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

İstanbul
Bilgi Üniversitesi
LAUREATE INTERNATIONAL UNIVERSITIES

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*.

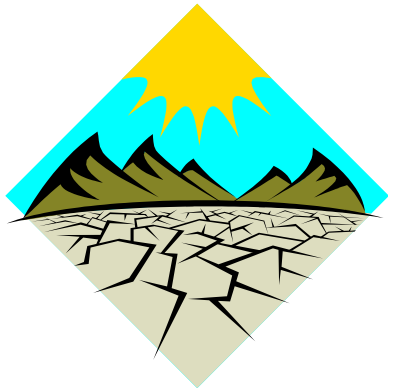
Outline

- 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



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

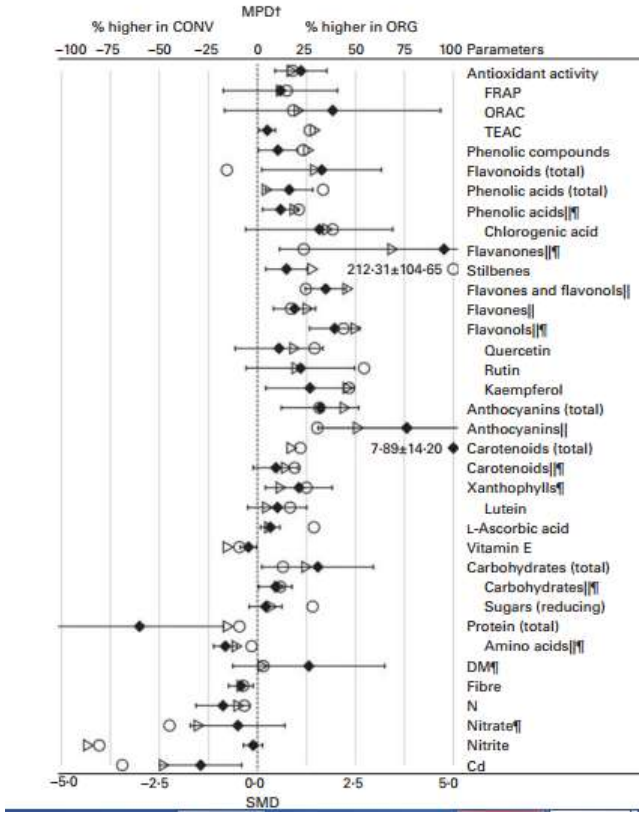
Conventional vs Organic Farming: Farming Metrics

- "*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

* Seufert, Ramankutty, and Foley, 2011, "Comparing the yields of organic and conventional agriculture", **Nature**

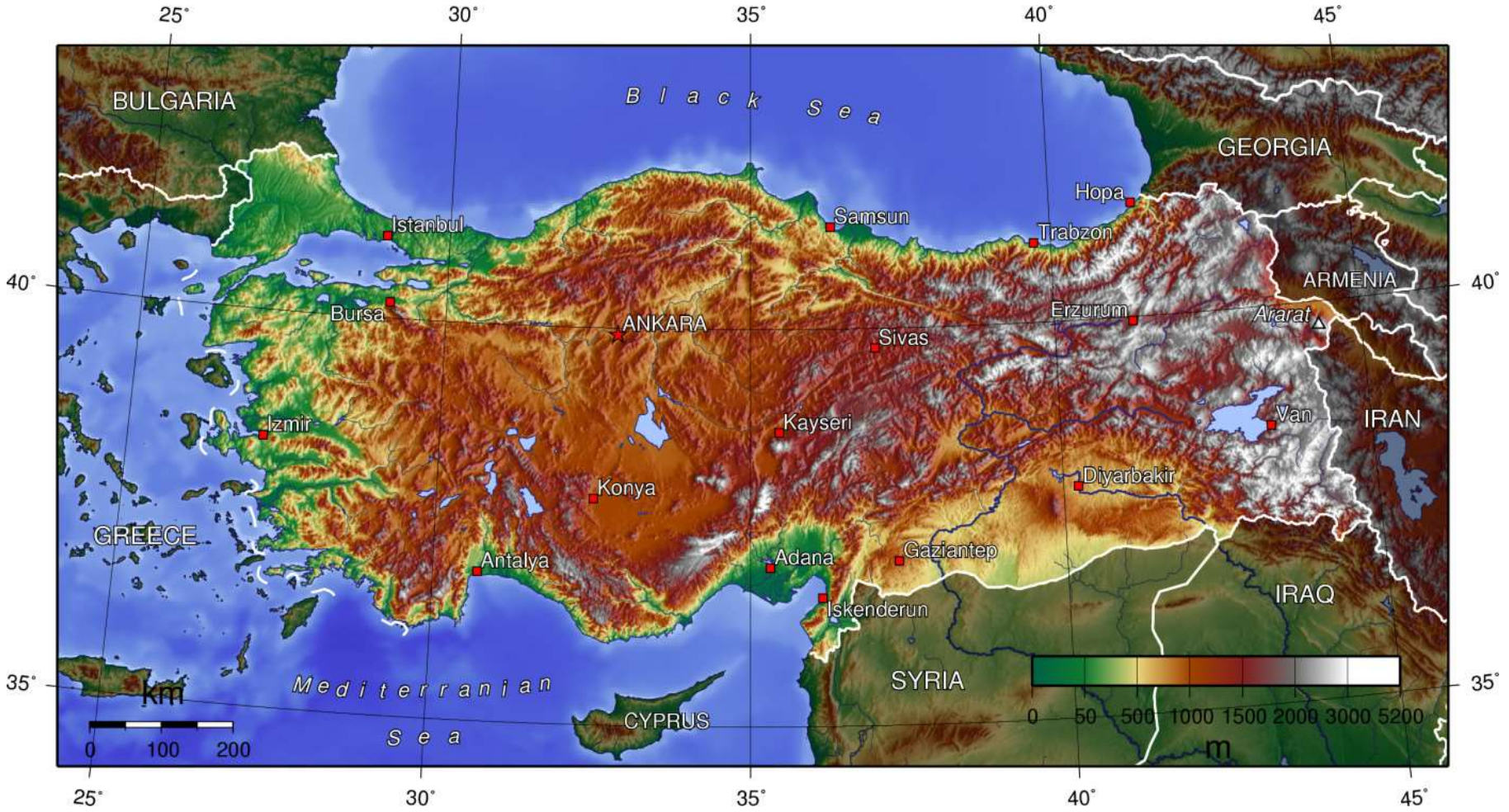
Conventional vs Organic Farming: Nutritional Metrics

