Can Organic Agriculture Feed Turkey?:
A Linear Programming Model

Dr. Bulut Aslan
Assistant Professor
Istanbul Bilgi University
Industrial Engineering Department

Dr. Yonca Demir
Assistant Professor
Istanbul Bilgi University
Business Administration Department
About myself

• Assistant Professor, Industrial Engineering, Istanbul Bilgi University, 2012-2014.
• Ph.D. in Management Science, Lancaster University, Lancaster, UK, 2011.
  • Supervisors: Prof. Linda Hendry & Dr Mark Stevenson
  • “Enterprise Resource Planning Systems: An Assessment of Applicability to Make-To-Order Companies”
• M.Sc. in Industrial Engineering, Bogazici University, Istanbul, 2007.
  • Supervisor: Prof. Ümit Bilge
  • “Load-Based Order Review/Release Strategies for Shop Floor Control”
• B.Sc. in Industrial Engineering, Middle East Technical University, Ankara, 2005.
  • Minor (Production) in Mechanical Engineering, METU.

For a while and from now on, interested in Sustainability, Agro-food Supply Chains and Ecological Farming.
Outline

• Motivation
• Conventional vs Organic Farming
• The Model
• Data Requirements and Sources
• Numerical Results for Aggregated Data
• Conclusion and Future Studies
Motivation

Health

Food Security & Quality

Eco-friendly applications

Climate Change

Tag Source: The IFOAM Norms for Organic Production and Processing - The Principles of Organic Agriculture
Motivation

Economically Fair

Equity, Respect and Justice

Care

Genetically-modified Organisms

Tag Source: The IFOAM Norms for Organic Production and Processing - The Principles of Organic Farming
**Conventional vs Organic Farming: Farming Metrics**

- “Overall, organic yields are 25% lower than conventional…” Seufert et al. (2011).
  - Yet, organic performance varies widely over crop types, species, practices, etc.

- Significant differences were found in soil health indicators; *nitrogen mineralization, microbial abundance* and *diversity*. (Drinkwater, 1995).
  - Nitrogen mineralization potential was *three times greater* in organic compared to conventional fields.
  - The organic fields had 28% more organic carbon.
  - The increased soil health in the organic farms resulted in considerably lower disease incidence

Conventional vs Organic Farming: Nutritional Metrics

• Meta-analysis based on 343 peer-reviewed publications
  • significant differences in composition between organic and non-organic.

• The concentrations of a range of antioxidants found to be substantially higher in organic crops/crop-based foods.

• Four times higher occurrence of pesticide residues in conventional crops,
  • also contains significantly higher concentrations of toxic metals.

• Significant differences detected for some other (e.g. minerals and vitamins) compounds between the groups.

• **Organic crops, on average, have higher concentrations of antioxidants, lower concentrations of Cd and a lower incidence of pesticide residues than the non-organic comparators across regions and production seasons.**

Natural conditions of Turkey for Farming
Organic Farming: Yet another Market Gap or a National/Regional Strategy?

• Cuba
  • 1959, Cuban Revolution.
  • 1989, Agricultural Revolution.
  • Sustainable agricultural systems induced by crisis and embargo, turned into an advantage.

• Bhutan
  • A small Himalayan kingdom of around 1.2m people.
  • Aims at becoming the first country in the world to go wholly organic within a decade.
  • Mountainous, prone to erosion, chemicals accelerates the process of soil destruction
Natural conditions of Turkey for Farming:
The effect of Climate Change

Overall, the intensity and duration of **droughts** and **hot spells** could increase in response to increasing temperatures and decreasing precipitation in Turkey.

Adapted from Sen (2013, December) “A Holistic View of Climate Change and Its Impacts in Turkey,” Istanbul Policy Center
Organic Farming in Turkey

• Agrochemicals entered in 1960s.
  • Increasingly used throughout the whole country.

• Certified Organic farming (dried fruits) started in 1985.
  • A vast number of for-profit companies have recently been involved.

• First “100% Organic Bazaar” founded in 2006, enabled to form a domestic market for ecological products.
  • Today, there are more than 15 organic bazaars in Turkey, operating on a weekly basis.
Organic Farming in Turkey: A SWOT Analysis

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of unpaid family labour</td>
<td>Lack of education level to capture innovation opp.</td>
</tr>
<tr>
<td>Low level of external-inputs use</td>
<td>Lack of knowledge about Organic Management Sys</td>
</tr>
<tr>
<td>Favourable natural conditions to grow diversely</td>
<td>Soil and environmental degradation</td>
</tr>
<tr>
<td>Diversified farming structure</td>
<td>Low income level</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>New lucrative markets to all over the world</td>
<td>Dependence mainly on foreign market</td>
</tr>
<tr>
<td>Development due to domestic demands</td>
<td>Weak government support and policies</td>
</tr>
<tr>
<td>Proximity to EU</td>
<td>Lack of environmental protection awareness</td>
</tr>
<tr>
<td>Being organized as farm commodity groups</td>
<td>Insufficient domestic R&amp;D activities.</td>
</tr>
</tbody>
</table>

Adapted from Rehber & Turhan (2002)

“Prospects and challenges for developing countries in trade and production of organic food and fibers: The case of Turkey.”
Natural conditions of Turkey for Farming
The Model: Parameters (Data Req.)

