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MESA LAB

Towards WATERSTAR:

Low Cost Scientific Data Drones for Agricultural Water Efficiency

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Cal Biochar Association Meeting

9:00-12:00 February 14, 2017. Tuesday

UC Merced Castle Research Facility, Atwater, CA

Brain food

Parallel: Energy Efficiency vs Water Efficiency

When we can file-n-fly?!

The new era of **Personal** Remote Sensing (PRS)!

Let us call it "**Wright Brothers 2.0**" age

An Analogy

- 1970s: **Personal** Computer (PC): Bill Gates/Steve Jobs
- 2010s: **Personal** Remote Sensing (PRS) - ????
  - Low cost, affordable. Robust, safe, easy to use
  - Run way free; Autonomous/cognitive
  - Swarm/coven;
  - Enabling new apps and services
    - Google 4D map (x,y,z,t) paid service
  - Ubiquitous remote sensing (Twitter as sensors …)
  - …

Drones for Farmers: Reality Check

http://www.precisionag.com/article/35499/precision-ag-2013-top-5-technologies-to-watch

1. Smart devices (smart phones)
2. continuing quest for data solutions or integration
3. variable-rate application (VRA) seeding (based on grid soil tests and seed plots)
4. in-cab solutions http://www.stratum.ie/Glossary (hardware or software solutions available to the truck driver)
5. **Drones (UAVs) (new in 2013 top 5 list)**

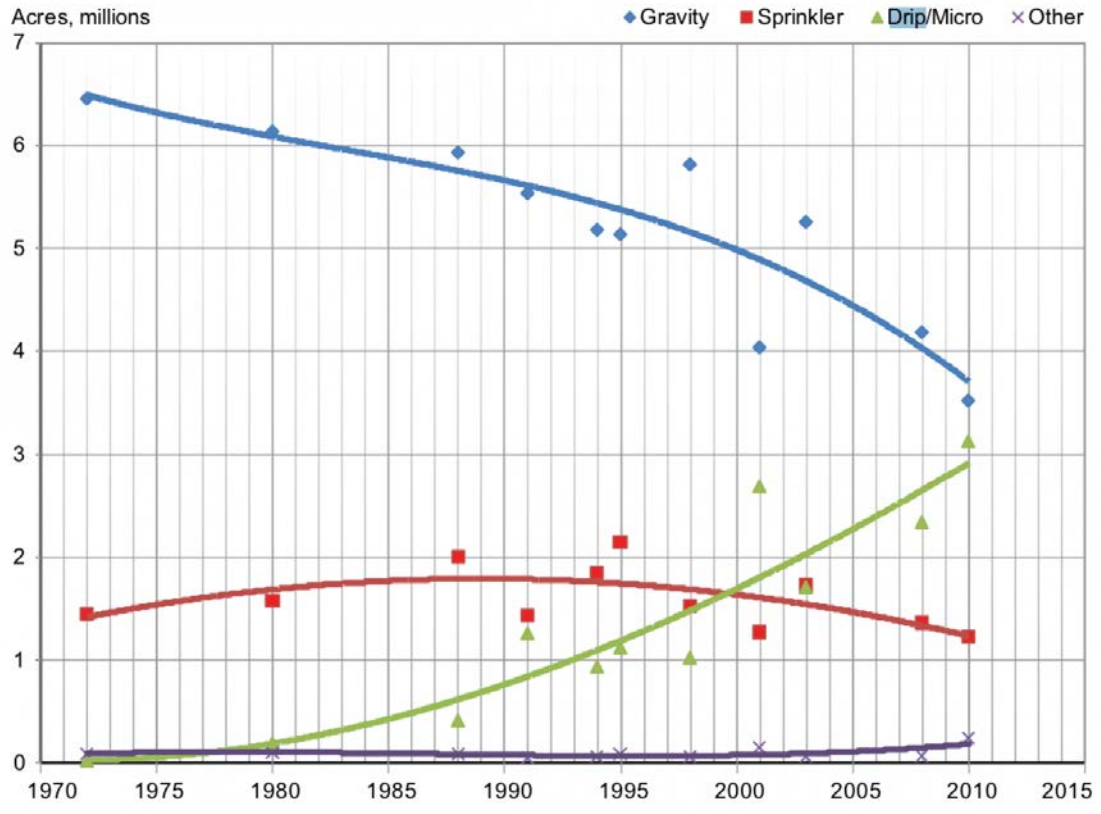
http://www.precisionag.com/guidance/variable-rate/2014-precision-ag-top-5-technologies/

1. **Unmanned Aerial Vehicles (UAVS)**
2. VRA Seeding
3. Data Solutions
4. Smart Devices
5. In Cab Solutions

80% water used in ag in CA

http://www.washingtonpost.com/blogs/govbeat/wp/2015/04/03/agriculture-is-80-percent-of-water-use-in-california-why-arent-farmers-being-forced-to-cut-back/

Figure 2-3 Change in Irrigation Methods in California (1977-2010)



More fine-grained controls

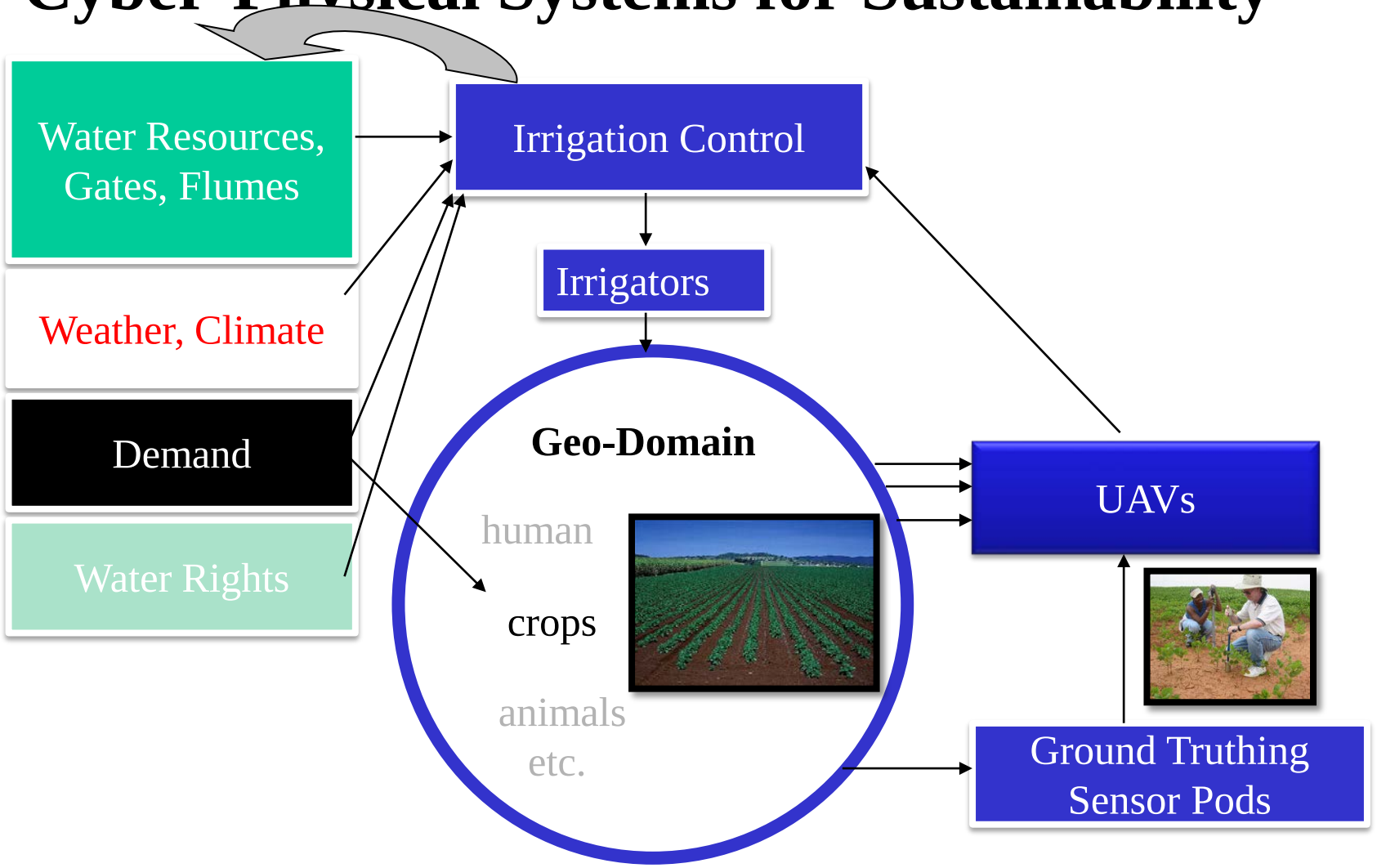
How to make sure

- **R**ight time?
- **R**ight amount?
- **R**ight place?

