Technology-Enabled, Rapid-Response Fresh Food Supply Chains (TERRa-Fresh) Market Intelligence Workshop

Facilitated by George Runger and Hector Flores
Introductions

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Vision

An integrated intelligence system continuously assessing relevant market signals to identify and recommend actionable opportunities.

*Uber gone agricultural…*
Key Components

- Customer-centric front-end design
  - Intuitive and easy-to-use
  - Clear and transparent transactions

- Efficient and secure back-end systems
  - Protects sensitive information
  - Consistent and reliable

- Host for latest AI technologies

- Seamless integration with decision support systems
Broad Strokes

Automated Data Processing Services

Data Transformation and Analytics

Dynamic Opportunity Exploration & Discovery

Virtual Enterprise Constructor

Cloud Intelligence Platform
Case in Point: Blast from the Past

Back in 2009…

Avg. profit margin: $0.12/lb*

* After applying profit maximization algorithms (in 2009 dollars)

Fast forward to 2020…
High Level View of How it Will Work

- Raw Data gathering
- Data refinement, standardization and storage
- Analytics Module
- Central Decision Platform

Input:
- Supply Information
- Other data
- Market/price Information
- Tracking Sensors
- Climate
- Social Networks
- SC status
- Market Price and variance estimates
- SC and Infrastructure Information
- Agronomic Information
- Local Conditions and risk profile

Output:
- Consumption
- Transportation
- Demand Logistics
- Investing
- Monitoring agent

Decision:
- Supply Logistics agent designation
- Demand Logistics agent designation
- Investing Opportunity Assignment
- Monitoring agent

Targeted basket of products

Investment needed and Profit Assessment
Initial Crop, planting timing and investment allocation

Spin off of Virtual Enterprises around specific products
Opportunity Identification

There is a market opportunity when a product is required by consumers at levels significantly higher than usual and there is a shortage of resources to satisfy such a demand.

By monitoring demand and price signals for the current and future market, we can identify opportunities.

Continuous monitoring and surveillance functionalities are employed to identify trends that have the potential to become market opportunities, estimate their duration, and calculate the risk related with the occurrence of these events.
The Celery Juice Challenge

Universe of Web Information:

What kind of insights can be obtained from online presence?
What Data Can We Use and How?

What is the online presence saying?

Google Trend Interest for Celery

How do we know the polarity of interest?

Score Sum = 29

What other indicators support this?

Imports for Celery

Other data sources?
To characterize the opportunity we need duration, profit, and risk measures.

An opportunity was identified and characterized. Is it feasible?
Components of Market Intelligence

Data Gathering
- Data Source Identification
- Data Download
- Storage Creation
- Processing Codes

Analytics
- Price Prediction Models
- Profitability Analysis
- Yield Models
- Surveillance

Visualizations
- Data Summaries
- Analyzed Data Visuals
- Intelligence Visuals
- Platform Creation
Data Gathering, Data-to-Information, and Centralization

1. Semi-continuous collection, standardization, and storage of relevant data
   - Market news APIs (e.g. https://www.ams.usda.gov/datasets/apis-open-data)
   - Climate data repository APIs (e.g. https://graphical.weather.gov/xml/rest.php)
   - Social and web-based APIs

2. Data transformation to continuous intelligent signals (e.g. trends, predictions, anomalies, etc.)

3. Data and intelligence uploads to a cloud-based centralized platform
Construction of Short/Long Term Supply Chain Opportunities

4. Continuously construct and assess different supply chain options formed by temporal market, climate, and logistics conditions at different levels
   - Strategic (i.e. long-term opportunities that require careful development and implementation)
   - Tactical (i.e. seasonal contracts given by mid-term temporal conditions)
   - Operational (i.e. one-time transaction opportunities given by market dislocations)

5. Identification of potential:
   - Demand agents (e.g. product specs, service level and logistics requirements)
   - Supply agents (e.g. producing regions, infrastructure, and logistic links)
   - Negotiation agents (e.g. speculator investment entities, brokerage)

6. Profitability estimations for parties involved (including risk mark-up costs)
Deployment of Transaction Opportunities to Centralized Decision Platform

7. Constructed supply chain options, which includes a description of temporal production, market, and logistics conditions, as well as estimated profitability

8. Continuous monitoring of the state of supply chain
   - Using real time information detect anomalies in echelons of the supply chain, recommend recovery procedures
   - Get metrics for continuous improvement of the supply chain
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Spin off of Virtual Enterprises around specific products
Analytics

Price Prediction
Prediction of non-terminal market prices for crops using a Gaussian Regression Random Field approach.

Cluster Analysis
Identifying 4-digit zip code regions with similar temperature, precipitation, and radiation patterns.

Profit Analysis
Profit estimation using predicted prices, transportation costs, and crop budget costs.
Simple generic crop model (SIMPLE) developed by Zhao et al. (2019) is used to predict crop yield.

