# The Future of Vertical Farming

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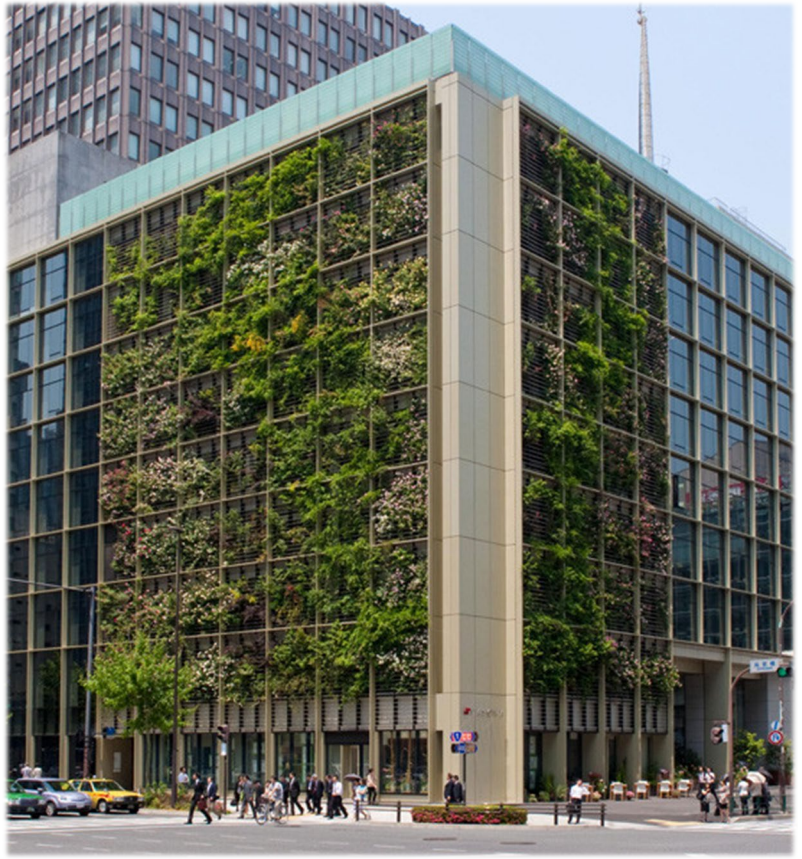


# Solving the Food Access Problem

***Can urban <u>vertical farming</u> help <u>solve</u> our growing crisis involving food mobility and availability?***

**Food Access Problem in Need of Global Solution:** Traditional farming production and distribution problems are complicating the provisioning of healthy produce to cities across the globe. A rise in food deserts is the result. There's a need to revamp our food production and distribution systems to ensure a future in which seamless access to food is possible wherever human habitats reside.

## COVID SHEDS LIGHT ON THE FRAGILITY OF OUR FOOD ECOSYSTEM


Left Photos: Lines of vehicles traveling to food banks during COVID (Dallas, TX)
Right Photos: Food spoilage due to transportation bottlenecks during COVID

## PROBLEM SOLVERS CONCEPTUALIZE AND DEVELOP VERTICAL FARMING SOLUTIONS


Depictions of urban vertical farming, from a close-up of actual stacks as in the photo on the top left to renderings of how stacks will be built into building facades in the future

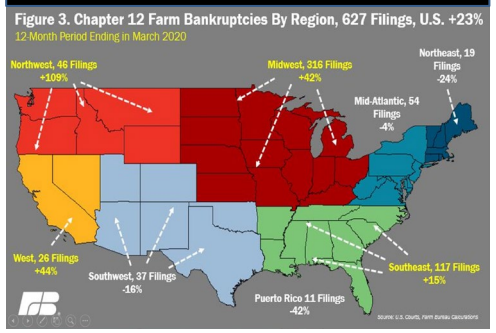
# Root Causes and Lifestyle Impacts of the Food Access Problem

The mobility of food is broken and food access faces production-side and consumer-side problems in need of creative solutions

## # People in Food Deserts

**23.5 million** people **live in food deserts**


## Farm Bankruptcy Stats

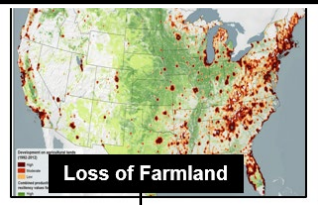



## Mobility Challenges


## Traditional Farming Problems Addressed by Urban Vertical Farming Solutions

### Root Causes of the Problem

**PRODUCTION-SIDE PROBLEMS**



**CONSUMER-SIDE PROBLEMS**




### Lifestyle Impacts

*Consumer-Level*

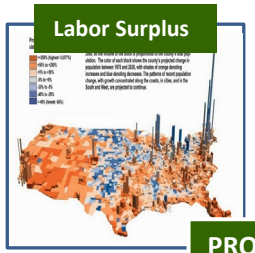
- Loss of Jobs
- Higher Prices
- Poor Access
- Increased Isolation
- Increased Obesity
- Low Affordability

*Society-Level*

- Increased Stress
- Insufficient Healthy Options
- Low Health Literacy
- Inadequate Health Monitoring

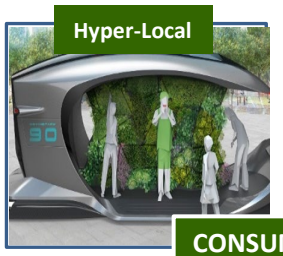
### Suggested Solution: Vertical Farming

**PRODUCTION-SIDE SOLUTIONS**






**CONSUMER-SIDE SOLUTIONS**





# Vertical Farming as a Solution: A Brief Introduction

Cultivating, harvesting and distributing produce (fruits, vegetables) in urban areas using indoor vertically stacked ecosystems

## HYDROPONICS

① **Hydroponic systems** are growing methods which substitute water for soil. Solutions are then added to the water to provide nutrients for a healthy yield.

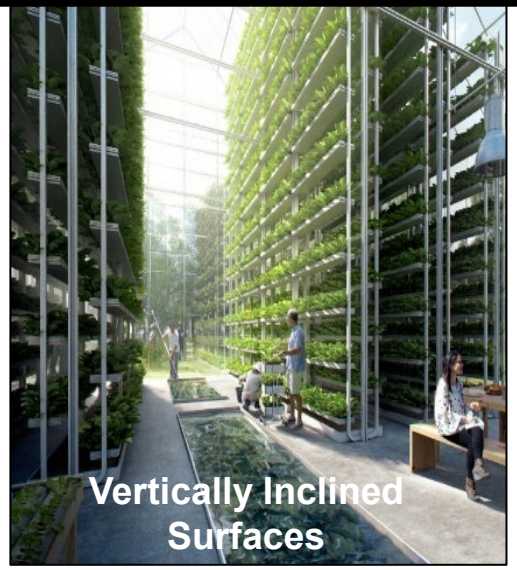
## MICRO-CLIMATE CONTROL

② ***Microclimate control systems** provide each plant in the greenhouse with a bubble of conditioned air, controlling temperature, CO2, and humidity levels.