- 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.*



Barański, et al., 2014, *Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses* . **British Journal of Nutrition**.

Natural conditions of Turkey for Farming

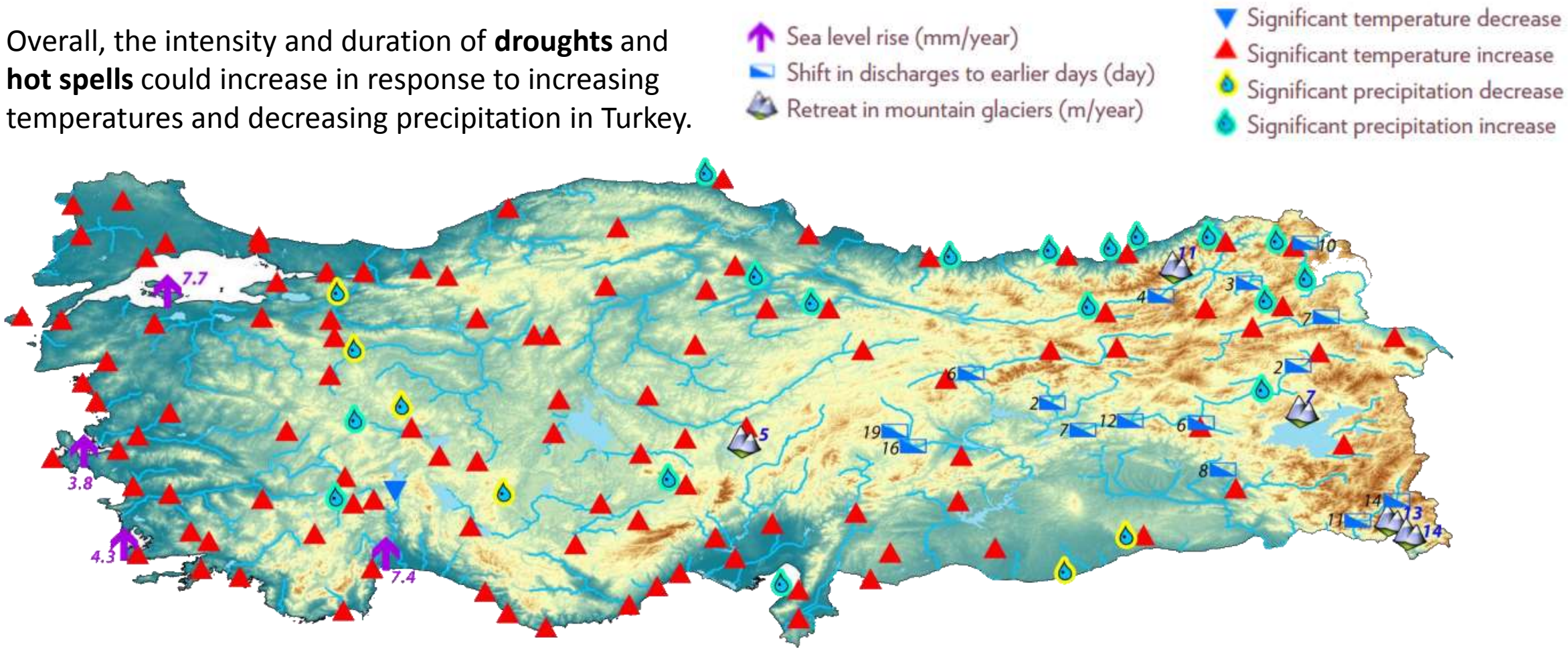


Organic Farming: Yet another Market Gap or a National/Regional Strategy?

- 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," Istabul 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

Strengths

Availability of unpaid family labour
Low level of external-inputs use
Favourable natural conditions to grow diversely
Diversified farming structure

Weaknesses

Lack of education level to capture innovation opp.
Lack of knowledge about Organic Management Sys
Soil and environmental degradation
Low income level

Opportunities

New lucrative markets to all over the world
Development due to domestic demands
Proximity to EU
Being organized as farm commodity groups

Threats

Dependence mainly on foreign market
Weak government support and policies
Lack of environmental protection awareness
Insufficient domestic R&D activities.

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.)

$\mathbf{H_j}$: Hectares in location *j* available for agriculture

$\mathbf{F_j}$: Number of typical families in location *j*

$\mathbf{R_i}$: Annual requirement of food *i* of one typical family (kgs)

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

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

$\mathbf{SC_{ij}}$: Cost of shortage of food type *i* in location *j*

The Model: Variables (Decision and State)

$\mathbf{x_{ij}}$: Hectares to be allocated for growing food type *i* in location *j*

$\mathbf{t_{ijk}}$: kgs of food *i* shipped from location *j* to location *k*

$\mathbf{r_{ij}}$: kgs of food type *i* produced in location *j* for consumption in the same location

$\mathbf{e_{ij}}$: Excess kgs of food type *i* in location *j*

$\mathbf{s_{ij}}$: kgs of food type *i* in shortage in location *j*

$\mathbf{i_{ij}}$: kgs of food type *i* inventoried in location *j*

The Model

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

Subject to

$$Y_{ij}\, x_{ij} = r_{ij} + \sum_{k=1} t_{ijk} + i_{ij}$$

(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.

$$r_{ij} + \sum_{k=1}^{L} t_{ikj} + s_{ij} - e_{ij} = F_j\, R_i$$

(2) the food needs of the population are met and keep an account of any food shortages.

$$\sum_{i=1}^{N} x_{ij} \le H_j$$

(3) the land availability.

