Lessons Learned from Growing Food in 100% Urbanized Singapore

Stella Liu, Visiting Fulbright Scholar at Nanyang Technological University

Agenda of topics

- Future Resource Constraints on the Global Food System Present a Critical Need for Alternative Farming Methods
- Urban Agri-tech's Relevance to the Food-Energy-Water Nexus: Its Potential to Sustainably Complement Traditional Agriculture and "Climate-Proof" Food Security
- Singapore's Unique Urban Environment: A Case Study for the Future of Farming
- Singapore Urban Agriculture Nexus: Challenges and Policy Enablers
- Urban Farm Pioneers: Sky Greens and Panasonic Case Studies
    - Technology
    - Business Model
    - Lessons Learned

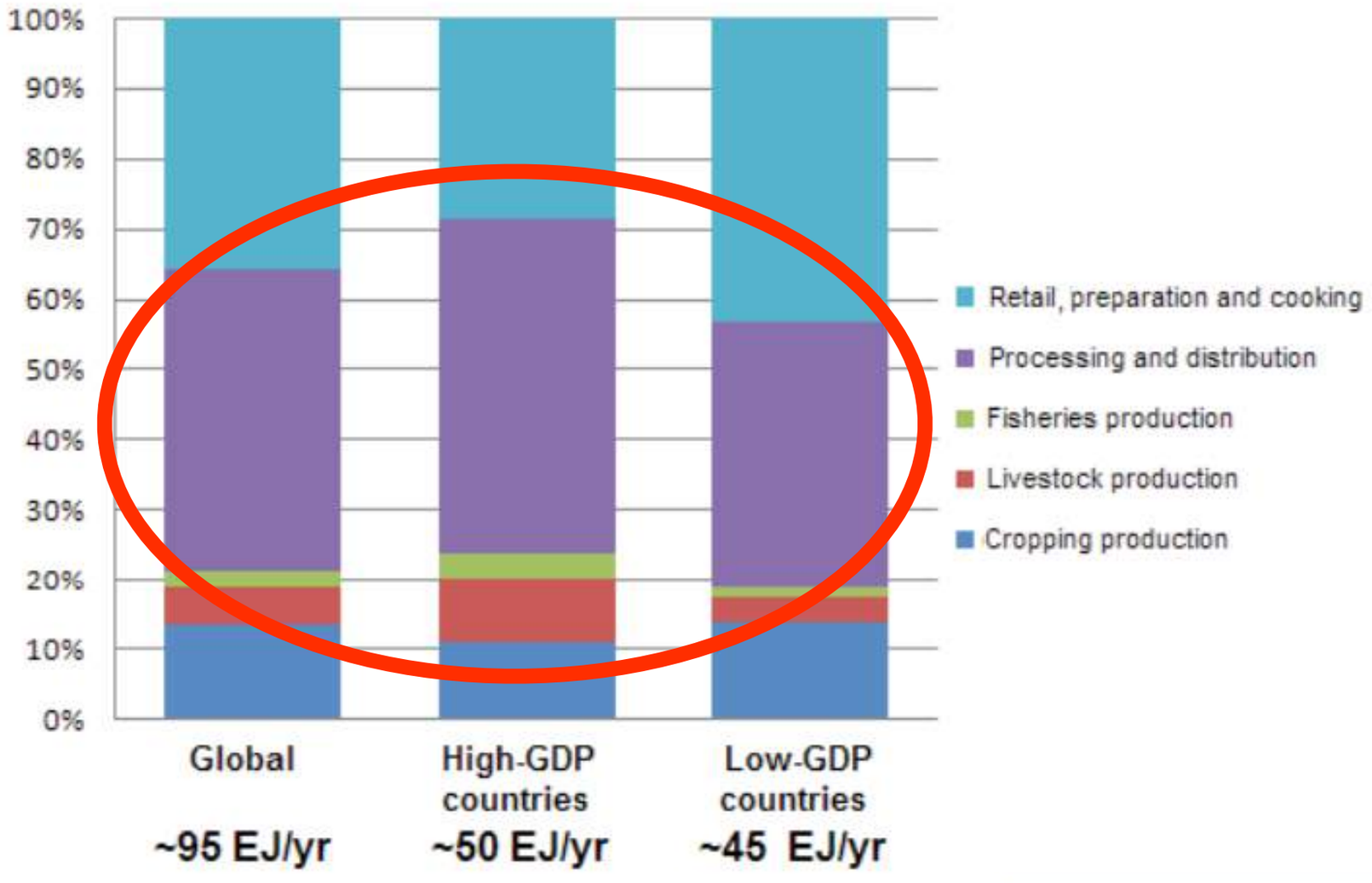
Future resource constraints on the global food system present a critical need for alternative farming methods