## HYDROPONIC & MICRO-CLIMATE BENEFITS

- **99%** less land
- **98%** less water
- **99%** sunlight
- **Zero** crop loss

## TYPES OF "VERTICAL" FARMING



## SAMPLES OF WHAT CAN BE GROWN

- Superfoods (kale, spinach)
- Lettuces (butterhead, romaine, green and red oak, arugula)
- Microgreens
- Asian Greens
- Collard Greens
- Chards
- Culinary Herbs (basil, mint, oregano, chives, fennel, thyme, parsley, cilantro, etc.)
- Essential herbs (lavender, lemongrass, etc.)
- Melons
- Tomatoes
- Cucumbers
- Snap peas
- Celery
- Strawberries
- Peppers (all)
- Edible flowers - e.g. Nasturtium

***50+ varieties of produce (herbs, spinach, kale, vegetables, etc.)***

Source: Eden Green (Dallas, TX), *microclimate control systems developed by Eden Green and not part of all vertical farming solutions

# Why Vertical Farming? Visualizing Vertical Farming on our Horizon for Urban Areas

Traditional farming problems (H1) are giving rise to hyper-local production needs (H2) to reach a wellness-conscious (H3) yet increasingly food-insecure public

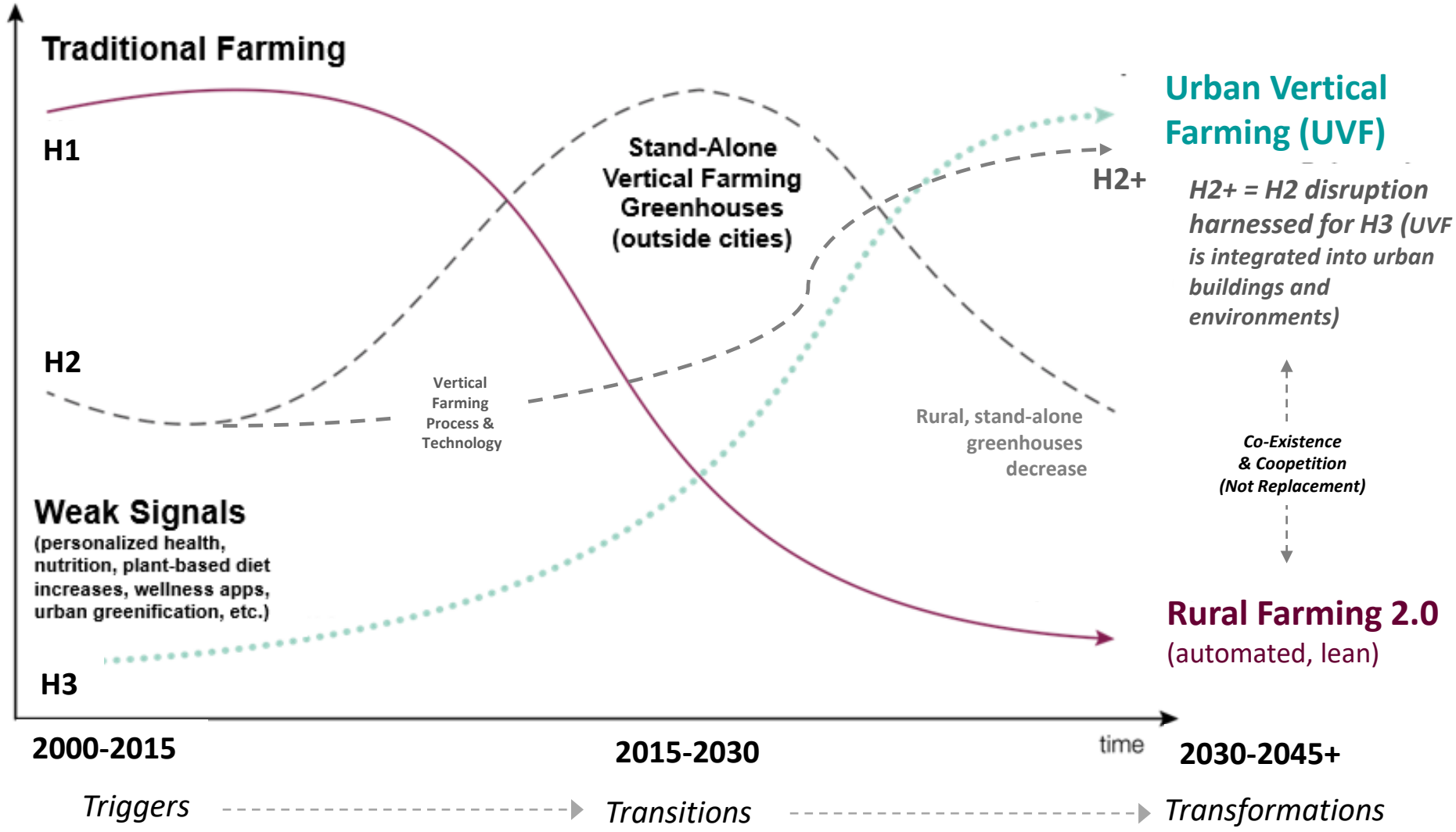
## THREE HORIZONS into Alternative Futures in Farming

**H1: Horizon 1**
*"Business as Usual"*

**H2: Horizon 2**
*"Disruptive Innovation"*

**H3: Horizon 3**
*"Emerging Future"*

Note: This Horizon Framework does not depict a "prediction", but rather shows future scenarios and the logic behind their formation (from triggers to transitions to transformations)



# Vertical What? Surveying Urban Public Perception of Vertical Farming

A survey revealed low public awareness and visibility but high potential and consideration of Vertical Farming as “the future of farming”