Drones as scientific flying sensors

Data to Decision to Action to Data

Cyber-Physical Systems for Sustainability



Credit: Dr. YangQuan Chen, 2005

UAS based scientific measurements enable new water management practices for much improved sustainability

"Sustainability of observations" – Jeanine Jones, 9/22/15 UAS for Cal Water Resource Summit, UC Davis.

Improved *sustainability of observations* for improved sustainability

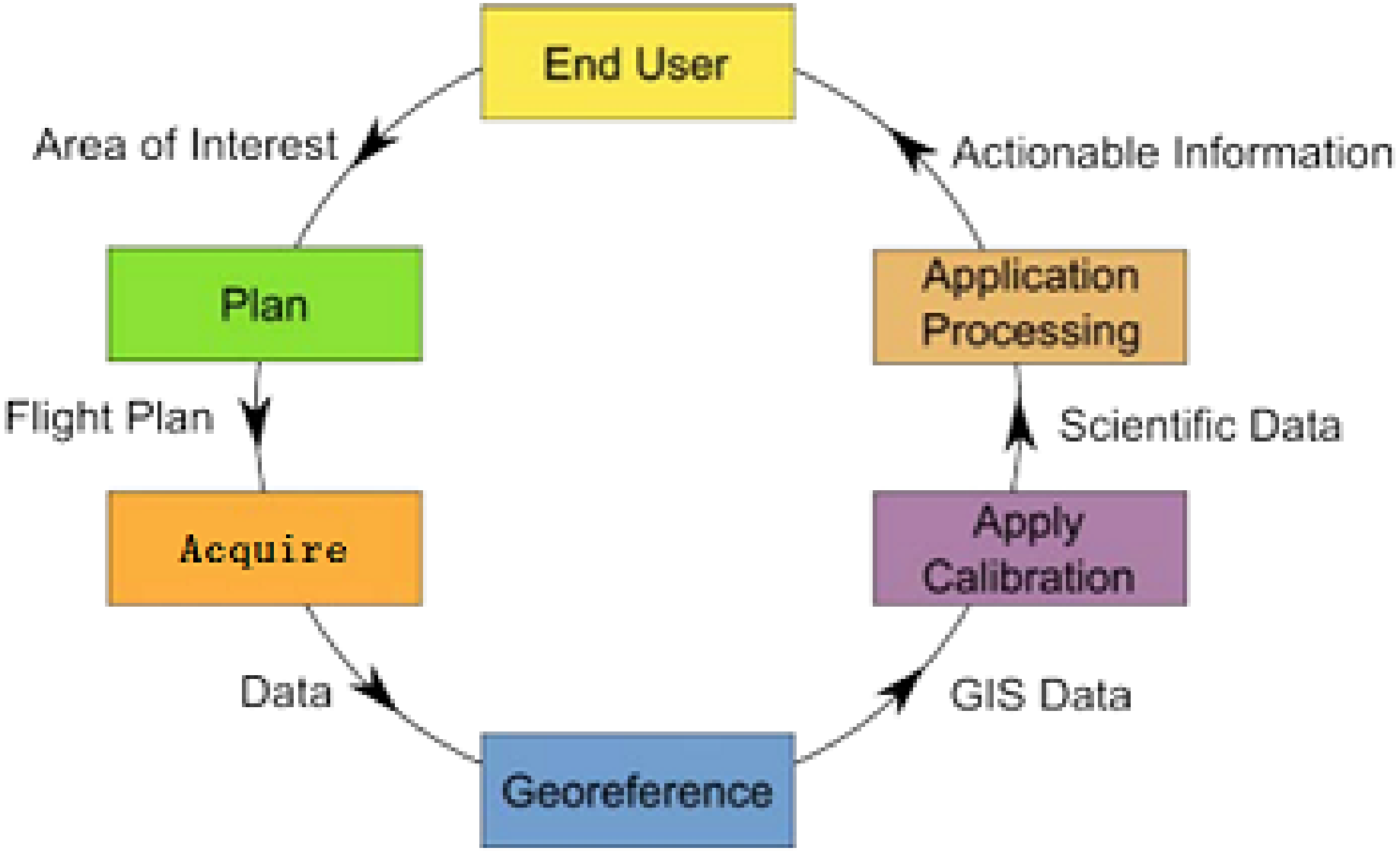
Right Time to Discuss UAS for Water Resources Management

Outline

- **UC Merced Scientific Data Drones Research**
  - **Overview**
  - **Related Projects**
- A Vision Towards WATERSTAR
  - Biomass, Biochar, Soil Amendments, Drone-assisted Assessment (M&V: measurement and verification)