Challenge	Impact On Global Food System Towards 2050	Description Of Constraints
Energy	Food system uses 30% of total global primary energy consumption; majority of energy consumption is in processing and distribution	Limited reserves of non-renewable resources
Water	69% of total water withdrawals are committed to agriculture; food production will require 11% more water	Potential 40% shortfall in water by 2030
Land	Food production is projected to need 107 million ha more land	Remaining land available for agriculture is limited and located in countries with political instability
Climate Change	Food production may face 10% of yield decreases due to temperature increases	Total food production needs to increase by 60%

Works cited for statistics on slide 15

Processing and distribution of food is a key driver of energy consumption

Figure 6. Indication of global, shares of end-use energy demands throughout the food supply chain showing total final energy for the sector and a breakdown between high-GDP and low-GDP countries. (Based on Giampietro, 2002; Smil, 2008; IEA, 2010; Woods et al., 2010; GoS, 2011 and others)



Day, FAO Climate-Smart Knowledge. "Energy-smart food for people and climate." (2011).

Urban agri-tech's relevance to the Food-Energy-Water Nexus: its potential to sustainably complement traditional agriculture and "climate-proof" food security

Resource	Aerofarm Example
Energy	Developed a localized distribution system
Water	Uses 95% less water than traditional farming
Land	Farms on less than 1% of land
Soil	Leverages soil-less farming
Climate Change	Developed a controlled, closed farming system

Aerofarm's Technology

Singapore's unique urban environment: a case study for the future of farming

Unique Dense Urban Environment:

- 100% Urban
- .09% of land allocated for farming
- Total country size: 719 km^2
- Third highest in population density (7,807 people per square km)

Farming is Influenced By:

- Limited land (but still much unused space)
- Concern for externalities (water pollution, air quality)
- Available cheaper food sources overseas

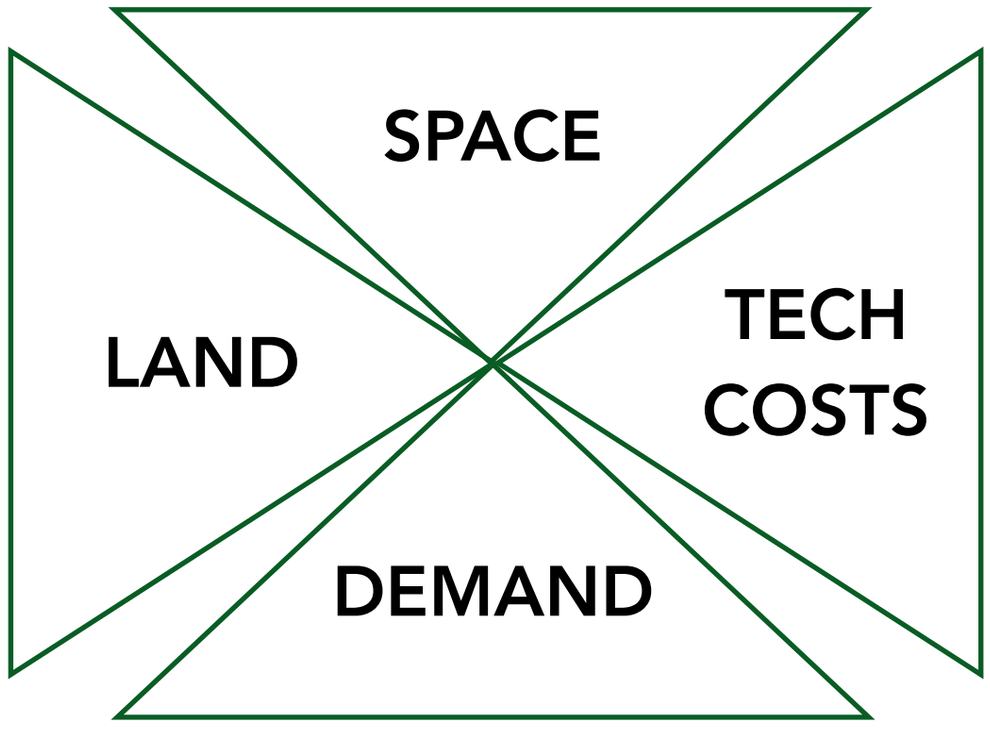
Singapore urban agriculture nexus: challenges and policy enablers