**1. How aware are you of vertical farming?**

*Awareness?* ***Low (47%)***

**2. How often do you see vertically farmed produce?**

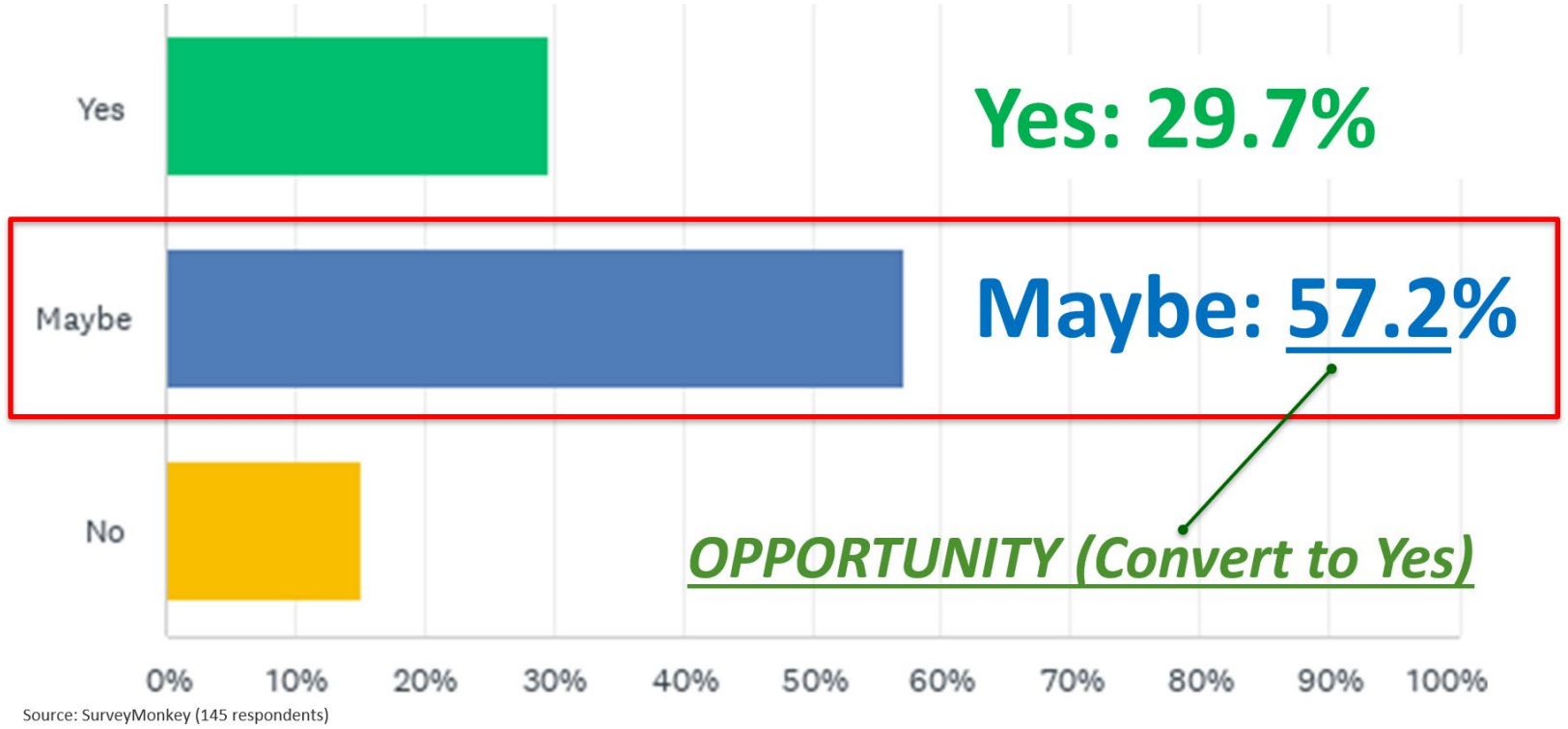
*Visibility?* ***Low (20%)***

***Low but rising fast?***

*“These numbers are low but double what we would have polled just a few years ago. This is actually encouraging.”*

- Vertical Farm CEO

**3. Do you believe that indoor vertical farms could be considered important to the future of farming?**




*Survey: 145 respondents (urban dwellers), U.S.-only*

# Getting Specific: Problems Behind Poor Food Access Addressed by Vertical Farming

*Vertical farming adds hyper-local food options that cut waste, promote holistic health, provide jobs and conserve environmental resources*

## Visualizing Problems

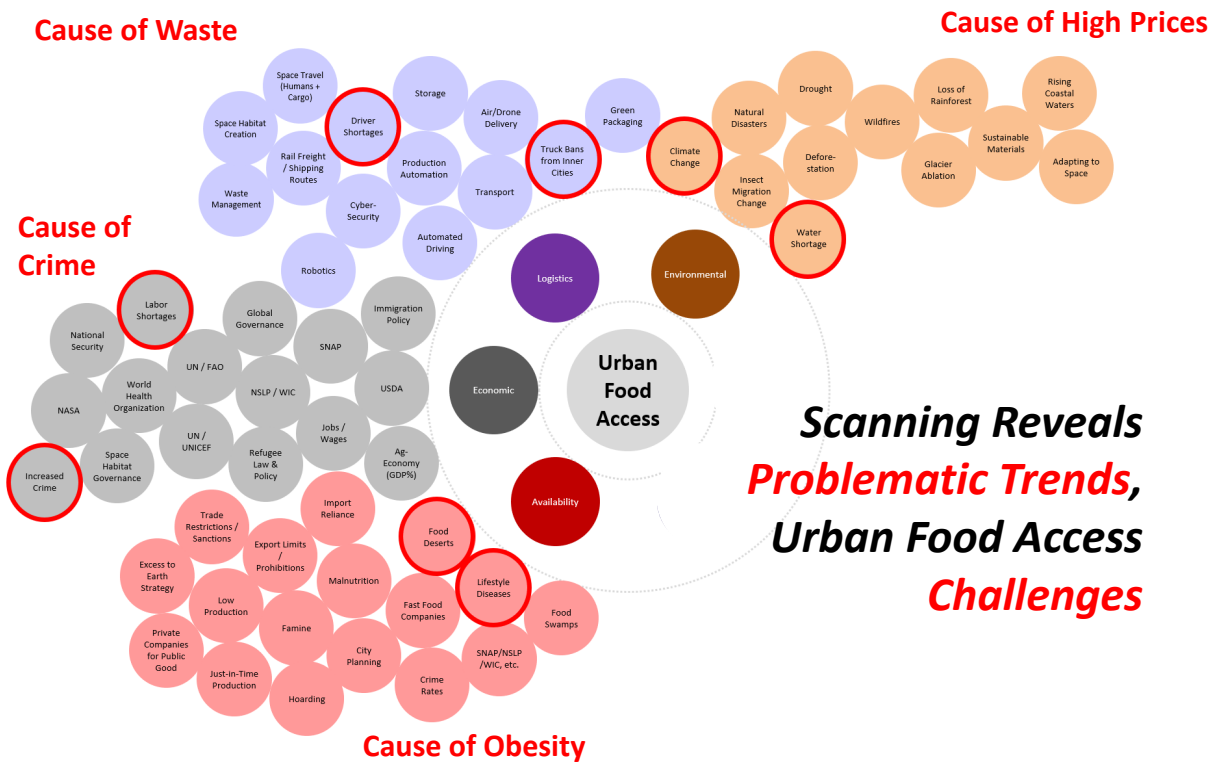
### Domain Map for Urban Food Access (with Traditional Farming)

Vertical Farming

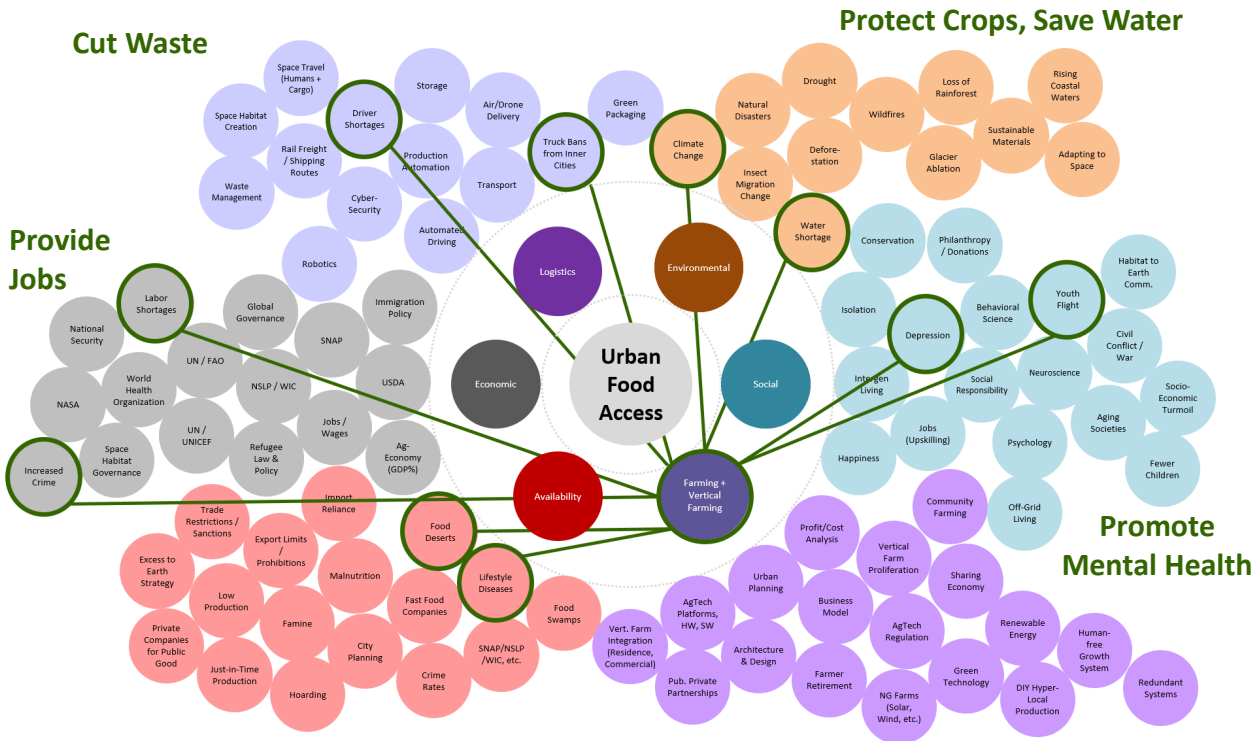
*Impact of Vertical Farming…*

## Visualizing Solutions

### Domain Map for Urban Food Access (with Vertical Farming)




***Scanning Reveals Problematic Trends, Urban Food Access Challenges***



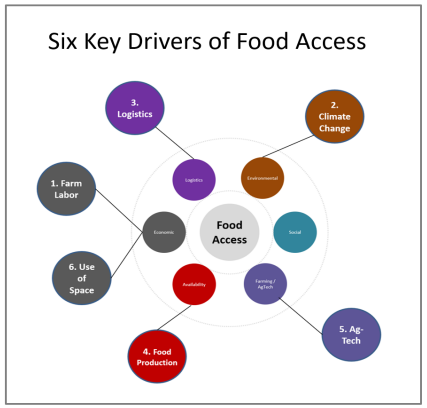
# Defining Future Scenarios: A 4-Step Approach