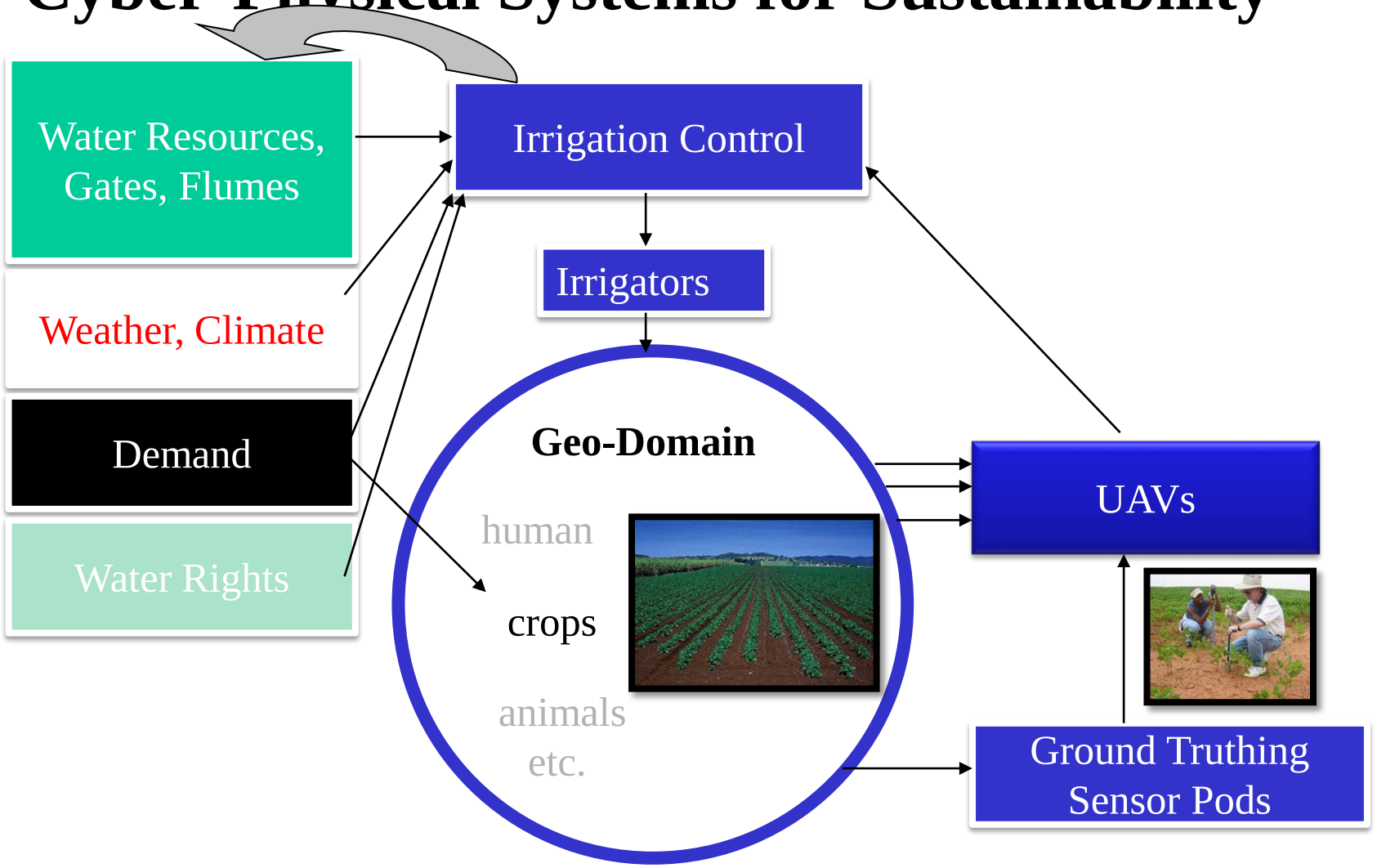
Scientific Data-Drones @ UC Merced

Scientific Data-Drones Two Cycles


End User
Area of Interest
Actionable Information
Plan
Application Processing
Flight Plan
Scientific Data
Acquire
Apply Calibration
Data
GIS Data
Georeference

Data to Decision to Action to Data

Cyber-Physical Systems for Sustainability



Credit: Dr. YangQuan Chen, 2005

UC Merced

- The Research University of the Central Valley
- Centrally Located
  - Sacramento – 2 hrs
  - San Fran. – 2 hrs
  - Yosemite – 1.5 hrs
  - LA – 4 hrs
- Surrounded by farmlands and sparsely populated areas

UC Merced

- Established 2005
- 1st research university in 21st century in USA.
- 6,200 Undergraduates
- 300 Grads (200+ Ph.D)

- Strong Undergraduate Research Presence (HSI, MSI)

UCMERCED w: mechatronics.ucmerced.edu MESA LAB

Dr. YangQuan Chen, yqchen@ieee.org

Mechatronics, Embedded Systems and Automation Lab

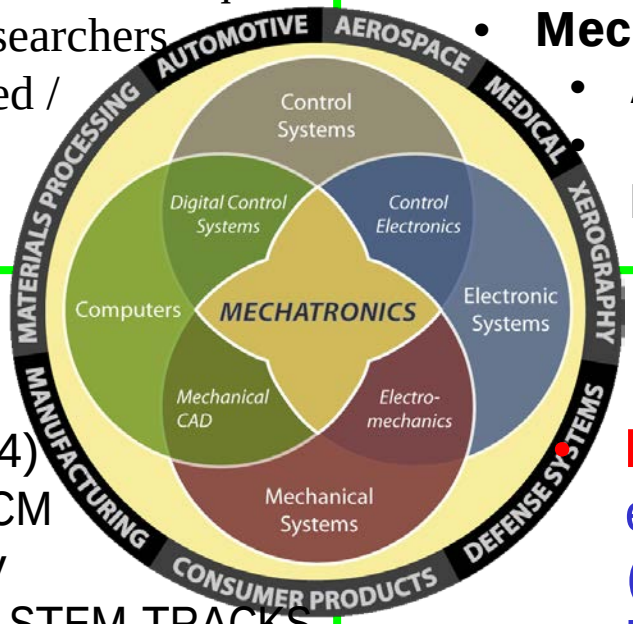
Real solutions for sustainability!

Established Aug. 2012 @ Castle, 5,000+ sq ft
7.5 Ph.D/40+ undergraduate researchers
10+ visiting scholars || sponsored / mentored many capstone teams

Research Areas of Excellence:

(ISI H-index=40, Google H-index=64; i10-index=326)

- Unmanned Aerial Systems & UAV-based Personal Remote Sensing (PRS)
- **Cyber-Physical Systems (CPS)**
  - **Mechatronics**
    - **Applied Fractional Calculus**
    - **Modeling and Control of Renewable Energy Systems**



Education and Outreach Activities:

- Eng Service Learning(Sp14)
- AIAA Student Branch @UCM
- Preview Days, Bobcat Day
- Robots-n-Ribs| MESABox! STEM-TRACKS TEAM-E
- UAS4STEM. USDA/NIFA HSI: 2016-2020
- **ME142 Mechatronics (**take-home labs**)**
- **ME280 Fractional Order Mechanics**
- **ME211 Nonlinear Control**
- **ME190 Unmanned Aerial Systems**

Projects Related to San Joaquin Valley:

Energy [Solar/wind energy, Building efficiency (HVAC lighting), smart grids integration, NG pipelines]

- **Water** (Water/soil salinity management, water sampling UAVs)
- **Precision Ag/Environment** (Crop dynamics, optimal harvest, pest, methane sniffing/mapping ...)

UC Multi-campus Synergy on CIDERS

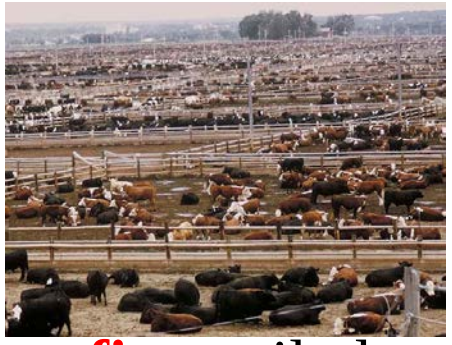
California Institute of Data-drone Engineering and Services

UCM, UCSC,UCB, UCSD, LLNL

CIDERS in Scientific data-drones: platforms, operation, and certification

UCM
UCD
UCSD

CIDERS in precision agriculture



UCM
UCD
LBL
SNL
UCSD

CIDERS in environmental monitoring: water, **fire**, soil, dust, AQ …

Fixed-Wing Platform (SDD1)

Total Weight	11.5 lbs
Wingspan	8 ft
Max Flight Time	80-100 minutes
Typical Flight Altitude	300 – 700 ft
Max Altitude	3000 ft
Typical Flight Area Coverage	1000 acres
Max Flight Area Coverage	2500 acres
Typical Payload	VIS Camera NIR Camera
Max Payload Capacity	4 lbs
VIS-NIR Resolution	2.5” – 12”
Thermal Resolution	12” – 60”

WATERSTAR

SDD: scientific data drone

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Multi-Rotor UAS Platforms

- Single or dual camera mobile sensing platforms
- Best utilized for small areas

Flight Time	10-15 minutes
Max Payload	1 lb
Max Flight Altitude	150 ft
Typical Flight Coverage	20 acres
VIS-RGB Resolution	< ¼”

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Other UAS Platforms @ MESA LAB (Water drone, soil co-physicist)

Imaging Systems	Point Sampling Systems
Thermal Camera^{+}	Water Collection Sampler*
Narrow-Band Imager*	Air Quality Sampler*
SWIR Imager	Soil Collection Sampler*

