The Role of Weather Information on Carrot Yield Performance-
Empirical Evidence from Field Data in Chinese Taipei

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Vegetables create more jobs and higher income than staple for smallholders.
Introduction- 1

- In a county government budget meeting, proposals from farmers’ groups are reviewed
- One co-op chairman raised a request to setup a local weather monitoring station

**WHY? (quoted from the chairman)**
- “My father told me we cannot make money every year, but we can break-even if we can win twice in every 5~10 years.”
- “Weather forecast do not have to be correct every time. If it is correct one time, I can make money out of it.”
- “My friends in watermelon business know how to use cumulated temperatures to decide when to harvest, so I need to learn how I can use weather info to produce good quality carrots for my client.”
- “I cannot control how farmers manage their crops, but I need a systematic way to predict how much risk is involved before signing my contract.”
Introduction-2

Why Carrot?

✓ Agronomy Side
  ● Root crops are produced in open field
  ● Most vegetables prefer cooler temperatures, thus warming will lower their productivity
  ● Management on chemical residues is critical
  ➔ Need to work with nature, not against nature

✓ Economics Side
  ○ Important cash crop in 2nd/3rd crop season for small farms.
  ○ Export Contracts
    ○ Seasonal difference from Japan
    ○ Require specific quantity, quality, and date of delivery.
  ➔ Intensify needs for timely weather information
Carrot Production, Acreage and Yield

<table>
<thead>
<tr>
<th>Year</th>
<th>Acreage (Ha)</th>
<th>Yield (Kg/ha)</th>
<th>Harvest (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>40,213</td>
<td>3,070</td>
<td>3,070</td>
</tr>
<tr>
<td>2003</td>
<td>36,928</td>
<td>2,521</td>
<td>2,521</td>
</tr>
<tr>
<td>2004</td>
<td>39,143</td>
<td>2,436</td>
<td>2,436</td>
</tr>
<tr>
<td>2005</td>
<td>38,098</td>
<td>2,571</td>
<td>2,571</td>
</tr>
<tr>
<td>2006</td>
<td>39,154</td>
<td>2,398</td>
<td>2,398</td>
</tr>
<tr>
<td>2007</td>
<td>39,682</td>
<td>2,162</td>
<td>2,162</td>
</tr>
<tr>
<td>2008</td>
<td>40,039</td>
<td>2,306</td>
<td>2,306</td>
</tr>
<tr>
<td>2009</td>
<td>40,410</td>
<td>2,756</td>
<td>2,756</td>
</tr>
<tr>
<td>2010</td>
<td>43,787</td>
<td>2,471</td>
<td>2,471</td>
</tr>
<tr>
<td>2011</td>
<td>49,535</td>
<td>2,111</td>
<td>2,111</td>
</tr>
</tbody>
</table>
**Key Question ➔ How to customize weather info services to meet demand?**

- **Link field data and local weather data directly**
  - Public-funded R&Ds are done on staple and main export crops
  - Growing demand in emergent markets from:
    - contract farming
    - index-based crop insurance contract

- **Identify Temperature and precipitation thresholds affecting crop yield performance**
  - Not all forecasts are accurate
  - Preventive measures can be developed to reduce losses
Empirical Analysis-1
Study sites

- Located at central Taiwan and marked in blue
- Belongs to 2 counties divided by a river

Er-lin village

Dong-shih village
Empirical Analysis-2
Data

- Field data of carrot
  - Collected from 275 farms of a carrot co-op
  - locations
  - Planting/Harvest date
  - Irrigation type
  - Carrot yield
  - Class (by size)

- Climatic data
  - 2 EPA monitoring stations
  - Temperature: hourly averaged
  - Precipitation: hourly accumulated
### Empirical Analysis-3
#### Factor analysis

<table>
<thead>
<tr>
<th>Location</th>
<th>Yield</th>
<th>Temp.</th>
<th>Prec.</th>
<th>Sowing date</th>
<th>Irrigation</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Er-lin Village</td>
<td><strong>High</strong></td>
<td>Low</td>
<td>High</td>
<td>August September October</td>
<td>Canal, Spray</td>
<td>Loam, Sand</td>
</tr>
<tr>
<td>Dong-shih village</td>
<td><strong>Low</strong></td>
<td>High</td>
<td>Low</td>
<td>August September</td>
<td>Canal</td>
<td>Loam</td>
</tr>
</tbody>
</table>

*: Indicated statistical significant differences (P<0.001)
Empirical Analysis-4
Does temperature have impacts on yield?

 Cooler weather have positive impact on yield
Empirical Analysis-5
Does temp have impact on the length of growing period?