Inputs for SIMPLE model includes crop-specific parameters, daily weather data, and water availability.

Following Zhao et al. (2019), daily biomass growth rate \( \text{Biomass}_{rate} \) is estimated as:

\[
\text{Biomass}_{rate} = \text{Radition} \times f_{\text{Solar}} \times RUE \times f(\text{CO}_2) \times f(\text{Temp}) \times \min(f(\text{Heat}), f(\text{Water}))
\]

- \( f_{\text{Solar}} \) is the fraction of solar radiation \( \text{Radition} \) intercepted by a crop canopy.
- \( RUE \) is the radiation use efficiency. \([=1]\)
- \( f(\text{CO}_2) \) measures the CO2 impact on biomass growth. \([=1]\)
- \( f(\text{Temp}) \) measures the temperature impact on biomass growth.
- \( f(\text{Heat}) \) measures the heat stress on biomass growth.
- \( f(\text{Water}) \) measures the heat stress on biomass growth. \([=1]\)
**SIMPLE Model Parameters and Inputs**

\[
\text{Biomass}_{rate} = Radition \times f_{Solar} \times RUE \times f(CO_2) \times f(Temp) \times \min(f(Heat), f(Water))
\]

- \(I_{50\%A}\) is the cumulative temperature required to intercept 50% of solar radiation during canopy closure \([=520]\).
- \(I_{50\%A}\) is the cumulative temperature required to 50% of radiation interception during canopy senescence \([=400]\).

\(f(Temp) = \begin{cases} 
0 & \text{if } T < T_{\text{base}} \\
\frac{T - T_{\text{base}}}{T_{\text{opt}} - T_{\text{base}}} & \text{if } T_{\text{base}} \leq T < T_{\text{opt}} \\
1 & \text{if } T \geq T_{\text{opt}}
\end{cases}\)

\(f(\text{heat}) = \begin{cases} 
1 & \text{if } T_{\text{max}} \leq T_{\text{heat}} \\
1 - \frac{T_{\text{max}} - T_{\text{heat}}}{T_{\text{extreme}} - T_{\text{heat}}} & \text{if } T_{\text{heat}} < T_{\text{max}} \leq T_{\text{extreme}} \\
0 & \text{if } T_{\text{max}} > T_{\text{extreme}}
\end{cases}\)

- \(T_{\text{base}}\) and \(T_{\text{opt}}\) are the base and optimal temperature for biomass growth.
- \(T_{\text{max}}, T_{\text{heat}}\) and \(T_{\text{extreme}}\) respectively represents daily maximum temperature, temperature threshold when biomass growth rate starts to reduced by heat stress, and temperature threshold when biomass growth rate rate reaches 0 due to heat stress.

<table>
<thead>
<tr>
<th>Crop Name</th>
<th>Harvest Index</th>
<th>T_base</th>
<th>T_opt</th>
<th>T_heat</th>
<th>T_extreme</th>
<th>Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>0.68</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>45</td>
<td>6%</td>
</tr>
<tr>
<td>Lettuce</td>
<td>0.68</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>45</td>
<td>10%</td>
</tr>
<tr>
<td>Celery</td>
<td>0.68</td>
<td>11</td>
<td>31</td>
<td>37</td>
<td>50</td>
<td>6%</td>
</tr>
<tr>
<td>Bell Pepper</td>
<td>0.68</td>
<td>11</td>
<td>31</td>
<td>37</td>
<td>50</td>
<td>8%</td>
</tr>
<tr>
<td>Carrot</td>
<td>0.7</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>45</td>
<td>12%</td>
</tr>
<tr>
<td>Cucumber</td>
<td>0.68</td>
<td>11</td>
<td>31</td>
<td>37</td>
<td>50</td>
<td>4%</td>
</tr>
<tr>
<td>Onion</td>
<td>0.85</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>45</td>
<td>10%</td>
</tr>
<tr>
<td>Green Bean</td>
<td>0.4</td>
<td>11</td>
<td>31</td>
<td>37</td>
<td>50</td>
<td>10%</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>0.68</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>45</td>
<td>8%</td>
</tr>
</tbody>
</table>
Estimating Yield using SIMPLE Crop Model

- The cumulative biomass until \( i^{th} \) day becomes:
  \[
  \text{Biomass\_cum}_{i+1} = \text{Biomass\_cum}_i + \text{Biomass\_rate}
  \]

- Finally, the total crop yield can be predicted as:
  \[
  \text{Yield} = \text{Biomass\_cum}_{\text{maturity}} \times \text{Harvest Index}
  \]

### Predicted Yields for Tomato in Las Cruces

<table>
<thead>
<tr>
<th>Planting Date</th>
<th>Total Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 4</td>
<td>26,347</td>
</tr>
<tr>
<td>March 3</td>
<td>22,850</td>
</tr>
</tbody>
</table>

![Graph showing predicted yields for tomato in Las Cruces]
Visualization

• Provide access to relevant information regarding crop market prices, product interest and trends, and .
• Present data and analyses in a visual manner that conveys important information without needing data analytics expertise.
• The information presented in the visualization is developed to aid in decision making for agricultural business and planning.
• The information we have includes data on terminal market crop prices, crop imports, google trends interest, weather and radiation, predicted yield, and region clustering.
Conclusion

• Market Intelligence is an essential component in agricultural planning.
• With the use of data and analytics we can better understand the emerging market and take action to be able to respond to opportunities.
• The examples, analysis, and tools presented in the workshop are not exhaustive. More work is yet to be done.