*We will define and map food access drivers, develop future scenarios based on driver performance, and analyze realization potential for each*

## ① FACTS

***What are the <u>biggest agents of change</u> when it comes to food access?***

### FOOD ACCESS AGENTS OF CHANGE

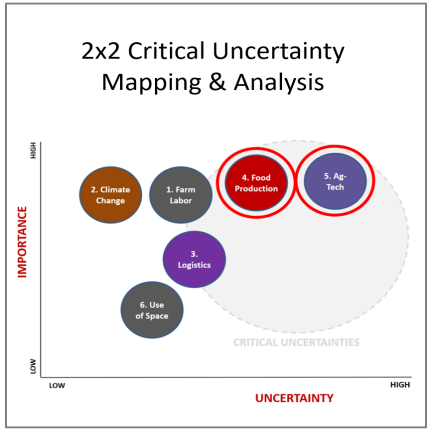



## ② PRIORITIES

***What is <u>most critical</u> and <u>most uncertain</u> among these agents of change?***

*(Select top 2)*

### CRITICAL UNCERTAINTIES

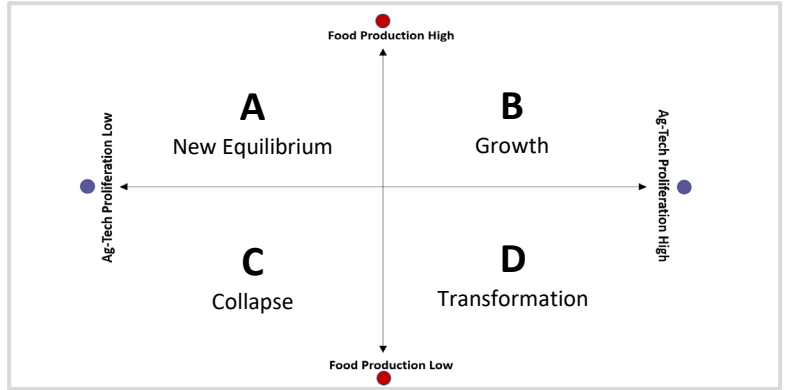



## ③ SCENARIOS

***What does a 2x2 analysis of these agents of change tell us about future scenarios?***

*(Four scenarios A-D)*

### 2X2 MATRIX FOR FUTURE SCENARIO BUILDING

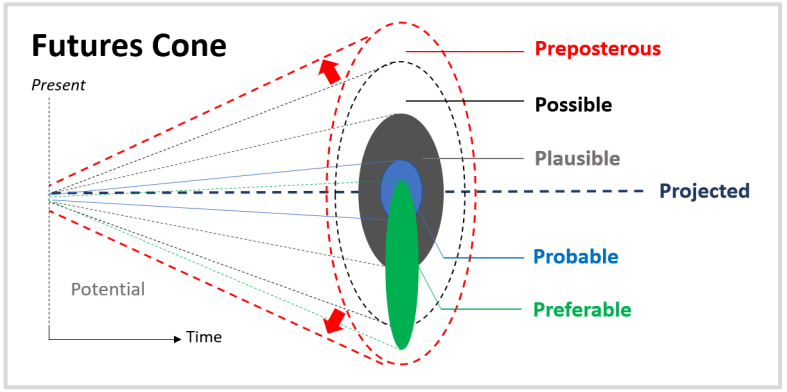



## ④ FUTURES

***What's the <u>potential</u> of each scenario <u>being realized</u> and <u>when</u>?***

*(2025-2045 & 2045-2065)*

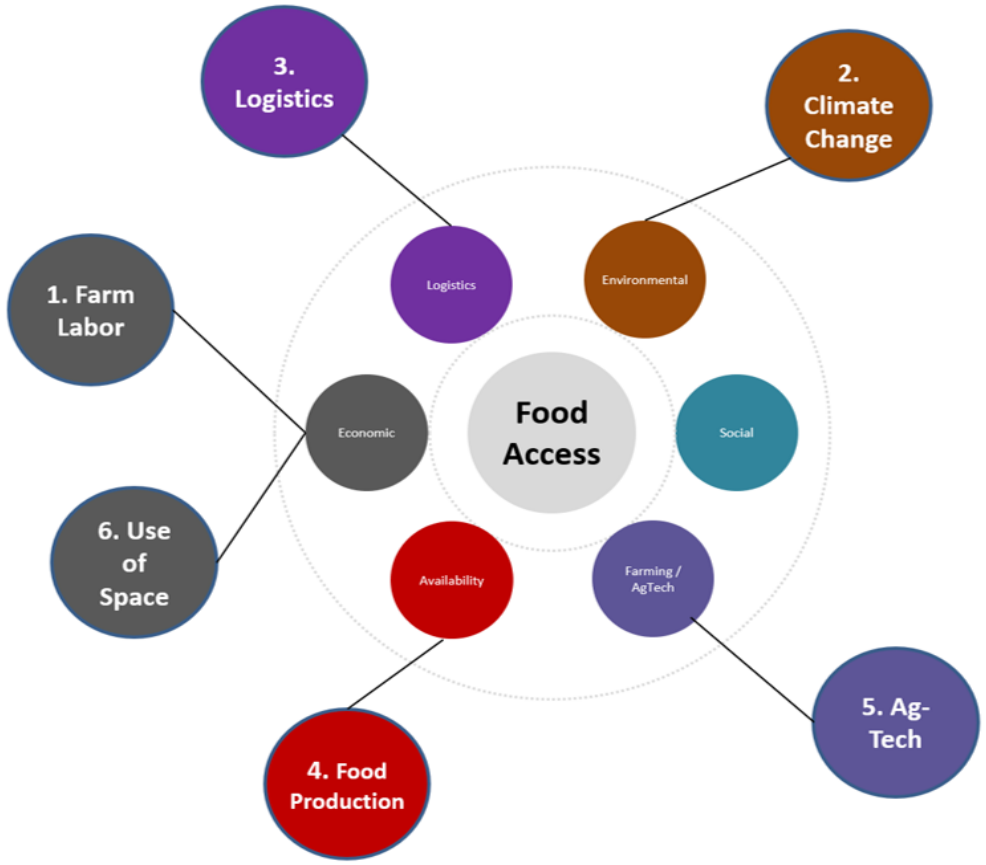
### FUTURES CONE TO ASSESS SCENARIO POTENTIAL



# ① FACTS: Defining Agents of Change

*Labor, climate change, logistics, food production, ag-tech and use of space are all key drivers that will drive the future of food access*

## Six Key Drivers of Food Access




| ① Farm Labor | ② Climate Change | ③ Logistics |
|---|---|---|
| Average age of farmers is near retirement age and youth aren't replacing them, stricter immigration policy further reducing ability to harvest, many farms having to fold. This driver is global. In Toyota's largest markets, the U.S. and Japan, it's becoming a significant problem. | Crops yields are decreasing because of a greater number of storms, from rising average temperatures and from changes in insect migration patterns. Climate change is forcing innovation in the farming space in attempts to cover production gaps stemming directly from climate change impacts. | The trucking industry is facing severe driver shortages. Poor wages, insufficient benefits lack of respect in the industry are driving the shortage globally. Problems with the global supply chain, evidenced by ocean port delays, compound the problem. Furthermore, trucks are being increasingly regulated out of city centers, leading to long-distance delivery delays. |