Under-utilized 1,000 hectares of rooftops in Singapore

Farming on rooftops

Rapid development displaced farmlands
Short 10 year lease

Ago-tech parks: 600 hectares for 200 farms
20 year lease



High tech adoption costs (ex. One A-Go-Grow tower costs ~ $11,000 USD)

2014 AVA Agriculture Productivity Fund: $63 Million

Premium price on locally grown produce and overall low consumer awareness can be barriers for consumers
Government funded campaigns

Sky Greens case study - technology

World's first low-carbon hydraulic driven urban vertical farm:

- Cultivation area: 36,500 m^2, 1,300 towers
- Output:1.8 Mil kg per yr at full capacity
- One A-Go-Grow Tower
  - 38 growing troughs
  - A-shaped 9 meters aluminum tower
  - 0.5 liters of water needed to rotate the structure
  - 40W of electricity

Benefits:

- Is 10x more productive than traditional farming
- Uses a fraction of water resources
- Has a low energy footprint

Sky Greens case study - business model

Primary sources of income:

- Supermarkets
  - FairPrice
    - Sells Nai Bai, Cai Xin, Xiao Bai Cai, Chinese Cabbage, Mao Bai, Lettuce, Bayam, Kai Lan, Kang Kong, and Spinach
- Exporting technologies for clients and partners
  - Established a 192-tower facility in Hainan, China
  - Opened up a 16-tower facility in Thailand
  - Will collaborate with farmers in other parts of China including Beijing, Fujian, Xi'an, and the Sino-Singapore Tianjin Eco-city

Panasonic case study - technology

Indoor LED lighting farm:

- Cultivation Area: 77 m^2
- Output: 907,185 kg / year
- Soil-based controlled farming (light, temperature, humidity and CO2)
- LED lighting that simulates blue and red sunlight rays necessary for photosynthesis

Benefits:

- Grows vegetables 2.5 times faster
- Uses 98% less water and 70% less fertilizer
- Mitigates farming risks through controlled environment
- Production all year round

Panasonic case study - business model

Primary sources of income:

- Hotels, restaurants and catering companies such as Resorts World Sentosa, Les Amis Restaurant and Ootoya Japanese Restaurant

- Initially sold premium Japanese crop varieties: mini red radish, red leafy lettuce and mizuna

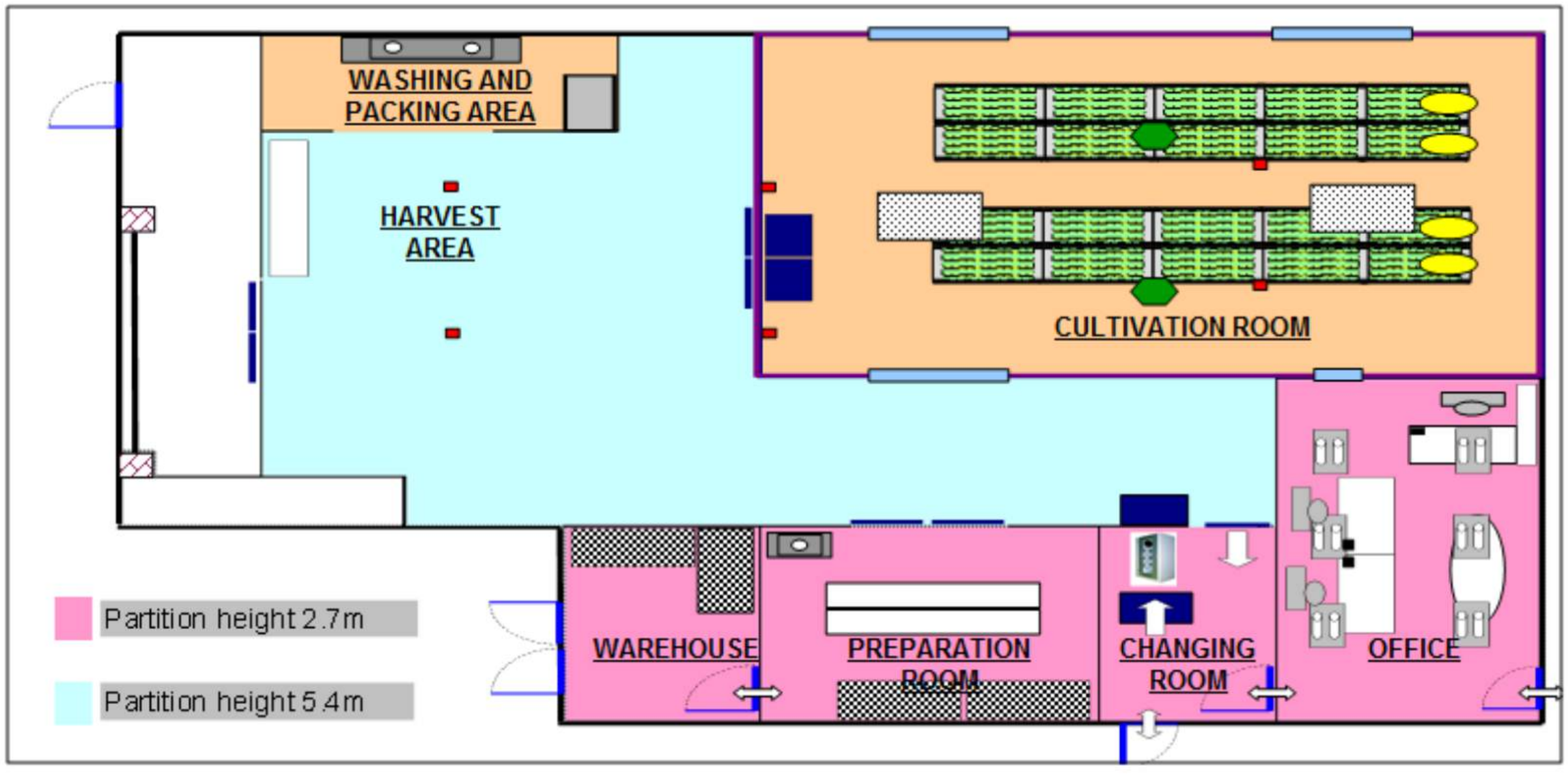
- Expanded to 30 varieties of vegetables