Chess playing drones/CaveDrones

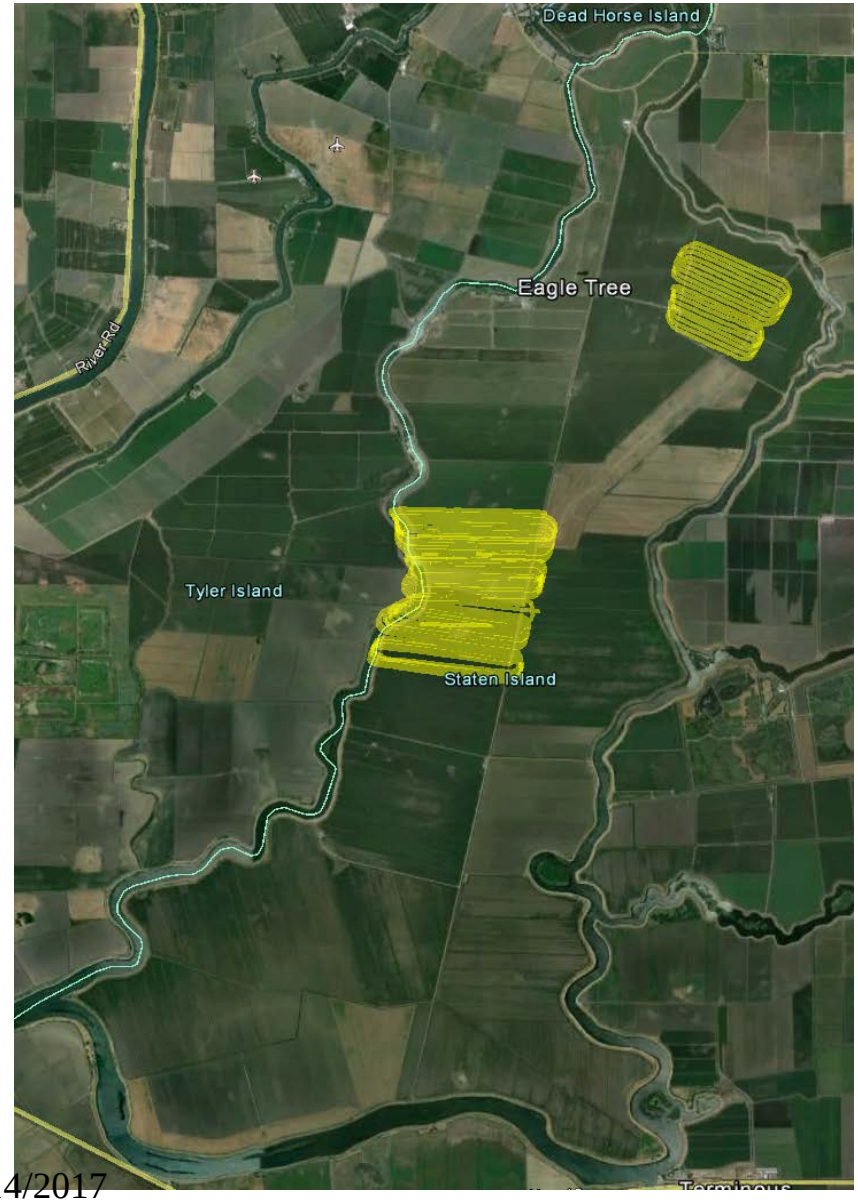
WATERSTAR

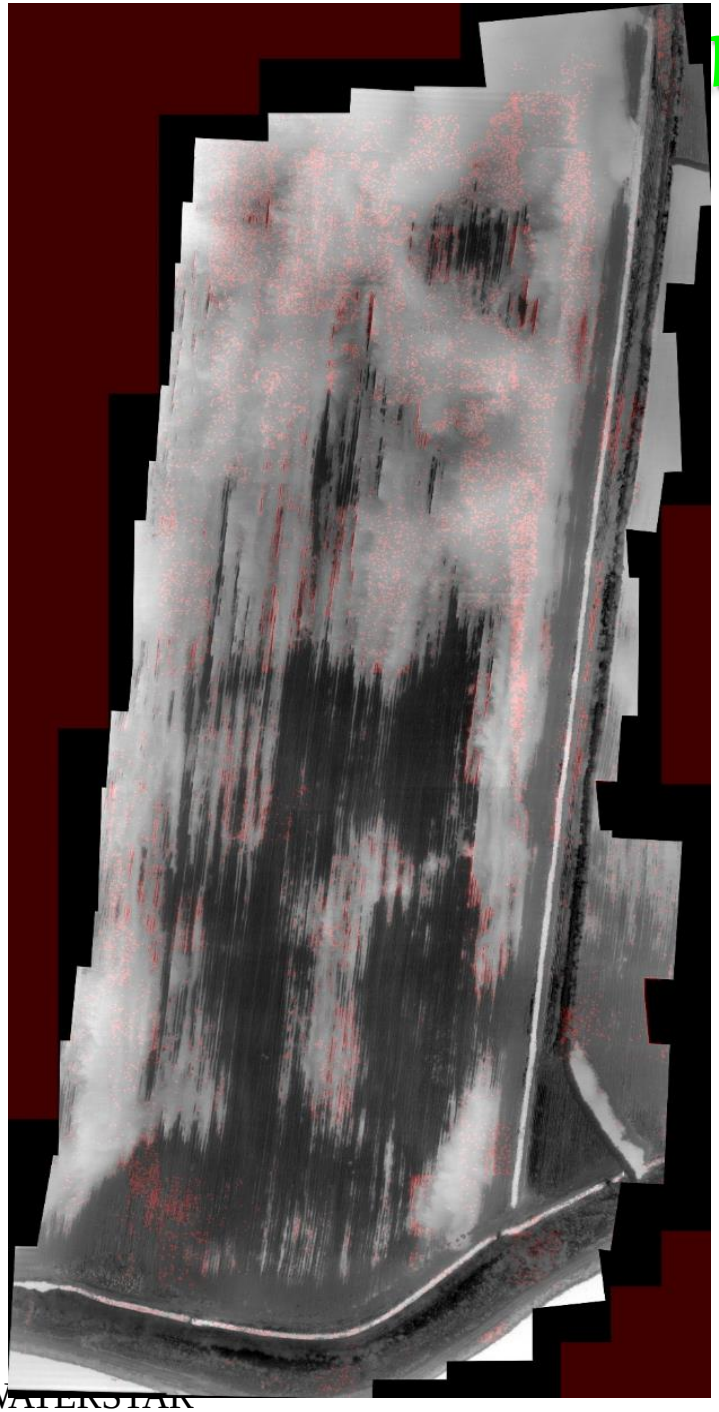
Floodplain Management

Flood conditions along the Cosumnes River allow researchers to study groundwater recharge.