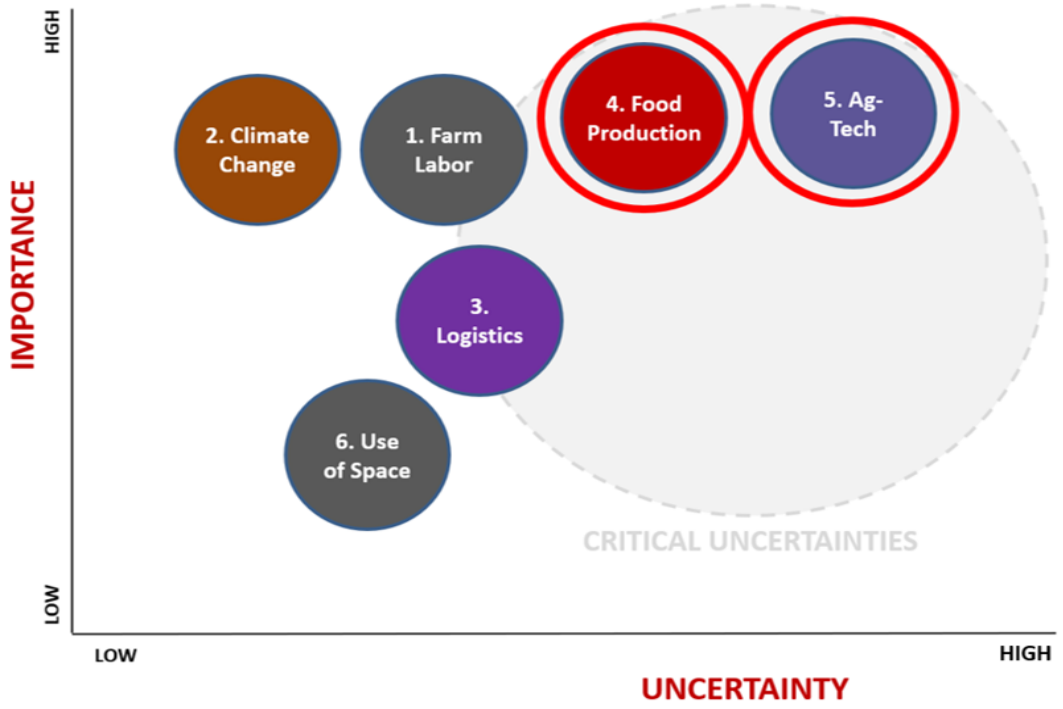
| ④ Food Production | ⑤ AgTech | ⑥ Use of Space |
|---|---|---|
| The most direct driver to food access is production. How much can be produced safely precedes all other drivers. Post-production challenges aside, the existing production ecosystem and supply chain drives availability first and foremost. | Production losses are forcing ag-tech innovation to improve farming efficiency. We're seeing connected devices, drone technologies, automation, robotics, computer vision, AI, among other technologies work their way into farming production ecosystems to improve profit outlooks for add longer term stability to production cycles. | In rural areas, farmland is being sold off to developers due to lack of profits. In urban areas, retailers are going out of business due to growth in online shopping. We're seeing more abandoned buildings and empty parking garages in these urban areas as a result. We're at a pivotal point in terms of rethinking land use for a new generation of consumers and services. |

# ② PRIORITIES: Defining the Most Uncertain and Important Change Agents to Food Access

*Food production and ag-tech are critical uncertainties and are key to analyze to define future food access scenarios (shown after this slide)*

## Critical Uncertainty Determinations
## (for 2x2 Matrix & Analysis)

*(see 2x2 Matrices on bottom left of next four slides)*



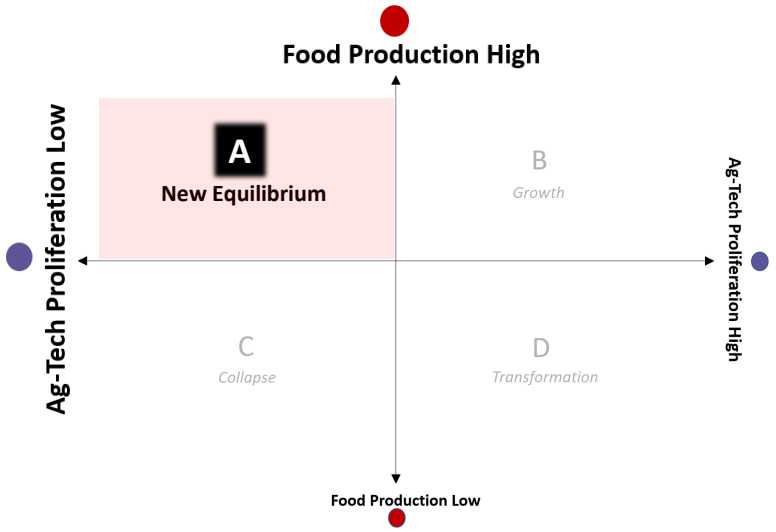

| DRIVER | IMPORTANCE | UNCERTAINTY |
|---|---|---|
| 1. Farm Labor | **Highly Important**<br>Human labor is highly important today but the degree to which ag-tech replaces labor needs will dictate the future level of importance. For now, it's high but such questions may pull labor down to moderate importance in the future. | **Moderate-to-Highly Uncertain**<br>Uncertainty varies significantly by region. Through a global lens we must consider all scenarios. Across all geographies, getting younger generations to work the farms is a growing challenge. Aging populations and retiring farmers is a global phenomenon. Varying legal restrictions by country impact level of uncertainty. |
| 2. Climate Change | **Highly Important**<br>Can we definitively state that climate change is causing farm failures? Many do and while there are several other factors involved, climate change is the root of several of these secondary factors, such as droughts, insect migration changes and flooding. Can't deny climate change is highly important. | **Moderately Uncertain**<br>It's tempting to place this immediately to low uncertainty but given the scope of related debates regarding climate change, out of respect for that debate, I'm placing this in middle and tagging it moderate. |
| 3. Logistics | **Moderate-to-Highly Important**<br>There's no doubt that truck driver shortages are crippling logistics, making this a highly important factor. However, even if drivers were fully available, the long delivery times are resulting in crop and revenue loss, dropping the importance judgement from highly to moderately high. | **Moderate-to-Highly Uncertain**<br>Logistics problems are unquestioned but the length of time that they will remain problematic is questioned. Uncertainty deemed moderate-to-high given unknowns about alternative measures for delivery that may alleviate bottlenecks in the future. |
| 4. Food Production | **Highly Important**<br>Limits to food production is at the core of food access and cost, making this a critically important driver. As food production trends go globally, so goes availability, which dictates food insecurity levels geography by geography. | **Highly Uncertain**<br>Food production has seen its share of chaos in recent years. Chaos has come post-production, further hindering access. There's an unmistakably high level of uncertainty regarding the future of traditional farming methods as a result. |
| 5. Ag-Tech | **Highly Important**<br>Innovation in farm technology is deemed highly important to the future of agriculture. The need stems from several factors such as fewer people in the workforce and the hardships imposed by climate change. | **Highly Uncertain**<br>It's tempting to place this immediately to low uncertainty but given the scope of related debates regarding climate change, out of respect for that debate, I'm placing this in middle and tagging it moderate. |
| 6. Use of Space | **Moderately Important**<br>As space becomes available by way of a failed business in a city or farm in a rural location, creative and practical considerations for reuse are growing in importance but deemed moderately important at this time. Many questions in need of answers, such as use case transitions and business models. | **Moderately Uncertain**<br>Unused urban space is on the rise, particularly post-COVID, but plans to re-purpose are mixed with wait-and-see attitudes. Why plan to fill space when people may not come back to cities in the same numbers post-COVID? Best to tag this as moderately uncertain for now. |

# ③ SCENARIOS (A. Ag-Tech Proliferation Low, Food Production High)

## New Equilibrium Scenario Narrative: *Traditional Farming Perseveres*

New incentive programs bring younger generations into the farm labor force, coupled with relaxed immigration policies that bring much needed migrant labor. Global hardship stemming from the pandemic, Ukraine conflict, economic recession and multiple natural disasters from climate change instill a disciplined "preservation" mentality among younger generations that infiltrates production processes, with one such process being food production. Ag-Tech developments continue but do not overtake production processes. Rather, they augment existing systems and add needed efficiencies to move product and profit margins to positive numbers. Significant gains in efficiency are seen in developing countries. We see increases in self-sustainability through the proliferation and perfection of existing farming techniques.