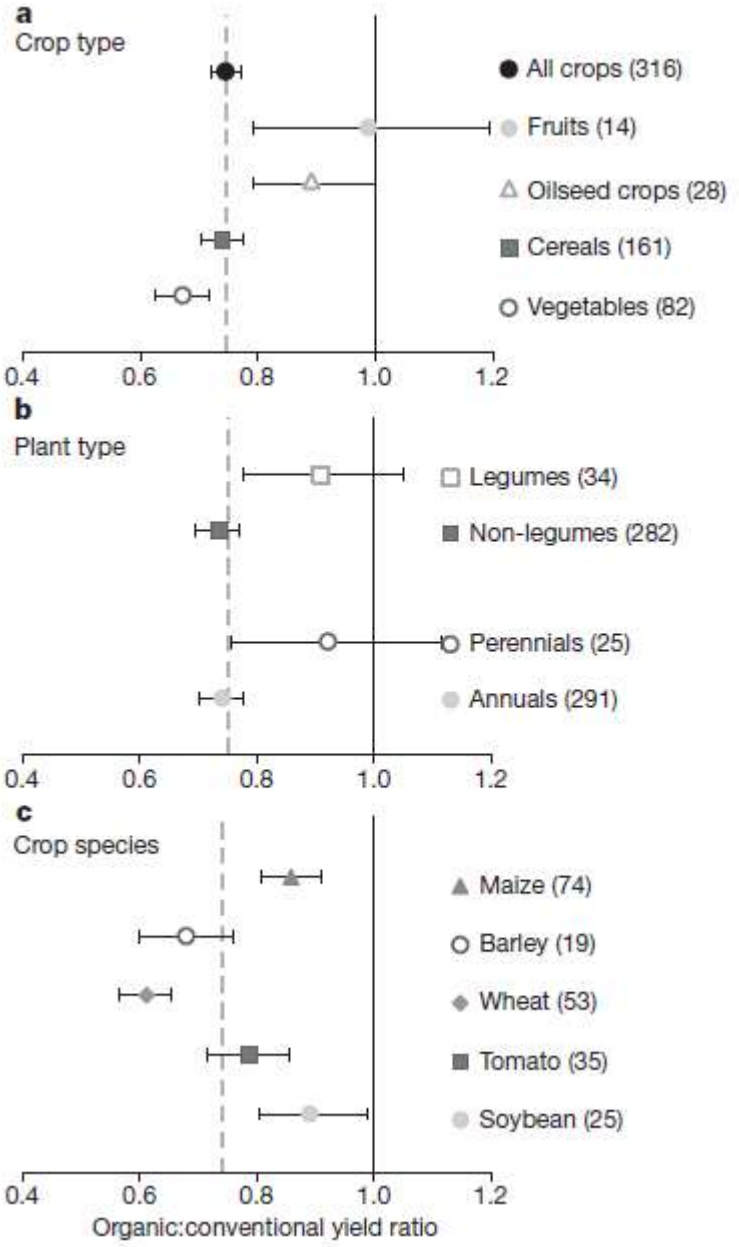
Data Requirement and Sources

- 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.



Seufert, Ramankutty, and Foley*, 2012, Comparing the yields of organic and conventional agricul*ture, **Nature.**

Numerical Results for Regionally-Aggregated Data

	REGIONS					
	Blacksea					
	g	l	c	v	f	0
Blacksea	485	388	388	36,811	775	485
Mediterranean	0	0	0	0	0	0
Marmara	0	0	0	0	0	0
Central anatolia	0	0	0	0	0	0
East & S-east	0	0	0	0	0	0
Regional needs	485	388	388	775	775	485
Regional shortages	0	0	0	0	0	0
Regional excesses	0	0	0	36,035	0	0

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

	REGIONS					
	Mediterranean					
	g	l	c	v	f	o
Blacksea	0	0	0	0	0	0
Mediterranean	1,710	1,369	1,369	62,492	2,733	1,710
Marmara	0	0	0	0	0	0
Central anatolia	0	0	0	0	0	0
East & S-east	0	0	0	0	0	0
Regional needs	1,710	1,369	1,369	2,733	2,733	1,710
Regional shortages	0	0	0	0	0	0
Regional excesses	0	0	0	59,758	0	0

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

	REGIONS					
	Marmara (incl. Istanbul)					
	g	l	c	v	f	o
Blacksea	0	0	0	0	0	0
Mediterranean	0	0	0	0	0	0
Marmara	2,178	443	1,744	3,482	3,482	2,178
Central anatolia	0	1,300	0	0	0	0
East & S-east	0	0	0	0	0	0
Regional needs	2,178	1,744	1,744	3,482	3,482	2,178
Regional shortages	0	0	0	0	0	0
Regional excesses	0	0	0	0	0	0

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

	REGIONS					
	Central anatolia					
	g	l	c	v	f	o
Blacksea	0	0	0	0	0	0
Mediterranean	0	0	0	0	0	0