\( H_j \): Hectares in location \( j \) available for agriculture

\( F_j \): Number of typical families in location \( j \)

\( R_i \): Annual requirement of food \( i \) of one typical family (kgs)

\( Y_{ij} \): Yield of food \( i \) in location \( j \) under organic farming (kgs/hectare)

\( d_{jk} \): Distance between locations \( j \) and \( k \) (km)

\( SC_{ij} \): Cost of shortage of food type \( i \) in location \( j \)
The Model: Variables (Decision and State)

- $x_{ij}$: Hectares to be allocated for growing food type $i$ in location $j$
- $t_{ijk}$: kgs of food $i$ shipped from location $j$ to location $k$
- $r_{ij}$: kgs of food type $i$ produced in location $j$ for consumption in the same location
- $e_{ij}$: Excess kgs of food type $i$ in location $j$
- $s_{ij}$: kgs of food type $i$ in shortage in location $j$
- $i_{ij}$: kgs of food type $i$ inventoried in location $j$
The Model

Minimize \( z = \sum_{i=1}^{N} \sum_{j=1}^{L} \sum_{k=1}^{L} d_{jk} t_{ijk} + \sum_{i=1}^{N} \sum_{j=1}^{L} SC_{ij} s_{ij} \)

Subject to

\( Y_{ij} x_{ij} = r_{ij} + \sum_{k=1}^{L} t_{ijk} + i_{ij} \)  \hspace{1cm} (1)  the amount of each food type produced in each region is either consumed or inventoried in the same region or shipped to other regions.

\( r_{ij} + \sum_{k=1}^{L} t_{ikj} + s_{ij} - e_{ij} = F_{j} R_{i} \) \hspace{1cm} (2)  the food needs of the population are met and keep an account of any food shortages.

\( \sum_{i=1}^{N} x_{ij} \leq H_{j} \) \hspace{1cm} (3)  the land availability.
Data Requirement and Sources

• The LP model proposed above has various data requirements.
• Main provided from 2013 statistics of Ministry of Food, Agriculture and Livestock or from the Turkish Statistical Institute to identify:
  • Amount of arable land in each region,
  • Number of people living in each region aggregated to typical families,
  • Yearly food requirements of typical families,
  • Yields* of each food in each region under organic farming conditions
  • Distances between regions
  • Costs of not satisfying a food requirement in a given region.
Yield data

Turkey’s province-based crop yield data for the last decade is
• averaged,
• aggregated,
• normalised, and
• cross-validated.

Numerical Results for Regionally-Aggregated Data

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>Blacksea</th>
<th>Mediterranean</th>
<th>Marmara</th>
<th>Central anatolia</th>
<th>East &amp; S-east</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g l c v f</td>
<td>g l c v f</td>
<td>g l c v f</td>
<td>g l c v f</td>
<td>g l c v f</td>
</tr>
<tr>
<td>Blacksea</td>
<td>485 388 388 36,811 775 485</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Marmara</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Central anatolia</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>East &amp; S-east</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Regional needs</td>
<td>485 388 388 775 775 485</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Regional shortages</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Regional excesses</td>
<td>0 0 0 36,035 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

* g: greenery, l: legumes, c: cereals, v: veggies, f: fruits; o: olives.
* **cell units**: million-kg
* **Diet set for minimum energy requirement**: 2300 cal/day
  (diets of 1770 and 1150 cal/day have also been computed and run)
Numerical Results for Regionally-Aggregated Data

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>Mediterranean</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>l</td>
<td>c</td>
<td>v</td>
<td>f</td>
</tr>
<tr>
<td>Blacksea</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>1,710</td>
<td>1,369</td>
<td>1,369</td>
<td>62,492</td>
<td>2,733</td>
</tr>
<tr>
<td>Marmara</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Central anatolia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>East &amp; S-east</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Regional needs</td>
<td>1,710</td>
<td>1,369</td>
<td>1,369</td>
<td>2,733</td>
<td>2,733</td>
</tr>
<tr>
<td>Regional shortages</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Regional excesses</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59,758</td>
<td>0</td>
</tr>
</tbody>
</table>

**g**: greenery, **l**: legumes, **c**: cereals, **v**: veggies, **f**: fruits; **o**: olives.

**cell units**: million-kg

**Diet set for minimum energy requirement**: 2300 cal/day
(diets of 1770 and 1150 cal/day have also been computed and run)
Numerical Results for Regionally-Aggregated Data

