Presentation at WRRC 2016 Annual Meeting
University of Arizona
Student Union Memorial Building
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Panel 1: Use of Technology to Enhance our Water Resource Portfolio

Energizing Controlled Environments Agriculture for Food & Water on Earth & Beyond

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While I'm certain we won't have time to get to all of these, the questions I will probably ask the panelists if the audience does not:

1) We have focused mainly on infrastructure technology. How can, or has, the use of vast computing capabilities and enterprise applications available to us today make, or made, a difference in how we enhance our water resources portfolio? (think in terms of real time monitoring of just about any parameter – flow, water quality, demand fluctuations, evapotranspiration, soil moisture, etc., or the integration of data from multiple sources to help make better decisions.)
2) Talk about the importance of proper operator training associated with the technologies you employ.
3) Do you experience any problems with the management of nutrients, salinity, hardness, or microbes in your technology applications, and if so, what do you do about it?
4) From your perspective as a practitioner, what should students be learning, and what should professors be teaching? Water is now an interdisciplinary issue that incorporates, engineering, physical science, social science, computing/electrical engineering, financial, and environmental disciplines. What are we missing? What kind of professionals are needed to develop the technologies needed to enhance our water resources portfolio?
5) A challenge for the next generation: What magical, un-invented technology that, if it existed, would help you extend or enhance our water resources portfolio?
6) How resilient to climate variability is your technology application? What impact does your technology have on greenhouse gases (an influence of climate variability). (Think in terms of chemicals, transportation, and power that is involved in your technology application).

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Power Sector Leader
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WATER IS OUR FOCUS, OUR BUSINESS, AND OUR PASSION

UA - Controlled Environment Agriculture Center

People focused on CE systems to help feed the world…..

Effectively using resources:

CEAC Students, Faculty, Staff, May 2014

- energy
- water
- nutrient
- labor
- capital resources

CEAC Tomatoes Live2.0! http://ag.arizona.edu/tomlive/GHmonitoring.html
CEAC Hydroponic Tomatoes in CEA http://ag.arizona.edu/tomlive/gh2091-A_idx.html

Controlled Environments for Food Production

"Controlled Environments — The Future of Economically viable, Environmentally reasonable and Socially acceptable Food Production"

and currently a worldwide development



No Ordinary Tomorrows https://www.youtube.com/watch?v=V02-msDXatI
The Center and Faculty Programs http://ag.arizona.edu/ceac/

Look to references!

Definition of CEA and Controlled Environment Plant Production Systems

CEA systems can produce
any plant, any where, at any time.

CE systems designed in many forms, such as:
Greenhouse
Growth room
Plant factory
Vertical farm

Multi-span Greenhouse

So. Pole Food Growth Chamber

Plant Factory

Agricultural Statistics

http://www.agcensus.usda.gov/Publications/2012/

Specialty Crop census 2015

516 nursery, greenhouse, and floriculture farms AZ (500 acres)

1945 vegetable farms (open field) in AZ (119,610 acres)

Specialty Crop census 2012

108 greenhouse farms of vegetables & fresh cut herbs AZ (2012)

26 greenhouse farms(2007)

400% increase in 5 years

12. Indoor Crop Production

Indoor Crop Production, Feeding the Future, Booklet from Indoor Ag white paper, March 2015

See pages 27, Case for GH Tomato – from 10% in '04 to 40+% in '11, USDA-ERS, Sept 2013

Page 36, the Investment Landscape - $51.59 M (2009 – 14) w/60% in 2014

Page 41, How Univ can Support – Fraunhafer Institute, 70% of income from industry contracts, demand driven, applied researcher, with scientific excellence"

See page 49, Crop Production Value by Crop, 2013, USDA-NASS – tomato $1.8B; 10 crops $12B

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A new survey of 370 urban farmers across the U.S., published this month in the *British Food Journal*.
The average urban farm sees sales of just under $54,000 a year;
although hydroponic operations earn more than double that and rooftop farms one-sixth;
1 in 3 urban farmers reported earning their living from their farms
study co-author Carolyn Dimitri, an economist in New York University's food studies department

THE SALT
Urban Farmers Say It's Time They Got Their Own Research Farms
Seventy-five percent of all farms in the U.S. post less than $50,000 a year in sales USDA;
many American farmers hold a second job, off-farm, obtaining from 10 to 83 percent of their incomes from 2nd job;

For fruit and vegetable farmers, off-farm earnings are 43% of their income;
field crop farmers earned nearly all their income—84 percent of it—by working off-farm.
average American farm was 434 acres in 2012, nearly 60 percent of all urban farms are less than 5 acres — and 20 percent are less than 1 acre

http://www.npr.org/sections/thesalt/2016/03/07/469500509/urban-farms-fuel-idealism-profits-not-so-much
http://traciemcmillan.com/articles/farmers-work-a-second-shift-to-supplement-income/

Indoor Crop Production

The greenhouse industry is rapidly growing sector of Arizona agriculture.
Famous for greenhouse tomato production

Arizona has a particular advantage in the greenhouse industry, for amount of natural light for plants during the winter months.