Marmara	0	0	0	0	0	0
Central anatolia	96,180	385	385	769	769	480
East & S-east	0	0	0	0	0	0
Regional needs	480	385	385	769	769	480
Regional shortages	0	0	0	0	0	0
Regional excesses	95,698	0	0	0	0	0

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

	REGIONS					
	East and Northeast					
	g	l	c	v	f	o
Blacksea	0	0	0	0	0	0
Mediterranean	0	0	0	0	0	0
Marmara	0	0	0	0	0	0
Central anatolia	0	0	0	0	0	0
East & S-east	1,080	865	865	72,200	1,728	1,080
Regional needs	1,080	865	865	1,728	1,728	1,080
Regional shortages	0	0	0	0	0	0
Regional excesses	0	0	0	70, 472	0	0

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

- Le-Si, Scandizzo, Kasnakoglu, 1983, *Turkey Agricultural Sector Model,* **World Bank Reports**.
- Rehber & Turhan, 2002, *Prospects and challenges for developing countries in trade and production of organic food and fibers: The case of Turkey*. **British Food Journal**.
- Acs, Berentsen, Huirne, 2007, *Conversion to organic arable farming in The Netherlands: A dynamic linear programming analysis,* **Agricultural Systems**.
- Seufert, Ramankutty, and Foley*, 2012, Comparing the yields of organic and conventional agricul*ture, **Nature.**
- Mehl, et al., 2012*, Climate Change Projections for the Twenty-First Century*
- *Ömer Lütfi Şen, 2013, A Holistic View of Climate Change and Its Impacts in Turkey*, **Istabul Policy Center**.
- Barański, et al., 2014, *Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses* . **British Journal of Nutrition**.