### 2x2 Matrix




### Drivers

- Jobs / wages
- Transport
- Policy development & planning (economic, immigration, climate, etc.)
- Community mindset

### Questions

- How will short-term "perseverance" stand up to longer term driver shortages, stricter immigration policies and natural disasters due to climate change?
- How will societal demographic changes (aging populations) impact this "perseverance" long-term?

### Enablers

- Farms re-establish profit margins
- Logistics bottlenecks remedied through policy to incentivize labor stickiness
- Collective global "preservation" mindset (allows humans to perfect what has worked to avoid collapse rather than gamble on what's new)

### Risks

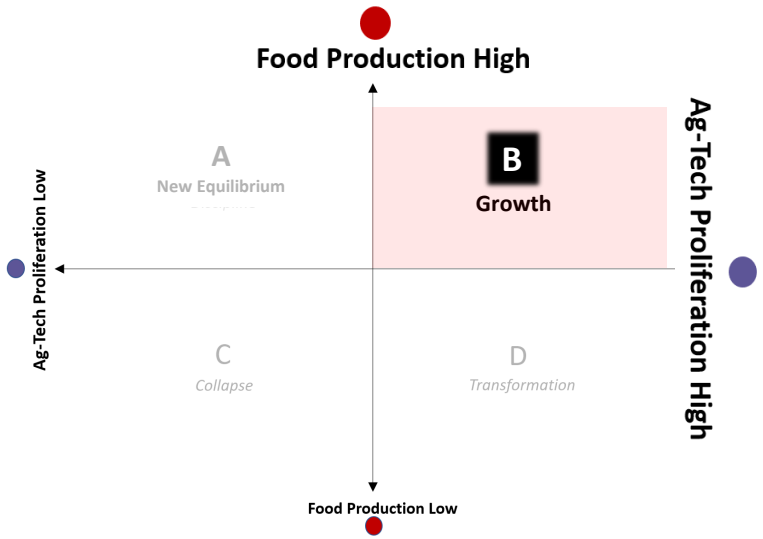
- Pest plagues
- Natural disasters

# ③ SCENARIOS (B. Ag-Tech Proliferation High, Food Production High)

## Growth Scenario Narrative: *Innovation is Our Salvation*

Mass adoption of agricultural technology takes place and the scale of production yield from new technology offsets development costs to make food more accessible globally. Advancements in renewable energy eliminate cost-preventiveness in production process deployment. Doubters remain but global acceptance of technology-enabled food production grows (significant automation in food production, distribution, storage, maintenance, monitoring and waste mitigation put in place and accepted globally). Several food production systems co-exist, as new urban production centers with a vertical farming focus join traditional farming, each playing a critical role in the overall provisioning process. “Coopetition” enables humans to work in harmony with machines to optimize food output for the good of all.

### 2x2 Matrix




### Drivers

- Agricultural tech + Vertical Farming
- Robotics
- Urban planning and design
- Renewable energy
- Other (sustainable materials, production automation, waste management, cyber security, global strategy for next-gen jobs)

### Questions

- Cyber-hacking and national security?
- Ag-tech system maintenance and security?
- System governance oversight?
- Equity in access to ag-tech by small-to-mid-to-large farm entities?

### Enablers

- Agtech to enhance food production efficiency
- Renewable energy
- Urban + rural food production systems
- “Coopetition”

### Risks

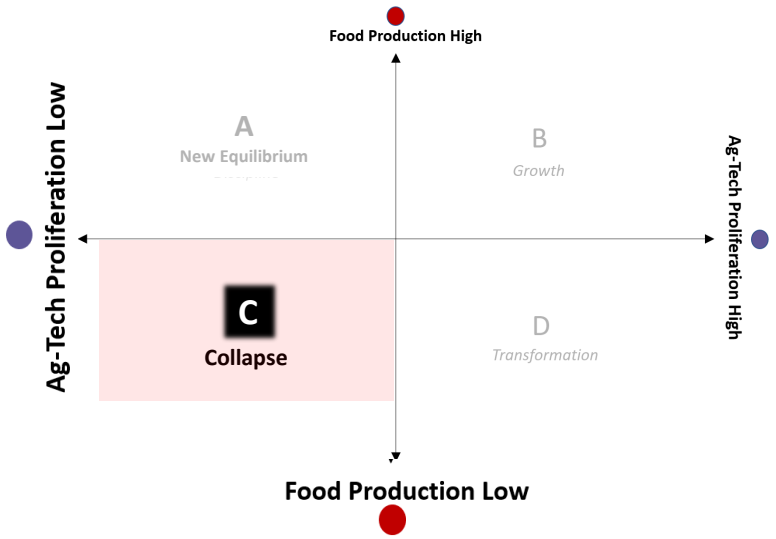
- Increased human detachment
- “Coopetition” collapse
- Technology-driven society

# ③ SCENARIOS (C. Ag-Tech Proliferation Low, Food Production Low)

## Collapse Scenario Narrative: *The Spread of Food Deserts*

Collapse characterizes this scenario as steps to remedy our broken global food ecosystem fail to consider the breadth of challenges negatively impacting it. People will continue to move from rural to urban areas, further decapitating traditional farm labor forces, a force already aging out into retirement. Farms continue to get hammered by increases in severe weather events and rising average temperatures. Measures to address climate change are slow and insufficient. Significant percentages of successfully harvested crops continue to be wasted due to inefficiencies and distances in delivery mechanisms. Localized urban production attempts are moderately successful but high prices limit their availability to those who can afford it hyper-locally. Increasing numbers of people work from home, limiting corporate footprints in urban areas, resulting in little incentive for investment. Food desert areas grow into full-blown urban deserts. Crime rates in these areas increase, further debilitating any chance of new investments to these areas. Haves vs. have nots grow in numbers and in degree of separation. Hoarding and looting become common. Society as we know it falls on the verge of total collapse.

### 2x2 Matrix




### Drivers

Inflation, food deserts food swamps, malnutrition, climate change, water shortages, drought, natural disasters, import reliance, growing wealth and digital divisions, inequity, increased conflict/crime, increased hoarding

### Questions

- National security issues?
- Crime rates and socio-economic turmoil?
- Human isolation/depression increase?
- Global famine/malnutrition trends?
- SNAP, NSLP, WIP?
- Refugee law & policy?
- Food deserts, food swamps?
- Lifestyle disease increases?