In 2015, 500 acres of greenhouse vegetables in Arizona, with commercial value of $738 million per year, approximately 2500 jobs, and a regional economic value of $2.2 billion per year.

Environment:

Less water used: 5 - 8 times, up to 27 times less water in greenhouse irrigation compared to open field irrigation

Lettuce Open Field: 163 – 490 gallons per head
Lettuce CEA Greenhouse: 1 - 1.5 gal per head;

Assumes, for Field: 2 lb / head; Yuma, AZ Sept – Dec crop, semi-arid region; 12 – 36 inches water per crop;@ 750, 24 head cartons lettuce / acre; 18 tons lettuce / acre, for Greenhouse: 5 – 8 oz. heads

Less land used: 10 – 11 times more production per sq ft per year in greenhouse than in open field; No need for 'quality' land; Urban Agriculture grow crops anywhere

Lettuce Open field -- 18 Tons/acre/yr
Lettuce CEA Greenhouse – 185 Tons/acre/yr

Assumes, for Greenhouse: 22 pl/m2 x 24 crops/yr x 160 g/pl x 50% space utilization x 4000 m2/acre x 2.2 lb/kg x 1 Ton/2000 lb] , or 42 kg/m2/yr, Cornell hydroponics, for Field: 18,000 heads per acre per season [1 season per year]; 2 lbs per head, Yuma, AZ

Environment:

Zero erosion base: soil conservation practices eliminate erosion around greenhouse enclosures/structures; crops are grown within containers, thus no soil erosion

Zero nutrient runoff: all plant nutrients applied to the crops are contained, recycled or reused

Zero pesticide: pest control by IPM (Integrated Pest Management) without need for chemical pesticides

Zero herbicide: weed control by exclusion with no need for chemical weed killers

Eliminates outdoor soil-borne diseases: disease control by exclusion and by IPM (Integrated Pest Management) without need for chemical pesticides

Statistics

Greenhouse Tomato - Irrigation water ROI in CEA compared to open field (dollar return per gallon of water invested) ranges from $0.20 - $0.12 per gallon for greenhouse tomato.

This equates to 39x and 125x the dollar return to the grower for their water input when compared to alfalfa ($0.0051 per gallon water) and cotton ($0.0016 per gallon water)

Here are sites for generating comparative data:

State data available for comparisons on nursery/greenhouse/shade structures:
2012:
http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Arizona/st04_1_041_041.pdf
2007:
http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_035_035.pdf
2002:
http://www.agcensus.usda.gov/Publications/2002/Volume_1,_Chapter_2_US_State_Level/st99_2_034_034.pdf

2014:
http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Census_of_Horticulture_Specialties/hortic_2_040_040.pdf
2009:
http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Census_of_Horticulture_Specialties/hortic_2_039_039.pdf

And, Eller site for Arizona Economy is a good source: (Also see Table 2 for Market value of agr. Products sold for state)
https://www.azeconomy.org/2014/09/featured/the-changing-face-of-agriculture-in-arizona/

Controlled Environment Plant Production Systems

Greenhouse Crop Production

Require:

Engineering, science & horticultural knowledge for technical success, and;

l and educated labor for
ction success, and;