Warmer weather shorten the length of growing period

$y = -7.4288x + 290.36$
$R^2 = 0.7856$

**ANOVA**

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>迴歸</td>
<td>1</td>
<td>76732.38</td>
<td>76732.38</td>
<td>1070.16</td>
<td>1.2E-99</td>
</tr>
<tr>
<td>殘差</td>
<td>292</td>
<td>20936.95</td>
<td>71.70188</td>
<td></td>
<td></td>
</tr>
<tr>
<td>總和</td>
<td>293</td>
<td>97669.33</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Empirical Analysis-6
Methodology

- **Thresholds of growing temperature** can be estimated by the maximum Pearson Correlation coefficients of:
  - Observed yield and Hours of Growing Degree (HGD)
  - Observed yield and Hours of Growing Rainfall (HGR)

\[
HGD_{\text{min}, \text{max}} = \sum_{t=1}^{N} H_t, \quad H = \begin{cases} 
0 & \text{if } T_t < T_{\text{min}} \text{ or } T_t > T_{\text{max}} \\
1 & \text{if } T_{\text{min}} \leq T_t \leq T_{\text{max}}
\end{cases}
\]

- \(t\): an individual hour within the growing season
- \(T_t\): observed average temperature during the hour
- \(N\): number of hours between sowing and maturity, i.e. length to maturity

**Example:**
- \(HGD_{5,30}\) corresponds to equation with \(T_{\text{min}}=5^\circ\text{C}\) and \(T_{\text{max}}=30^\circ\text{C}\)
- \(HGR_{0,2.5}\) is the total hours of accumulated rainfall between 0mm and 2.5mm.
Major Findings -1
Optimum Temperature Range

- Optimum growing temperature is between 10-17°C.
- Temperature below 10°C and above 21°C may reduce yields.
Major Findings-2
Yield and GDH$_{10,21}$ are positively correlated

Scatter distribution of yield and GDH$_{10,21}$

Carrot yield is positively related to the number of hours in the optimal temperature range (10-21°C).
Major Findings-3
Optimum Rainfall Range

- Cannot identify the optimal range for precipitation
- No direct correlation between HGR and yield.
- Rainfall strength larger than 8~10mm/hr may cause damage on yield
Major Findings - 4
Yield and HGR_{0,2.5} are positively correlated

- Despite irrigation control, hours of rainfall less than 2.5mm (HGR_{0,2.5}) are positively related to final yield.
Major Findings-5
Multiple regression analysis

<table>
<thead>
<tr>
<th></th>
<th>Coefficient estimates</th>
<th>Standard Deviation</th>
<th>t-statistics</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>92.11766</td>
<td>19.33655</td>
<td>4.76391</td>
<td>0.00000</td>
</tr>
<tr>
<td><strong>HGD_{10,21}</strong></td>
<td>0.02885</td>
<td>0.00509</td>
<td>5.67146</td>
<td>0.00000</td>
</tr>
<tr>
<td><strong>HGR_{0,2.5}</strong></td>
<td>-0.01231</td>
<td>0.00769</td>
<td>-1.59994</td>
<td>0.11078</td>
</tr>
<tr>
<td><strong>Irrigation</strong> (Canal)</td>
<td>-11.30040</td>
<td>3.61583</td>
<td>-3.12526</td>
<td>0.00197</td>
</tr>
</tbody>
</table>

- **HGD_{10,21}** is a **positive** contributor to yield ➞ **confirmed**
- **HGR_{0,2.5}** is negative but insignificant ➞ **need better indicators**
- **Canal irrigation** is **negatively** associated with yields significantly.
Conclusions – Value Come from Downstream Users

- **Farming is sensitive to weather**
  - Optimal temperature can be identified ➔ No risk
  - **Uncertainty in rainfall** becomes a major risk factor
- **Weather forecasts can be instrumental in:**
  - Reduce potential losses from natural hazards
  - Stabilize **farm income**
- **Value of weather information depends upon:**
  - **How** to transform local weather info into agron info?
  - **When/How** to disseminate this information?
  - **Who** should be the targeted recipient?
  - ➔ **Who determines the price farmers received?**
  - ➔ **Is customized weather info still “public “ goods?**
Conclusions – Implication for Decision Making

1. Decision-Making “Before Planting”

- **Traditional wisdom**
  - Need vegetable germplasm to reduce environmental stress
  - Need seasonal forecast to select crop variety

- **New challenges**
  - Market offers better prices for off-seasonal harvests
  - Market demands safe/organic products
  - How to provide farmers “advanced knowledge” to meet conflicting demand?
Conclusions – Implication for Decision Making

Decision Making “After Planting”?  
- Raised beds  
- Mulching  
- Nets, shelters

➡️ Need to decide whether to invest  
➡️ Need innovations to reduce labor and costs
Conclusions: Public or Private Goods?

- Weather is critical in all stages of crop growth and market value.
  - **Scientific Side**
    - Will climate change enhance environmental stress on crop?
    - Can weather info offer an opportunity to raise farm income?
  - **Policy Side**
    - Who should pay—Is customized weather info public or private goods?
    - What kind of public-private partnership is needed?
    - How should the supply chain be involved?
THANK YOU & COMMENT WELCOME