### Disablers

- Traditional farming collapse
- Political, social and digital divisions inhibit preventive policies to be enacted and technologies to be adopted to prevent food ecosystem collapse
- Food access battle heats up with large masses of lower income populations losing out to wealthier ones

### Risks

- Civil war/conflict
- Human extinction
- Spread of lifestyle diseases and malnutrition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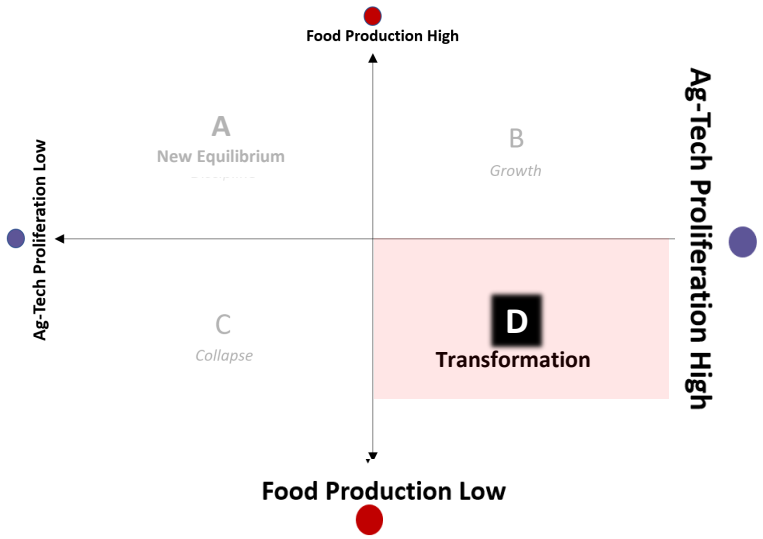
# ③ SCENARIOS (D. Ag-Tech Proliferation High, Food Production Low)

## Transformation Scenario Narrative: *Diet-by-Science*

Traditional farming continues to collapse under impacts from climate change, labor shortages and logistical bottlenecks. Regenerative agriculture efforts fail, global food crisis ensues calling for generational leap founded in new technology to solve growing global hunger crisis, transforming how we consume food and nutrients for survival. 3D printed and lab-generated food advancements bring new food sources to market that fill gaps out of necessity in some geographies, out of curiosity in others. Skeptics and supporters co-exist but the benefits of access outweigh safety concerns in markets of greatest dire need. Consumption, coupled with very few incidents of health problems tied to these new sources, broaden acceptance and trust. New generations of biodegradable packaging and food-replacement nutritional supplements reduce waste and widen the net of effective circular economies. The pain from food production losses resulting from failed traditional farms is eased by networks of urban production centers. Yield is lower but nutritional profiles are higher.

### 2x2 Matrix




### Drivers

- Agricultural technology
- Cellular agriculture
- Bio/Tissue engineering
- Molecular/synthetic biology
- 3D printing
- Computer/data science

### Questions

- Circular economy in play?
- Climate change unstoppable?
- 3D-printed or lab-produced food sources?
- Personalized consumption management?
- Next-gen nutritional supplements replacing food?

### Enablers

- 3D-printed or lab-generated food
- Food-free diets via hyper-personalized next-gen nutritional supplements
- Urbanized/localized food production (vertical farms, urban gardens, etc.)

### Risks

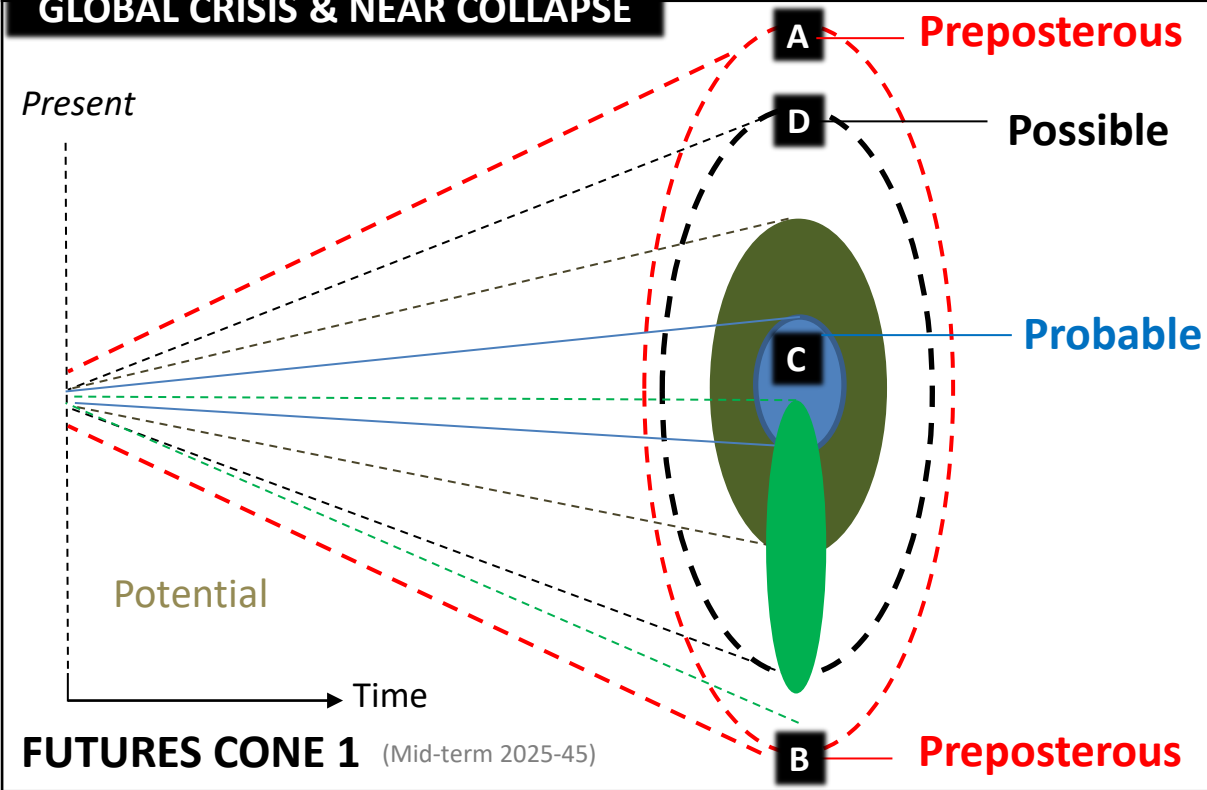
- Long-term unknown health consequences of lab-produced and/or 3D-printed food

# ④ FUTURES in VISUALS (2025-2045 and 2045-2065)

| SCENARIO | NARRATIVE | 2045 | 2065 |
|---|---|---|---|
| A | *Traditional Farming Perseveres* | Preposterous | Preposterous |
| B | *Innovation is Our Salvation* | Preposterous | Possible/Preferable |
| C | *The Spread of Food Deserts* | Probable | Plausible |
| D | *Diet-by-Science* | Possible | Plausible |