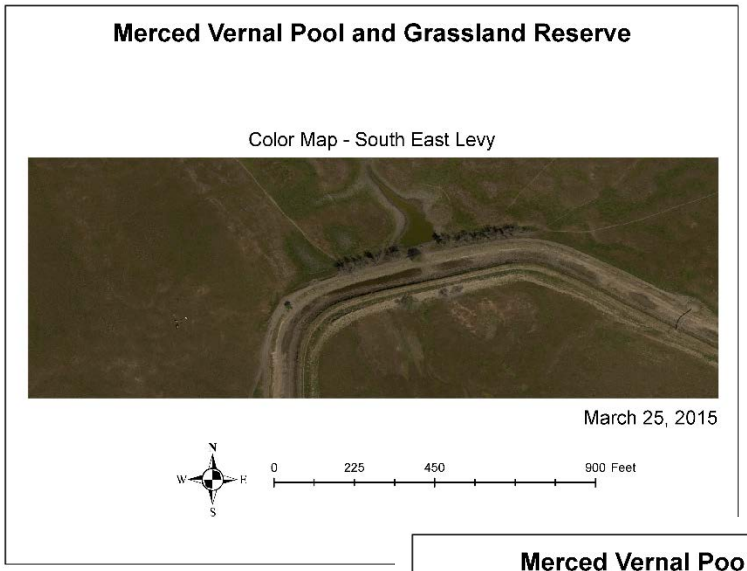
WATERSTAR

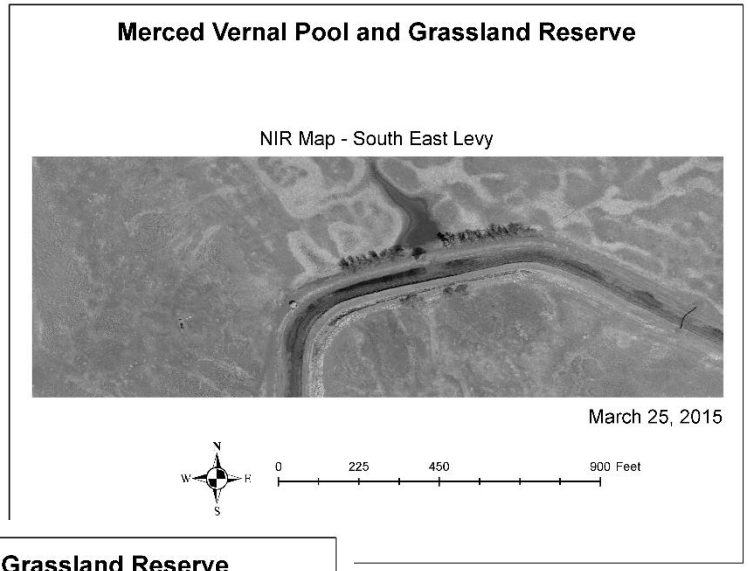
Sandhill Crane Night Counting

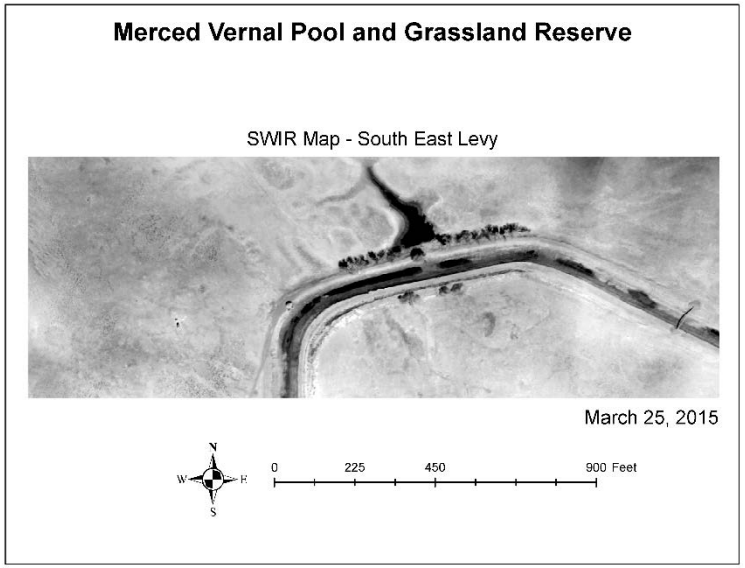




RGB, NIR, SWIR mapping



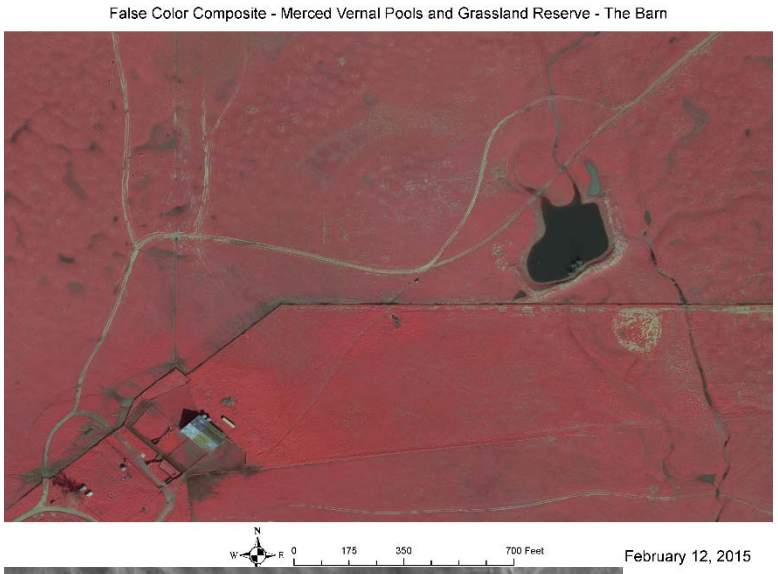


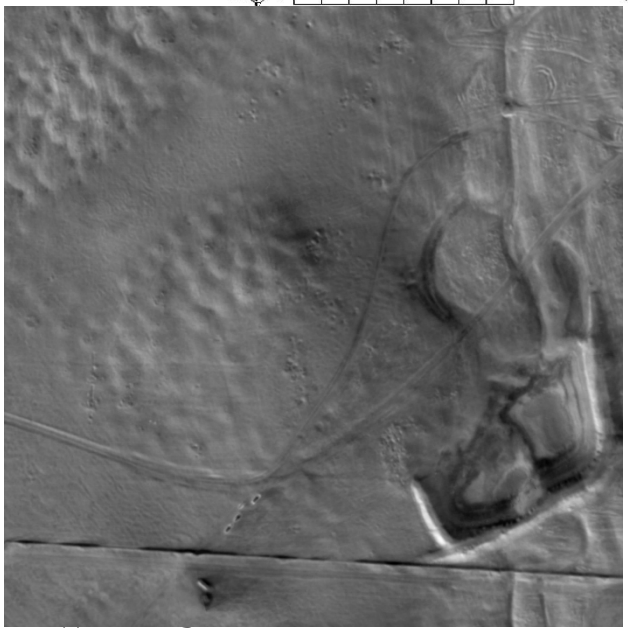


RGB, NDVI, TIR

100 acres – 8cm resolution

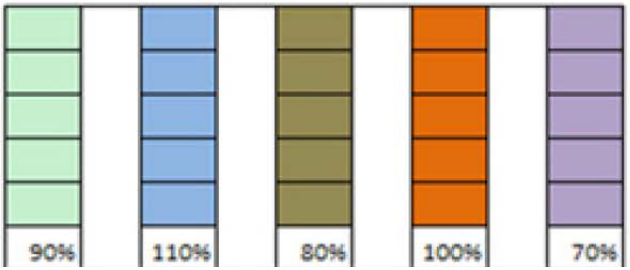
Flight Time – 7 minutes

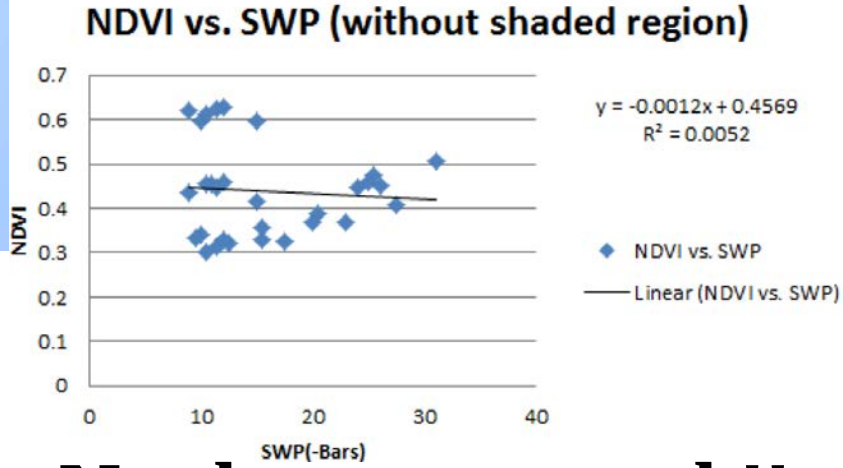


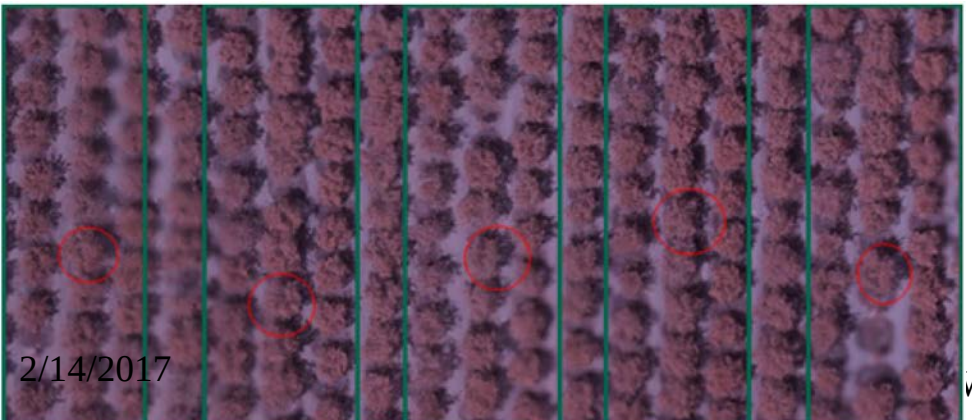


TIR Ortho – 15 cm resolution

2014 growing season crop water stress with ground truthing





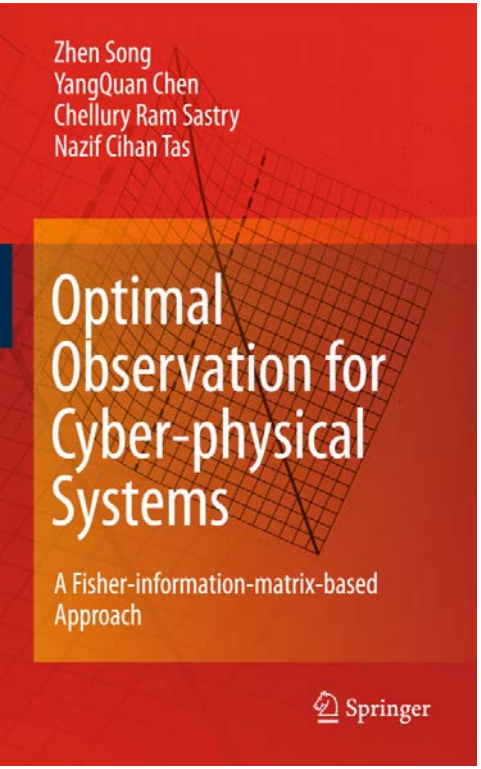


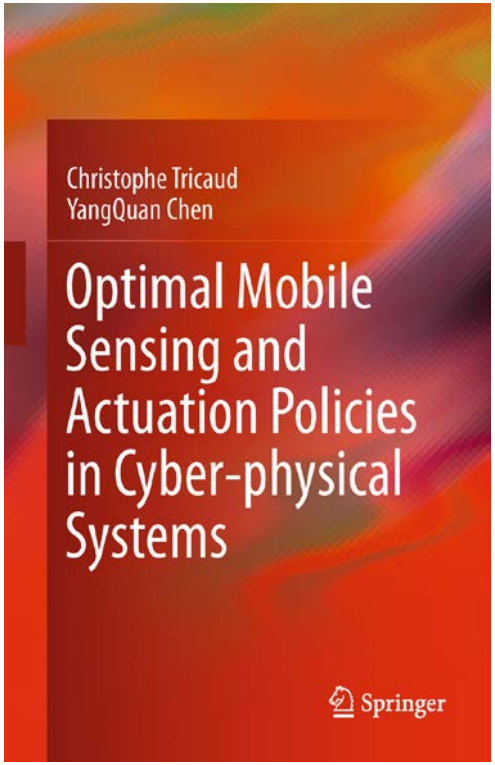
Need more research!!

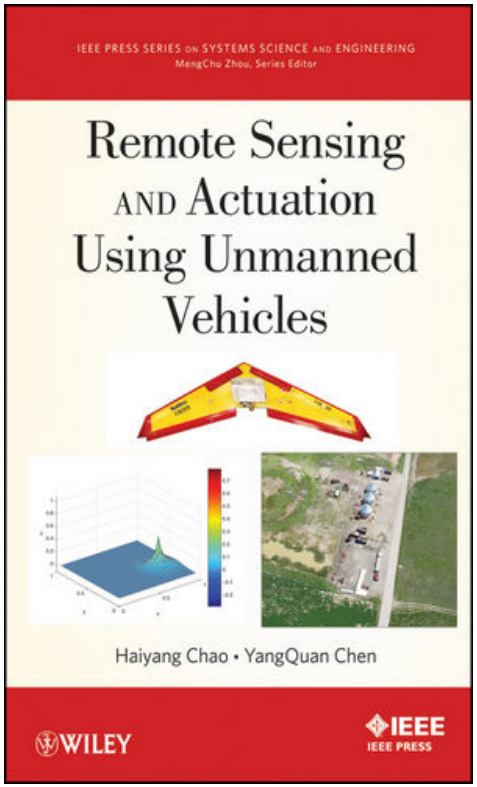
(Round-Robin competition)

- Drone Research Emphasis @ MESA Lab
  - Platform
  - Sensing Payload
  - Actuation Payload
  - Down-stream Processing
  - Smart sensing & actuation policies, operational issues

Smart sensing and actuation policies







???????????

By
Brandon Stark
Brendan Smith
Tiebiao Zhao *et al*

Operational Issues

- Safely flying once is easy; Safely flying always, is hard
- Operational Issues for Routine Successful Missions
- Ground Truthing

"Unmanned System Integration into the National Airspace System" by Dr. Wilson Felder, Director, William J. Hughes Technical Center, FAA. ICUAS12 Keynote

- **Five Challenges for UAS2NAS**
  - Procedural
  - Technical (i.e.: Sense and Avoid, Lost Link etc.)
  - Aircraft Safety (Certification of aircraft)
  - Crew Credentialing (including engineers'), AND