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>Marmara (incl. Istanbul)</th>
<th>Blacksea</th>
<th>Mediterranean</th>
<th>Marmara</th>
<th>Central anatolia</th>
<th>East &amp; S-east</th>
<th>Regional needs</th>
<th>Regional shortages</th>
<th>Regional excesses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>l</td>
<td>c</td>
<td>v</td>
<td>f</td>
<td>o</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blacksea</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mediterranean</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marmara</td>
<td>2,178</td>
<td>443</td>
<td>1,744</td>
<td>3,482</td>
<td>3,482</td>
<td>2,178</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central anatolia</td>
<td>0</td>
<td>1,300</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East &amp; S-east</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional needs</td>
<td>2,178</td>
<td>1,744</td>
<td>1,744</td>
<td>3,482</td>
<td>3,482</td>
<td>2,178</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional shortages</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional excesses</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* g: greenery, l: legumes, c: cereals, v: veggies, f: fruits; o: olives.
* **cell units**: million-kg

**Diet set for minimum energy requirement**: 2300 cal/day
(diets of 1770 and 1150 cal/day have also been computed and run)
Numerical Results for Regionally-Aggregated Data

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>Central anatolia</th>
<th>Blacksea</th>
<th>Mediterranean</th>
<th>Marmara</th>
<th>Central anatolia</th>
<th>East &amp; S-east</th>
<th>Regional needs</th>
<th>Regional shortages</th>
<th>Regional excesses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>g l c v f o</td>
<td></td>
<td></td>
<td>g l c v f o</td>
<td></td>
<td>g l c v f o</td>
<td></td>
<td>g l c v f o</td>
</tr>
<tr>
<td>Blacksea</td>
<td>0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>480</td>
<td>0 0 0 0 0 0</td>
<td>95,698</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>385</td>
<td>385</td>
<td>769 769 480</td>
</tr>
<tr>
<td>Marmara</td>
<td>0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 0 0 0 0 0 0 0 0</td>
<td></td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Central anatolia</td>
<td>96,180 385 385 769 769 480</td>
<td>0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0</td>
<td></td>
<td>480</td>
<td></td>
<td>385</td>
<td>385</td>
<td>769 769 480</td>
</tr>
<tr>
<td>East &amp; S-east</td>
<td>0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 0 0 0 0 0 0 0 0</td>
<td></td>
<td>0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

| g: greenery, l: legumes, c: cereals, v: veggies, f: fruits; o: olives.
| cell units: million-kg
| Diet set for minimum energy requirement: 2300 cal/day
| (diets of 1770 and 1150 cal/day have also been computed and run) |
Numerical Results for Regionally-Aggregated Data

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>East and Northeast</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>l</td>
<td>c</td>
<td>v</td>
<td>f</td>
</tr>
<tr>
<td>Blacksea</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Marmara</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Central anatolia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>East &amp; S-east</td>
<td>1,080</td>
<td>865</td>
<td>865</td>
<td>72,200</td>
<td>1,728</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>g</th>
<th>l</th>
<th>c</th>
<th>v</th>
<th>f</th>
<th>o</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional needs</td>
<td>1,080</td>
<td>865</td>
<td>865</td>
<td>1,728</td>
<td>1,728</td>
<td>1,080</td>
</tr>
<tr>
<td>Regional shortages</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Regional excesses</td>
<td>0</td>
<td>0</td>
<td>70,472</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\( g \): greenery, \( l \): legumes, \( c \): cereals, \( v \): veggies, \( f \): fruits; \( o \): olives.

**cell units**: million-kg

**Diet set for minimum energy requirement**: 2300 cal/day

(diets of 1770 and 1150 cal/day have also been computed and run)
Conclusion

• Self-sufficiency and surplus is possible for Turkey on solely producing organic farming products.
  • Simply by converting the existing arable lands used for conventional into organic farming.
  • No need for deforestation to increase arable land size.
• Crop yields may look low, yet encouraging small farmers could increase the system yield significantly by:
  • multiple cropping
  • efficient irrigation and water harvesting
  • low labour alienation
Future Study

Data disaggregation:

• Disaggregate the regions (6) into provinces (81), and then into towns (957).
• Disaggregate the grouped crops (i.e., cereals, legumes, fruits, vegetables, greenery, olives) into individual crops (at least 108 commercial varieties, currently available).

Model extension:

• Integrate animal husbandry into the model to act as an input (e.g., manure) and output (e.g., meat, dairy products) for the entire system.
• Commodity products to be exported
• Risk factors (seasonality, farming practices, etc.) to be reflected as deviations in the model.
Selected References


• Mehl, et al., 2012, *Climate Change Projections for the Twenty-First Century*