ancial, marketing and sales
or economic success

Village Farms, Co. 'semi-closed' Greenhouse

photo credit: P. Selina

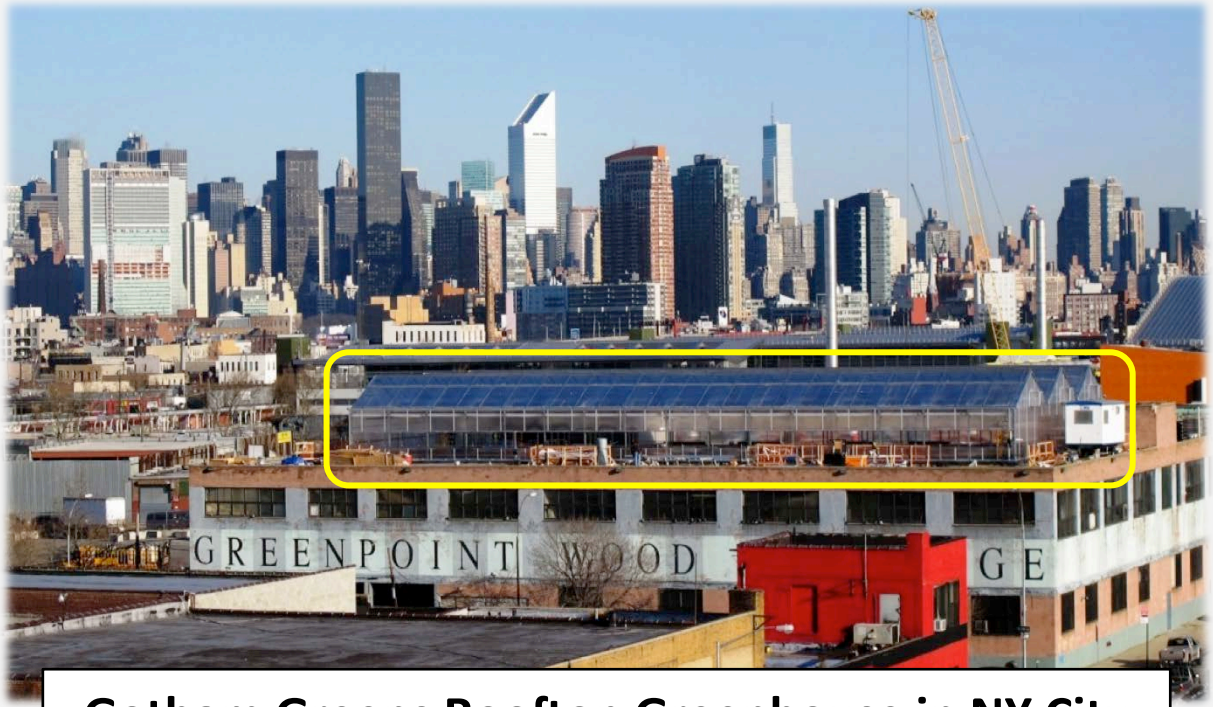
Annual Yields
100 kg/m^2 (20 lb/ft^2) 435 ton/acre

Village Farms http://www.villagefarms.com/default.aspx

Perspective of Controlled Environment Agriculture

Need for food nourishment (vitamins, minerals)

even for 'urban' situations where the people are…..



Gotham Greens Rooftop Greenhouse in NY City

photo credit: Gotham Greens

Complement to soil-based agriculture;

Not replacement of it!

Local Produce http://gothamgreens.com/

Rooftop Greenhouse Food Production

System

Gotham Greens, Brooklyn, NYC

Located on Whole Foods Market (20,000 ft², 1860 m²).

Commercial-scale greenhouse integrated into retail food store

Image courtesy Gotham Greens

Where Do Our Fresh Veggies Come From?

Open Field (soil)

90%

Yuma, Arizona Produces 90% USA Winter Greens

Greenhouse (sunlight)

10%

Greenhouse Hydroponic Lettuce

Hydronov, Inc
http://www.hydronov.com/

Indoor Building (electrical lamps)

<1%

Green Sense Farms Portage, Indiana

http://greensensefarms.com/produce/

Environment – Aerial and Root Zone

Aerial Environment

air temperature,

relative humidity,

CO_2, light,

air movement,

physical support,

labor access

Sand Culture
Drip irrigation

photo credits: M. Kacira

Environment – Aerial and Root Zone

Root Environment

water,

nutrients,

dissolved oxygen,

root temperature,

water flow,

no light,

physical support

Deep Water Culture
Floating rafts

Types of Controlled Environments

Greenhouse – indoor controlled environment (CE), with transparent cover, using sun energy lighting; commercially viable; low to high technology levels.

High Technology Greenhouse Technology
(Nature's Sweet Co.)

Low Cost "High Tunnel" Greenhouse Technology Production

Annual Yields
100 kg/m² (20 lb/ft²) 435 ton/acre

Nature's Sweet Tomatoes http://naturesweet.com/
High Tunnels http://hightunnels.org/

U.S. greenhouse edibles market to grow to over $4 billion by 2020

"The Growing US Greenhouse Produce Niche -- Capitalizing on High Tech Quality & Consistency"

According to a report released by Rabobank's Food & Agribusiness Research and Advisory group, the U.S. greenhouse produce industry has reached sales of over $3 billion and is estimated to continue to increase to over $4 billion by 2020. This growth has been driven in part by the need for more intensive production due to limited land, water and labor. The report tit