- Ready-to-go salads in grocery stores: Antioxidant Mix, Nourish Mix and Vibrant Mix

Challenges and lessons learned

Relevance	Challenges	Lessons Learned
Both	High Startup Costs • Panasonic: $2 Mil USD • Sky Greens: $18 Mil USD	• Hire purchase loans • Economies of scale • Multiple income streams
Open System Farms (Ex. Sky Greens)	Farming Risks • Pests • Disease Outbreaks	• Cross-disciplinary team • Operations • Plant Scientists • Engineering
Closed System Farms (Ex. Panasonic)	High Energy Costs	• Vertical integration

Panasonic farm's vertical integration



Contact information

- Stella Liu
- E-mail: stella.liu@fulbrightmail.org

WORKS CITED FOR STATISTICS

- **Energy Statistic:**

- Day, FAO Climate-Smart Knowledge. "Energy-smart food for people and climate." (2011).

- **Water Statistics:**

- Alexandratos, Nikos, and Jelle Bruinsma. World agriculture towards 2030/2050: the 2012 revision. No. 12-03. Rome, FAO: ESA Working paper, 2012.

- FAO. 2014. AQUASTAT database . http://www.fao.org/nr/aquastat

- Connor, Richard. The United Nations world water development report 2015: water for a sustainable world. Vol. 1. UNESCO Publishing, 2015.

- **Land Statistic:**

- Alexandratos, Nikos, and Jelle Bruinsma. World agriculture towards 2030/2050: the 2012 revision. No. 12-03. Rome, FAO: ESA Working paper, 2012.

- **Climate Change Statistic:**

- Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N. 2014. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change 4: 287 – 291.

- **Food Production Statistic:**

- Godfray, H. Charles J., John R. Beddington, Ian R. Crute, Lawrence Haddad, David Lawrence, James F. Muir, Jules Pretty, Sherman Robinson, Sandy M. Thomas, and Camilla Toulmin. "Food security: the challenge of feeding 9 billion people." science 327, no. 5967 (2010): 812-818.