  - Public Acceptance


Mail - YangQua...
UAS for California ...
Energy Star - W...
ENERGY STAR | ...
Mechatronics ...
Agriculture is 8...
UAS Training, C...
mechatronics.ucmerced.edu/DroneDMV
ag water use in california
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Getting Started
Web Slice Gallery
Imported From IE
3 long survey papers b...
YouTube
datainsider
TurboTax Home & Bus...
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UAS Training, Certification and Risk Assessment
Home › News › 2015 › UAS Training, Certification and Risk Assessment
JULY 1, 2015
We have been building our capacity and credibility in UAS Training, Certification and Risk Assessment for many years. Check this link for our past efforts.
Events
July 7, 2015. "UAV Safety and Best Practices Technical Workshop". Organized and administered by CITRIS@UC Merced. Implemented and offered by MESA Lab@UC Merced. Hands-on Flight Training and Evaluation Session at UCM's SDDTS (Scientific Data-Drone Test Site) [netted space with a drone hangar] (Flyer, participant binder - table of contents). Final Program.
Recent News Items
SpARC Fall 2015 Announcement
08/30/2015
mechatronics.ece.usu.edu webpages moved to new site
08/10/2015
Dr. Chen will serve as Invited Panelist for NASA UTM (UAS Traffic Management) Convention
07/01/2015
Latest News
2015
2014
99%
4:05 PM
9/20/2015

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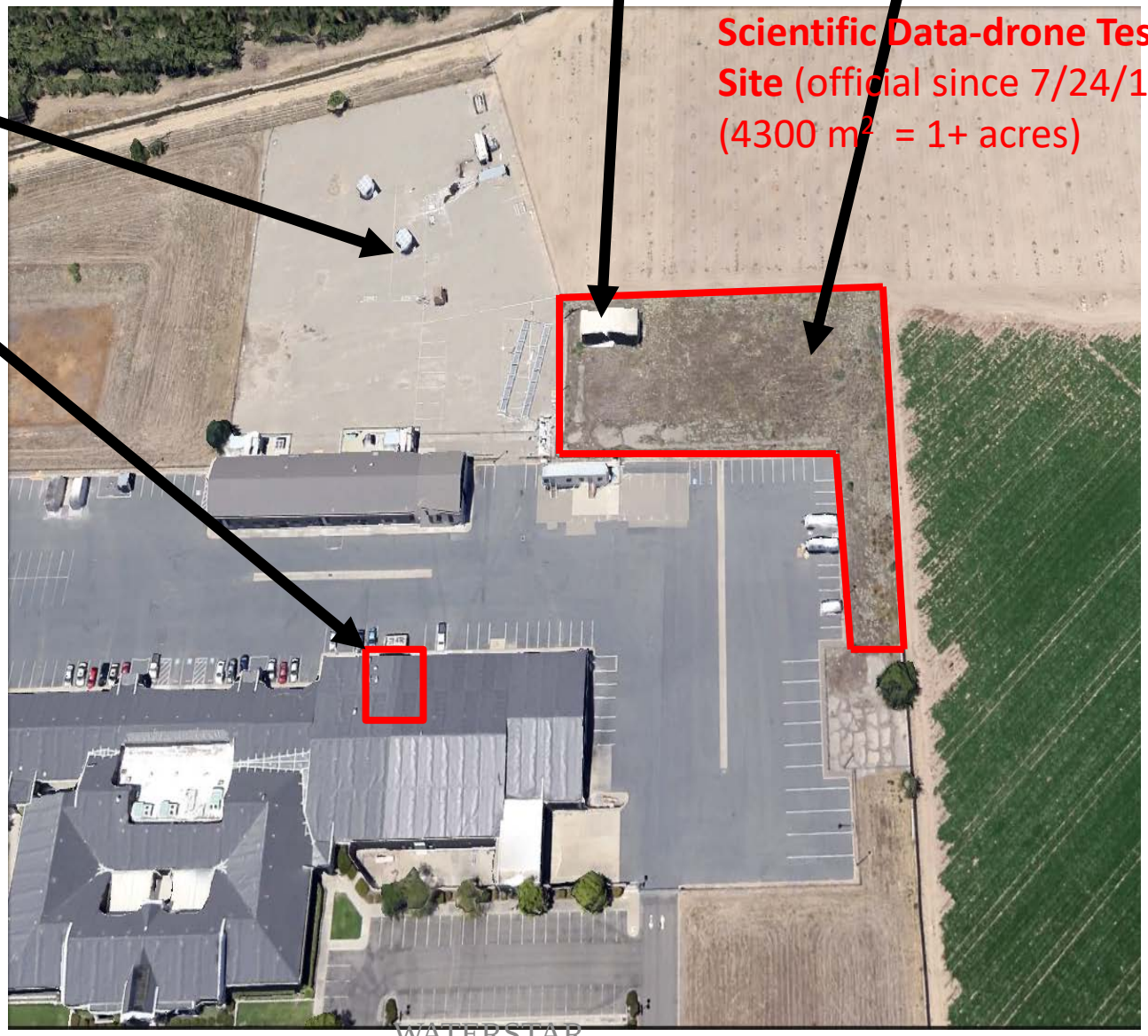
UC Merced
Castle Research Facility

