S\(_i\) = Total number of seeds in evaluated pod
n = Total number of evaluated pods with evaluated P&D Combination
DS\(_i\) = Total number of destroyed seeds in evaluated pod

Average Seeds per Pod (meanS) for CCN-51 = 46
Results - Seed Damage Ratios (SDRs) for each P&D

- **Black Pod**: 9.89%
  
- **Frosty Pod Rot**: 68.19%
  
- **American Pod Borer**: 49.57%
  
- **American Pod Borer + Black Pod**: 13.14%

### Seed Damage Ratios

- **Destroyed Seed Ratio (DSR)**
- **Affected Seed Ratio (ASR)**
- **Healthy Seed Ratio (1-SDR)**

**Frosty Pod Rot** → Most damaging P&D in the zone

**American Pod Borer** → Least amount of damage caused

**American Pod Borer + Black Pod** → Appear to synergize, increasing damage
e. Yield Loss

\[ \text{Yield Loss} = \sum_{i=1}^{n} (\text{AP} \times IC_i \times \text{meanS} \times SDR_i) \]

AP = Total Number of Affected Pods  
IC\(_i\) = Incidence of each P&D Combination  
meanS = Average Seeds per Pod (46)  
SDR\(_i\) = Seed Damage Ratio per Pod of each P&D Combination  
n = Number of P&D combinations

Modified versions of this equation were utilized to estimate the crop loss.
### Materials & Methods - Model Application

#### e. Market Simulations (Crop Loss - CL)

<table>
<thead>
<tr>
<th>Seed Type</th>
<th>Crop Loss</th>
<th>Market Type</th>
<th>CL = [P * ΠL] - [Gain from Healthy Pods + Gain from Affected Pods]</th>
<th>Gain from Healthy Pods</th>
<th>Gain from Affected Pods</th>
<th>Destroyed Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>([P − AP] * ΠL)</td>
<td>1^\text{st}</td>
<td>2^\text{nd}</td>
<td></td>
</tr>
<tr>
<td>Local Conventional</td>
<td>CL</td>
<td>Local Market</td>
<td>ΠL</td>
<td>Healthy Seeds</td>
<td>ΠL</td>
<td></td>
</tr>
<tr>
<td>(ΠL) - 1.83€/kg</td>
<td>X</td>
<td></td>
<td>Σ_{i=1}^n ((AP * IC_{i}) * (1 − SDR_{i}) * ΠL)</td>
<td>X</td>
<td>(AP * IC_{i} * ASR_{i}) * ΠB</td>
<td></td>
</tr>
<tr>
<td>Local Organic</td>
<td>CL</td>
<td></td>
<td>ΠL</td>
<td>Healthy Seeds</td>
<td>ΠL</td>
<td></td>
</tr>
<tr>
<td>(ΠL) - 1.93€/kg</td>
<td>X</td>
<td></td>
<td>Σ_{i=1}^n ((AP * IC_{i}) * (1 − SDR_{i}) * ΠL)</td>
<td>X</td>
<td>(AP * IC_{i} * ASR_{i}) * ΠB</td>
<td></td>
</tr>
<tr>
<td>Local Black</td>
<td>CL</td>
<td></td>
<td>ΠL</td>
<td>Healthy Seeds</td>
<td>ΠL</td>
<td></td>
</tr>
<tr>
<td>(ΠB) - 1.63€/kg</td>
<td>X</td>
<td></td>
<td>Σ_{i=1}^n ((AP * IC_{i} * ASR_{i}) * ΠB)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ΠL = Local Market Index - Product of (meanS * SW * MV\text{Local}) to calculate the gain in the Conventional and Organic Markets

P = Total number of pods

AP = Total affected number of pods

IC_{i} = Incidence of each P&D Combination

ΠB = Black Market Index - Product of (meanS * SW * MV\text{Black}) to calculate the gain in the Black Market

MV\text{Black} = Black Market Value
Results - Simulation

Simulation 1

3095 Pods

Incidence Distribution

Simulation 2

3095 Pods

Incidence Distribution
Simulation - Results

Profitability Comparison Between Local Cocoa Markets in San Martin

- **Potential gain** Organic > Conventional
- **Crop Losses** Organic > Conventional
- Simulation 2 CL doubles Simulation 1 CL
- Crop Losses depend on P&D composition
- Model allows crop loss estimation through incidence of each P&D combination

Value in Euros

- Local Conventional
  - Mk = 1.83€/kg
- Local Organic
  - Mk = 1.93€/kg
- **Potential gain** Organic > Conventional
- **Crop Loss for Simulation 2**
- **Crop Loss for Simulation 1**
Discussion & Conclusion

- The SDRs originate from a simple model, allow easy yield loss quantification and are versatile

- Crop Loss Estimation can support decision making. This may help farmers & technical personnel to:
  - Prioritize most damaging P&Ds
  - Prioritize specific control practices
  - Adjust investment strategies
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Thank you for your attention!!
Questions? (marcos-javier.ramos@cirad.fr)