REMAINING LAND AVAILABLE FOR AGRICULTURE IS LIMITED AND LOCATED IN COUNTRIES WITH POLITICAL INSTABILITY

Table 4.8 Total arable land in use: data and projections

	Arable land in use					Annual growth		
	1961/1963	2005/2007	2005/2007 adjusted	2030	2050	1961-2007	1991-2007	2005/2007-2050
	million ha					percent p.a.		
World	1 372	1 548	1 592	1 645	1 661	0.28	0.13	0.10
Developed countries	678	624	624	608	586	-0.17	-0.51	-0.14
Developing countries	693	923	968	1 036	1 075	0.65	0.60	0.24
idem excl. China and India	427	604	668	734	775	0.74	0.70	0.34
Sub-Saharan Africa	133	200	240	266	291	0.83	1.25	0.44
Latin America	105	167	202	235	251	0.98	0.61	0.49
Near East / North Africa	86	97	84	84	84	0.31	-0.17	0.00
South Asia	191	204	206	210	213	0.14	0.06	0.08
East Asia	178	255	236	241	236	0.93	0.87	0.00

Alexandratos, Nikos, and Jelle Bruinsma. *World agriculture towards 2030/2050: the 2012 revision*. No. 12-03. Rome, FAO: ESA Working paper, 2012.

PROJECTED LOCAL SEVERE WATER SHORTAGES IN AFRICA AND SOUTH ASIA

Table 4.11 Annual renewable water resources and irrigation water withdrawal

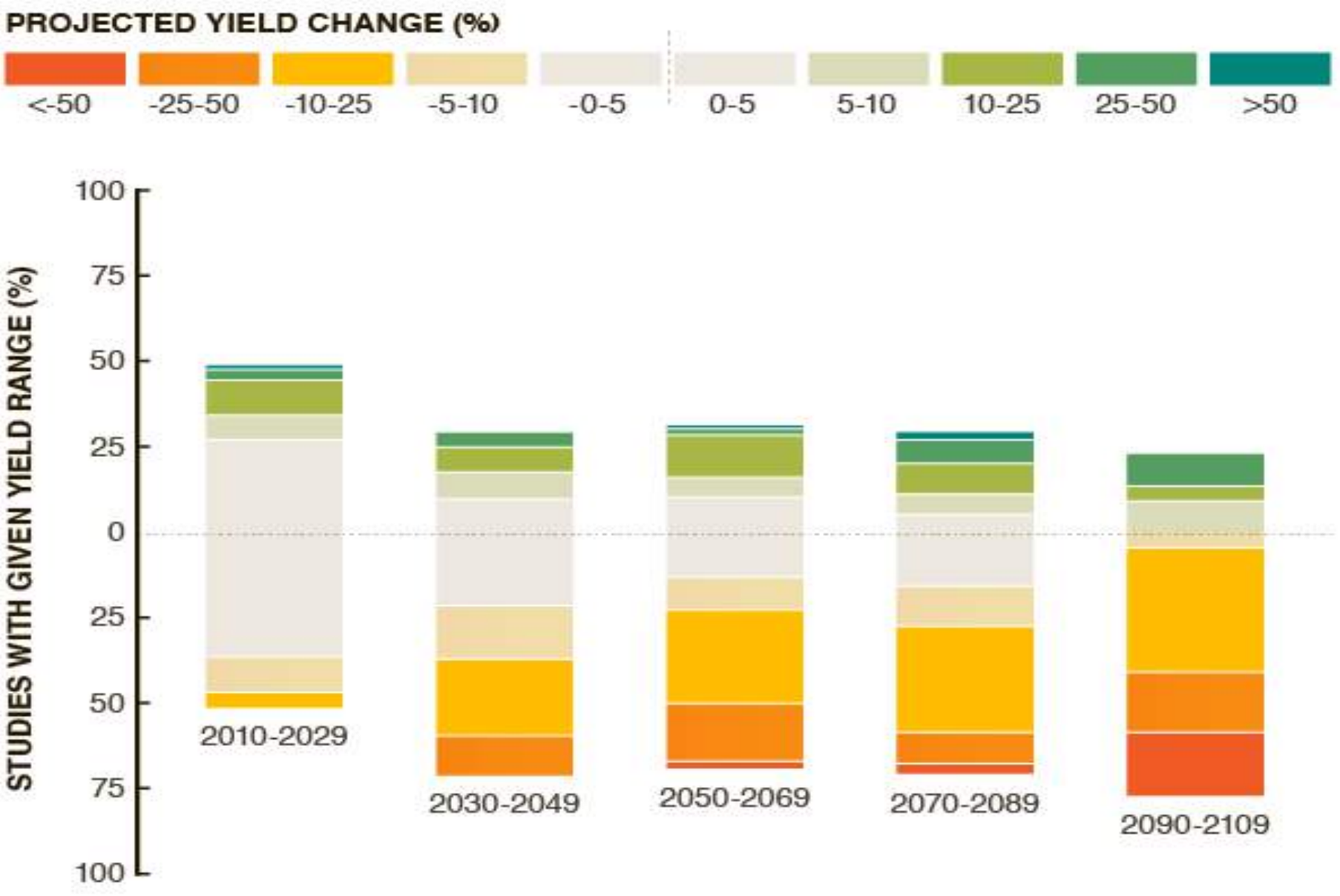
	Renewable water resources*	Water use efficiency ratio		Irrigation water withdrawal		Pressure on water resources due to irrigation	
		2005/2007	2050	2005/2007	2050	2005/2007	2050
	cubic km	percent		cubic km		percent	
World	42 000	50	51	2 761	2 926	6.6	7.0
Developed countries	14 000	41	42	550	560	3.9	4.0
Developing countries	28 000	52	53	2 211	2 366	7.9	8.5
Sub-Saharan Africa	3 500	25	30	96	133	2.7	3.8
Latin America	13 500	42	42	183	214	1.4	1.6
Near East/North Africa	600	56	65	311	325	51.8	54.1
South Asia	2 300	58	58	913	896	39.7	38.9
East Asia	8 600	49	50	708	799	8.2	9.3