UCSolar.org

MESA Lab

Scientific Data-drone Hangar (18m x 7m x 5m)

MESA Lab @ UC Merced
Scientific Data-drone Test Site (official since 7/24/14)
(4300 m^2 = 1+ acres)

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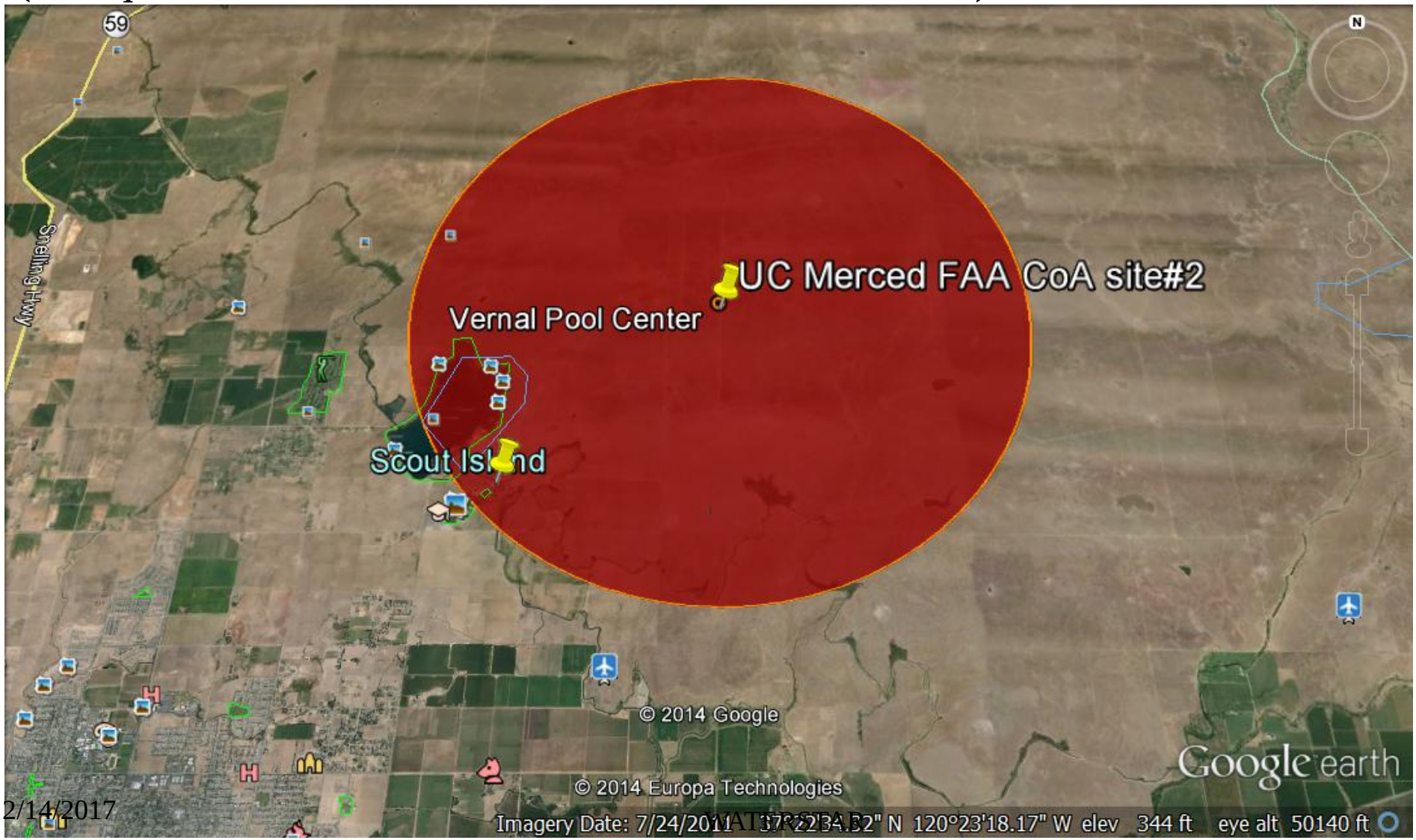
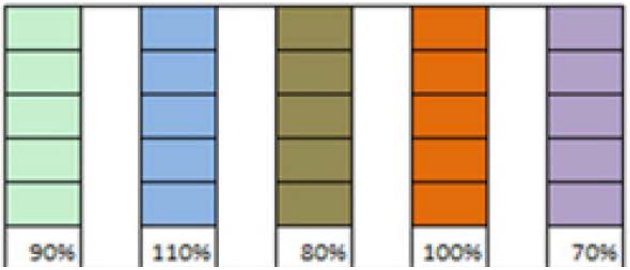
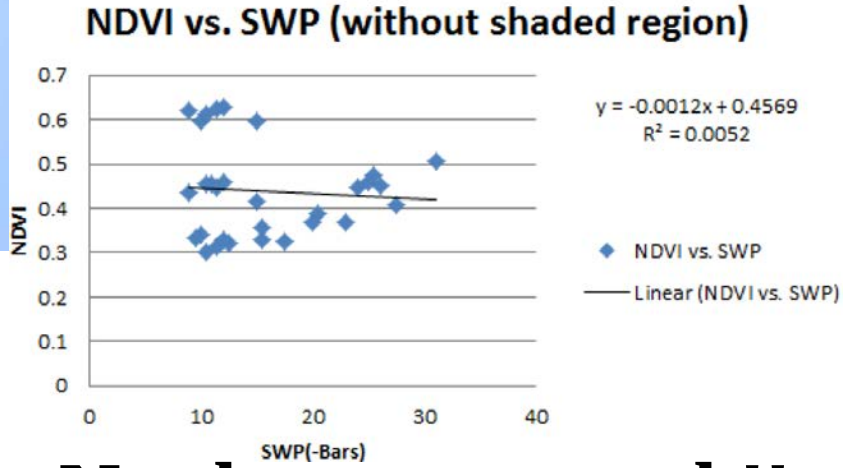
2nd FAA CoA Site – UC Merced

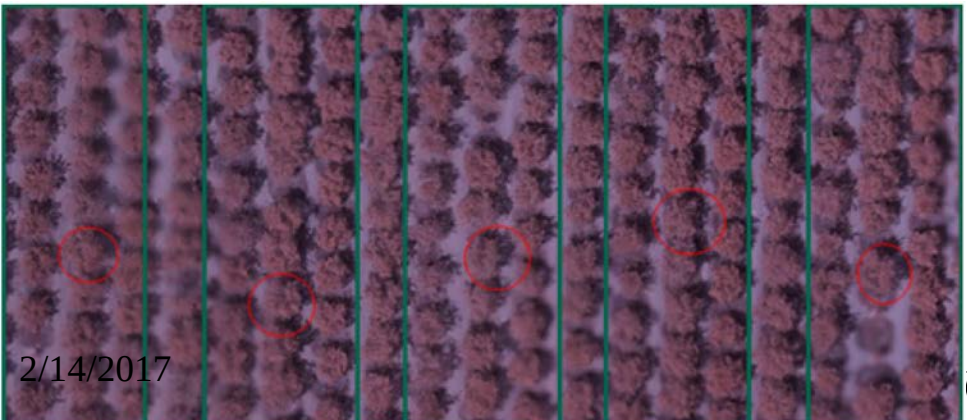
(26 square miles in red, 2.5 nautical mile in radius) SHOW 3D WALK



2014 growing season crop water stress with ground truthing







Need more research!!