The Produce Niche--Capi

and point out that reducir

gree differentiating from l

hou se competition will b

The use production will lik

the ge to that growth will

whil use-grown products from lower-tech products. The report said the stricter labeling laws as well as making the public aware of U.S. and Canadian certification programs can aid in this education as well. Success in

Impactful Program Activities

Mycoculture program – Dr. Barry Pryor, SPLS
https://uanews.arizona.edu/story/how-plant-science-can-grow-small-business

A 30 x 16 ft greenhouse $50,000 gross yearly income

Oyster mushrooms for $10/lb retail
Shitake or lion's mane gourmet varieties for $18/lb retail

Greenhouse Production Systems for People

The Focus remains on the Plant……
so bring on the Biology

High quality & high yields;
Safe, Secure;
Pesticide-Free;
Efficient use of Land, Water, & Nutrients;
Predictable harvest

Controlled Precision Agriculture

Summary of Challenges

Educated people – producer, consumer, distributor

Water - availability, quality, re-use

Energy - solar, renewable, light

Plant Nutrients - inorganic, organic

Finances - powering change

Market & Social Development - powering change

List of Web References

No Ordinary Tomorrows https://www.youtube.com/watch?v=V02-msDXatI
The Center and Faculty Programs http://ag.arizona.edu/ceac/
CEAC Tomatoes Live2.0! http://ag.arizona.edu/tomlive/GHmonitoring.html
CEAC Hydroponic Tomatoes in CEA http://ag.arizona.edu/tomlive/gh2091-A_idx.html
Village Farms http://www.villagefarms.com/default.aspx
Hydronov, Inc http://www.hydronov.com/
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Intro Hydroponics & CEA http://ag.arizona.edu/ceac/pls-217-introduction-hydroponics-and-cea
Aquaponics: http://ag.arizona.edu/ceac/sites/ag.arizona.edu.ceac/files/UA_Aquaponcs.pdf
http://community.theaquaponicsource.com/video/aquaponics-multi-crop-systems-regenerate-global-coasts
Nature's Sweet Tomatoes http://naturesweet.com/
High Tunnels http://hightunnels.org/
Plant Factory http://bt.e-ditionsbyfry.com/display_article.php?id=1327146
Green Sense Farms http://greensensefarms.com/produce/
Challenges in Vertical Farming Workshop, 2012:
http://www.bing.com/videos/search?q=gene+giacomelli+video&FORM=VIRE5#view=detail&mid=4D8EC3E49966FC3A92794D8EC3E49966FC3A9279
Local Produce http://gothamgreens.com/

List of Web References

Lufa Farms
http://www.hortidaily.com/article/3248/Canada-Lufa-Farms-to-open-second-large-urban-farm-this-week
SPFGC http://ag.arizona.edu/ceac/south-pole ;
SPFGC Description
http://ag.arizona.edu/ceac/sites/ag.arizona.edu.ceac/files/final%20SPFGC%20Habitation%202003%20talk%20giacomelli.pdf
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LGH Moon deployment http://www.youtube.com/watch?v=Z-0qJ4eZhs4&feature=related
LGH Description http://www.youtube.com/watch?v=Q128I9KNY9k
Earthlight Documentary http://cals.arizona.edu/earthlight/
NASA Steckler Space Grant Program http://ag.arizona.edu/lunargreenhouse/

For Further Information

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Prof. Gene Giacomelli is a faculty member within the Department of Agricultural and Biosystems Engineering at The University of Arizona, and Director of the Controlled Environment Agriculture Center. Giacomelli has gained international reputation through his pioneering work and expertise in the area of protected crops. Growing food on other planets is one of the collaborative international projects that he is leading, which is supported by the NASA Space Grant Consortium at the University of Arizona. The focus is efficient use of water, energy and other resources for implementation of a food and life support system for Moon/Mars. The results from this project will be applied to Earth protected agriculture food production systems."

For Further Information

The CEAC (Controlled Environment Agriculture Center) and The University of Arizona are dedicated to development of CE (Controlled Environment) technologies and worldwide applications, and for educating young people about the science and engineering of CE and hydroponic food support systems, and the other CE applications.

We will implement an interactive outreach and educational program to promote the benefits of CE for food production for modern agriculture, as well as, the new technologies of CE for enhancing, restoring, and maintaining critical earth life systems and human quality of life scenarios.

CE systems will be developed to help feed the world, while utilizing energy, labor and water resources effectively, and CE will become the platform for applications of new technologies using plant physiological processes [biomass fuels]; for space colonization life support [recycling all resources]; for remediation of air [carbon sequestration] and water [salts, heavy metals]; and for phytochemicals and plant-made pharmaceuticals [lycopene, vaccines].

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