* Includes at the regional level 'incoming flows'.

Alexandratos, Nikos, and Jelle Bruinsma. *World agriculture towards 2030/2050: the 2012 revision*. No. 12-03. Rome, FAO: ESA Working paper, 2012.

ESTIMATED 10% OF YIELD DECREASES DUE TO TEMPERATURE INCREASES

The majority of modeling studies agree that climate change impacts on crop yields will be negative from the 2030s onwards. Nearly half of projections beyond 2050 indicate yield **DECREASES GREATER THAN 10%.**

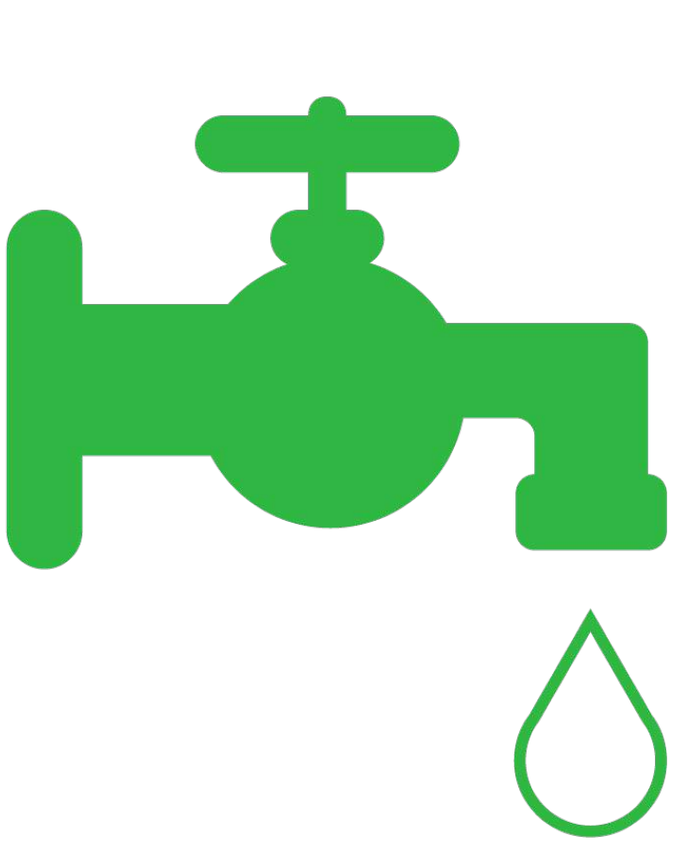


Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N. 2014. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change 4: 287 – 291.

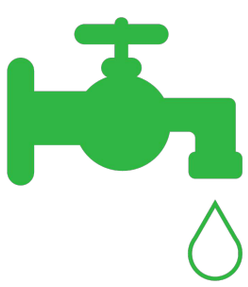
THE GOVERNMENT'S FOUR TAPS TO ENSURE FOOD SECURITY AND MITIGATE EMERGING RISKS

Four Taps

1. Food Imports (>90%)



2. Self Production (~10%)



3. Overseas Contract Farming

4. Reserves / Stockpiling

Risks

1. Climate Change
2. Volatility of Food Prices

LOCAL FOOD PRODUCTION TARGETS: STILL MAKING PROGRESS

Key Food Item	Local Production Targets	2015 Production	2010 Production
Eggs	30%	23%	22%
Leafy Vegetables	10%	4.5%	7%
Fish	15%	7.5%	4%