What
• Expand Visualization Gallery

Is
• Include non-terminal market price predictions.

Next?
• Publish a yield prediction tool on the website.
Sponsors

Completed:
Omar Ahumada, Ph.D. Dissertation
Octavio Sánchez, M.S. Thesis
Hector Flores, M.S. Thesis
Nicholas Mason, Ph.D.
Christopher Wishon, Ph.D.
Hector Flores, Ph.D.

In Progress:
Rodrigo Ulloa, Ph.D.
Xaimarie Hernández Cruz, Ph.D.
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Thank you.

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International Logistics and Productivity Improvement Laboratory (http://ilpil.asu.edu/)
School of Computing, Informatics and Decision Systems Engineering
Additional Material
How Will It Work (in Design)

Automated Data Monitoring, Retrieval, and Processing Services

- Google Analytics API
- USDA API
  - News/Events
  - Tracking Sensors
  - Currency Exchanges
- NOAA API
  - (Historical) Climate Forecasting
- Production
  - Input prices
- Transportation Prices
- Currency Exchanges

Market \( \lambda/t \)

Logistics \( \alpha/t \)

Production \( \beta/t \)

Data Ingestion/Standardization

Data Lake
How Will It Work (in Design)

Data Transformation and Analytics

- Querying
- Processing
- Enablement

Analytics Module

Market
- Market Price
- Trend/Forecasting
- NLP-based Sentiment Analysis
- Market Demand Estimations

Logistics
- Quality/Waste Monitoring
- Rate Trends (e.g. transportation)
- Agent Profiler (e.g. logistic availability)

Production
- Weather Pattern Trends
- Input cost trends (e.g. labor, water)
- Crop Profiler (e.g. agronomic reqs.)
How Will It Work (in Design)

Dynamic Opportunity Exploration and Discovery Services

- Planting/Harvesting Schedules
- Logistics/Transportation Routing
- Market Selection
- Agent Identification
- Service Level/Product Requirements
- Investment Requirements
- Profitability Estimation
- Minimum Negotiation Requirements
- Risk Assessment

SC Design Constructor

Framework

Agents

Profitability/Risk
How Will It Work (in Design)

Virtual Enterprise Enablement

Virtual Bidding Platform Block

- Framework
- Agents
- Profitability

Option 1

Option 2

Option N

Bull Pen
How Will It Work (in Design)

- Automated Data Processing Services
- Data Transformation and Analytics
- Dynamic Opportunity Exploration & Discovery
- Virtual Enterprise Constructor

Cloud Intelligence Platform

- Long-term planning
- Larger Investment Requirements
- Long-term partnerships

E2E Enterprises

- Seasonal opportunities
- Mid-level investments
- Seasonal partnerships

Seasonal Partnerships

- Arbitrage opportunities
- Low cost
- Minimal partnership requirements

Transactional
Market Intelligence Interactions

Data
- USDA Terminal Market Prices
- GATS Imports
- Google Trends
- Social Media
- Weather

Processing
- raw data
- Querying
- Enablement

Visualization
- visuals’ data
- tableau

Analytics
- Strategic Model
- Tactical Model
- Operational Model

Decisions Platform

Price Prediction
- Profitability
- Price Elasticity
- Continuous Monitoring

Local Price Estimates
- Price Index
- Kriging Methods

Demand Prediction
- Surveillance

Trends
- Estimates
- Alerts

Intelligence Platform
- Opportunistic Marketing
- Market Dislocations
Data Gathering and Storage

Sources
Identify data sources related to crop market prices, imports, demand, interest, transportation costs, among others.

Storage
Creation of a database platform to store relevant data and automatically update it according to a pre-defined frequency.

Processing
Creation of codes or scripts to process raw data and transform it into the needed formats.

USDA Terminal Market Prices
GATS Imports
Google Trends
Social Media
Weather

Data Lake

Querying
Processing
Enablement
Analytics
Prescriptive Analytics

Yield Prediction
Usage of biological models to predict the total yield and its harvest distribution for each possible planting week.

Planning Unit Definition
Identify yield homogeneous regions.

Farm Planning
Usage of predicted prices and yields as inputs for agricultural planning optimization models.