## 2025-2045 Scenario C The Spread of Food Deserts

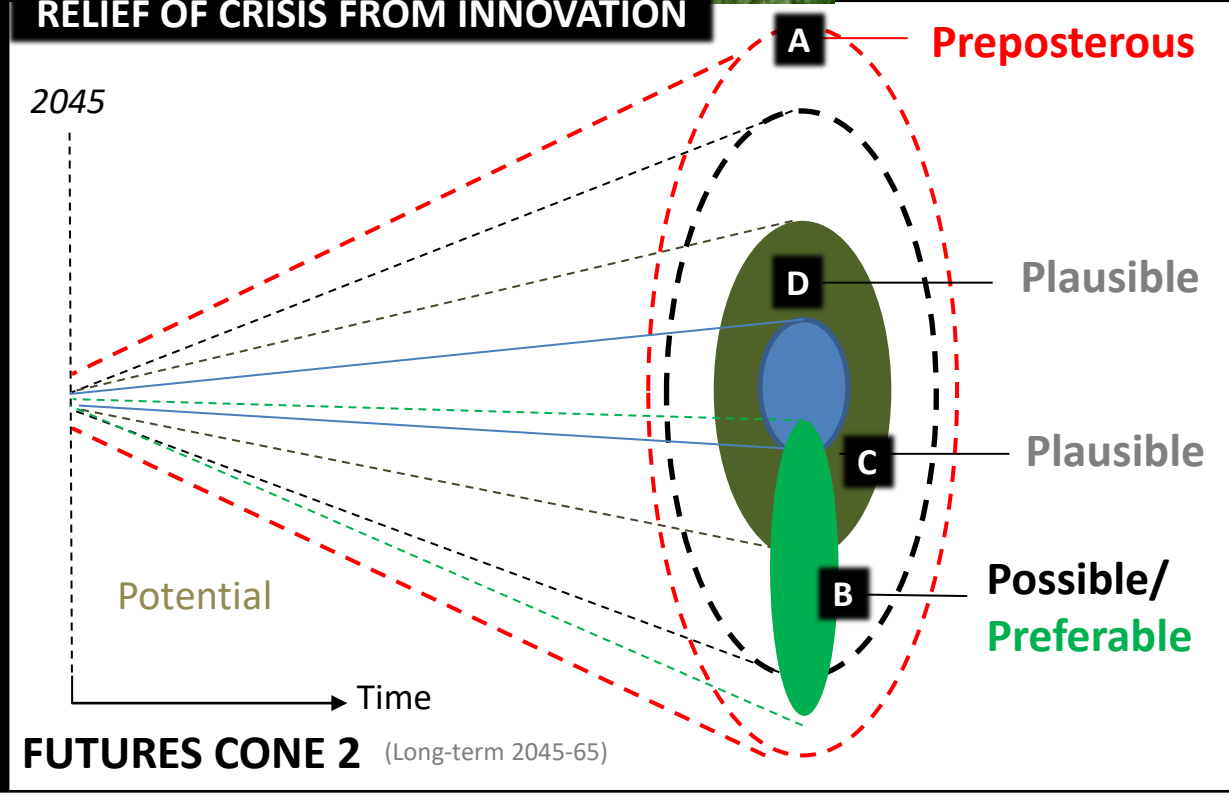
**GLOBAL CRISIS & NEAR COLLAPSE**




**FUTURES CONE 1** (Mid-term 2025-45)

## 2045-2065 Scenario B: Innovation is Our Salvation / Scenario D: Diet-on-Demand

**RELIEF OF CRISIS FROM INNOVATION**




**FUTURES CONE 2** (Long-term 2045-65)

# ④ FUTURES in WORDS (2025-2045 and 2045-2065)

## 2025-2045 Scenario C The Spread of Food Deserts

*(taken from p. 14 with modifications at end to align with 2045-65 scenario)*

*Collapse characterizes this scenario as steps to remedy our broken global food ecosystem fail to consider the breadth of challenges negatively impacting it. A collapse phase and mass failures in our global food ecosystem is experienced over the course of the next two decades, resulting in death and global conflict. People continue to move from rural to urban areas, further decapitating traditional farm labor forces, a force already aging out into retirement. Farms continue to get hammered by increases in severe weather events and rising average temperatures. Measures to address climate change are slow and insufficient. Significant percentages of successfully harvested crops continue to be wasted due to inefficiencies and distances in delivery mechanisms. Localized urban production attempts are moderately successful but high prices limit their availability to those who can afford it hyper-locally. Increasing numbers of people work from home, limiting corporate footprints in urban areas, resulting in little incentive for investment. Food desert areas grow into full-blown urban deserts. Crime rates in these areas increase, further debilitating any chance of new investments to these areas. Haves vs. have-nots grow in numbers and in degree of separation. Another pandemic pushes the world toward collapse but spurs successes in food innovation that finally gain traction from the late 30's onward, setting up our mid-40's "salvation" scenario.*

## 2045-2065 Scenario B Innovation is Our Salvation
## Scenario D Diet-on-Demand

*We will see a combination of impacts from two of the three remaining scenarios to ease the pain of a broken food ecosystem. Vertical farming will be integrated into urban settings. It will serve larger populations in warmer climates best, where solar power will make it more cost-effective. Automation, drone and robotics innovation will revolutionize vertical and traditional farming production and will reach the more remote countries and farming regions of the world. Global food crises of the late 2020's and 2030's will give birth to new food industry innovation. 3D-printed and lab-produced food will be realized but mass-consumption to be limited until well into the 2050's. Nutritional supplements will be personalized and micronized, enabling more targeted nutritional intake requiring less food to meet and maintain daily nutritional needs. Ocean city developments will introduce new forms of vertical farming, extending vertically in the ocean, revitalizing ocean ecosystems while providing new forms of food sources for life on land. The food crisis of the 2030's also gave rise to stronger tendencies toward independence and self-sustainability in lifestyles, making individually owned, managed and harvested indoor home gardens quite common, gardens that require little water and achieve multiple harvest cycles per year. For humans, life goes on but only after learning brutal lessons and suffering significant global human loss as a result of poor food access. Food deserts remain but nutritional innovation cuts hunger.*

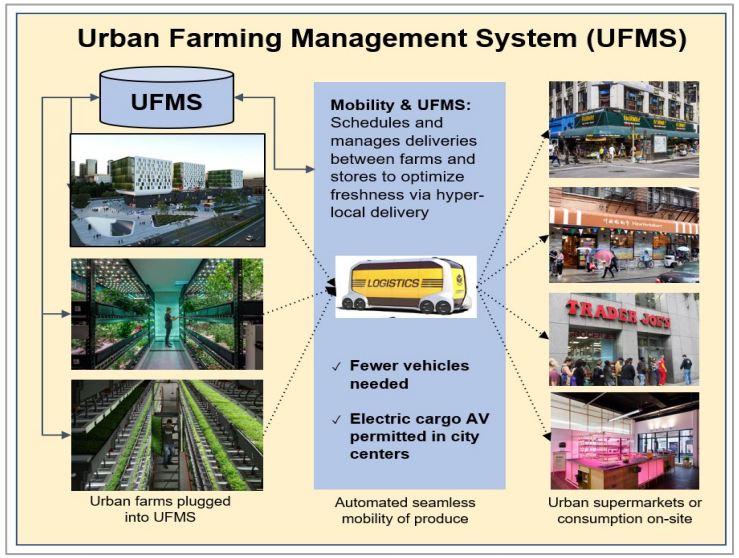
# Recommended Actions (Phase ① 2025-40; Phase ② 2040-55; Phase ③ 2055-2070)

*We will solve world food crises long-term by localizing production, developing a management system and extending system globally and beyond*

## PHASE ① LOCALIZE PRODUCTION

- ***Integrate vertical farms into residential and commercial urban infrastructure***
- ***Develop solar power, robotics, autonomous transport, computer vision and drone capabilities to add efficiencies***
- ***Trial and perfect production system and business model, expand as success allows***

## PHASE ② DEVELOP UFMS




- ***Develop an Urban Farming Management System (UFMS) that integrates latest ag-tech, food innovation, and Phase ① technology***
- ***Apply UFMS technologies as appropriate to traditional farming to add efficiencies***
- ***Tweak and further refine production + management systems and business model for different geographies, countries, etc.***

## PHASE ③ EXTEND GLOBALLY +


- ***Extend UFMS both in newly developed as well as older cities worldwide***
- ***Trial and implement UFMS as part of new ocean city developments worldwide***
- ***Initiate plans to incorporate UFMS system with appropriate modifications as part of space station food system planning***


(short video available in slide mode on next slide)

# What Vertical Farming Could Look Like…

## Video Introduction:
Vertical Farming Integration

*Video depicts a mock-up of a future vertical farming integration into a mixed commercial-residential city building*