(Round-Robin competition)

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A Call for Round-Robin Competition for Crop Water Stress Quantification

Groundtruthed Detection of Crop Water Stress Benchmark Data Set

Outline

- UC Merced Scientific Data Drones Research
  - Overview
  - Related Projects
- **A Vision Towards WATERSTAR**
  - **Biomass, Biochar, Soil Amendments, Drone-assisted Assessment (M&V: measurement and verification)**

The dream cycle

- **Ag** => Biomass => Biochar => Soil =>Water Efficiency => (More sustainable) **Ag**

- Environmental benefits
  - Energy (by-)production
  - Better air quality
  - Better groundwater quality

Biomass Gasification @ UC Merced

Mail - YangQ... | UAS for Californi... | Energy Star - ... | ENERGY STA... | Mechatronics... | prime lawnm... | How to Fix a ... | carbon cycle ... | SPGL Ov...

https://spglab.ucmerced.edu

gdiaz ucmerced

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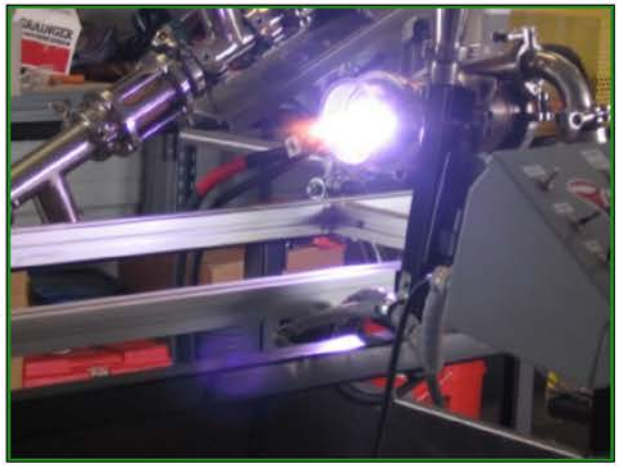
Sustainable Plasma Gasification Laboratory

- SPGL HOME
- Research
- Facilities
- People
- Publications
- Contact Information
- News & Updates
- Links

SPGL Overview

Plasma Gasification of waste is a current technology that denotes a clean and efficient method of managing waste.

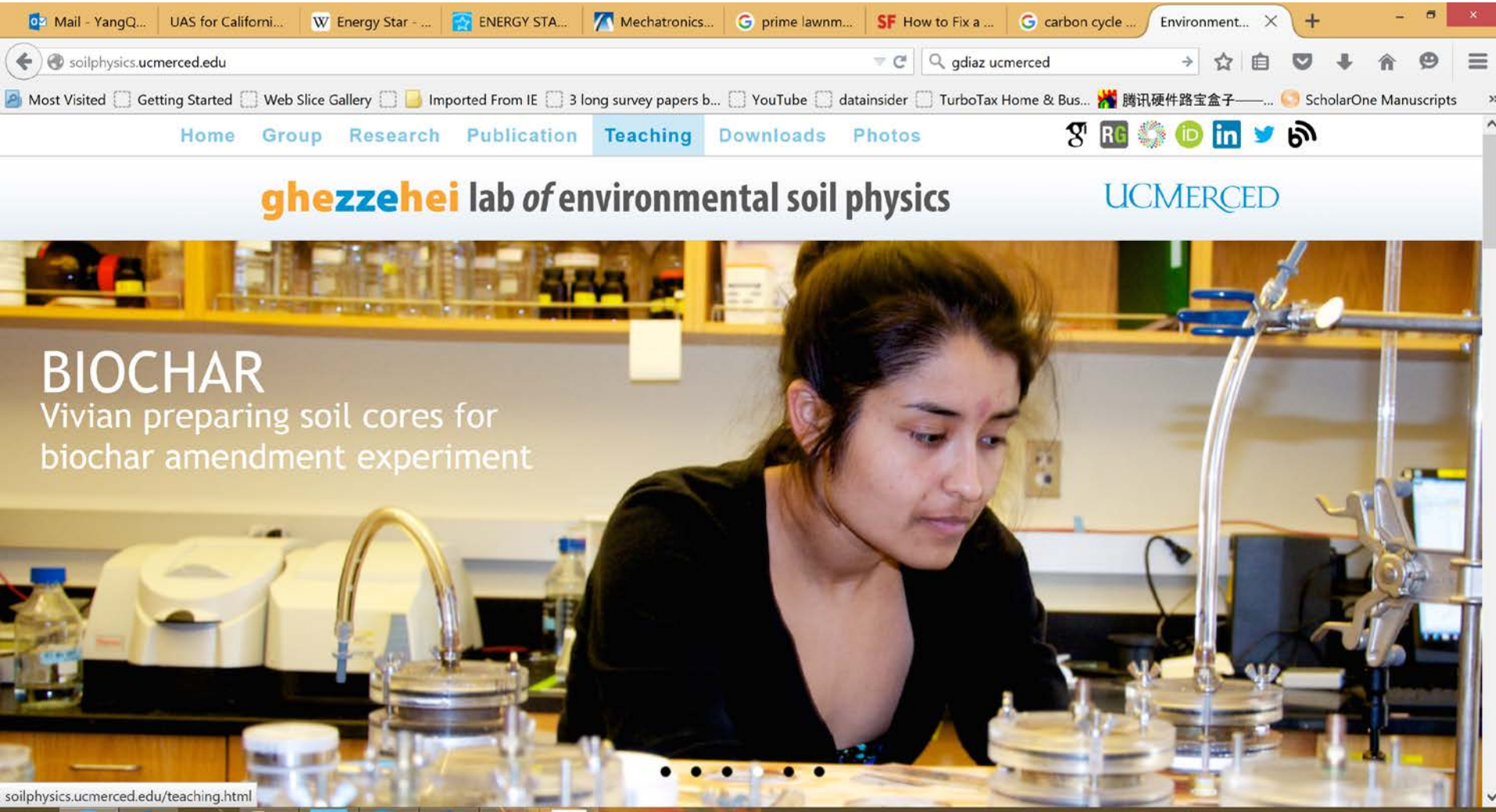
Plasma is an ionized gas and is usually referred to as the 4th state of matter. It is made up of a quasi-neutral gas that is composed of neutral and charged particles that exhibit a collective behavior. It is formed whenever ordinary matter, or in this case: waste, is heated to a very high temperature. This results in electrically charged gases.



Gasification is a process that converts organic molecules in solids to low molecular weight gaseous components

99% 5:12 PM 9/20/2015

Soil Physics Sciences @ UC Merced



THE DRONE's role: **M&V and soil variability mapping**

- https://en.wikipedia.org/wiki/Measurement_and_Verification
- Just like E/E's M/V
- Drone should be used for mapping/documenting and QUANTIFICATION of before/after applying biochar or other soil amendments in larger region/area.
- WATERSTAR incentives can then be implemented
- VRA of biochar possible – **optimal applications**

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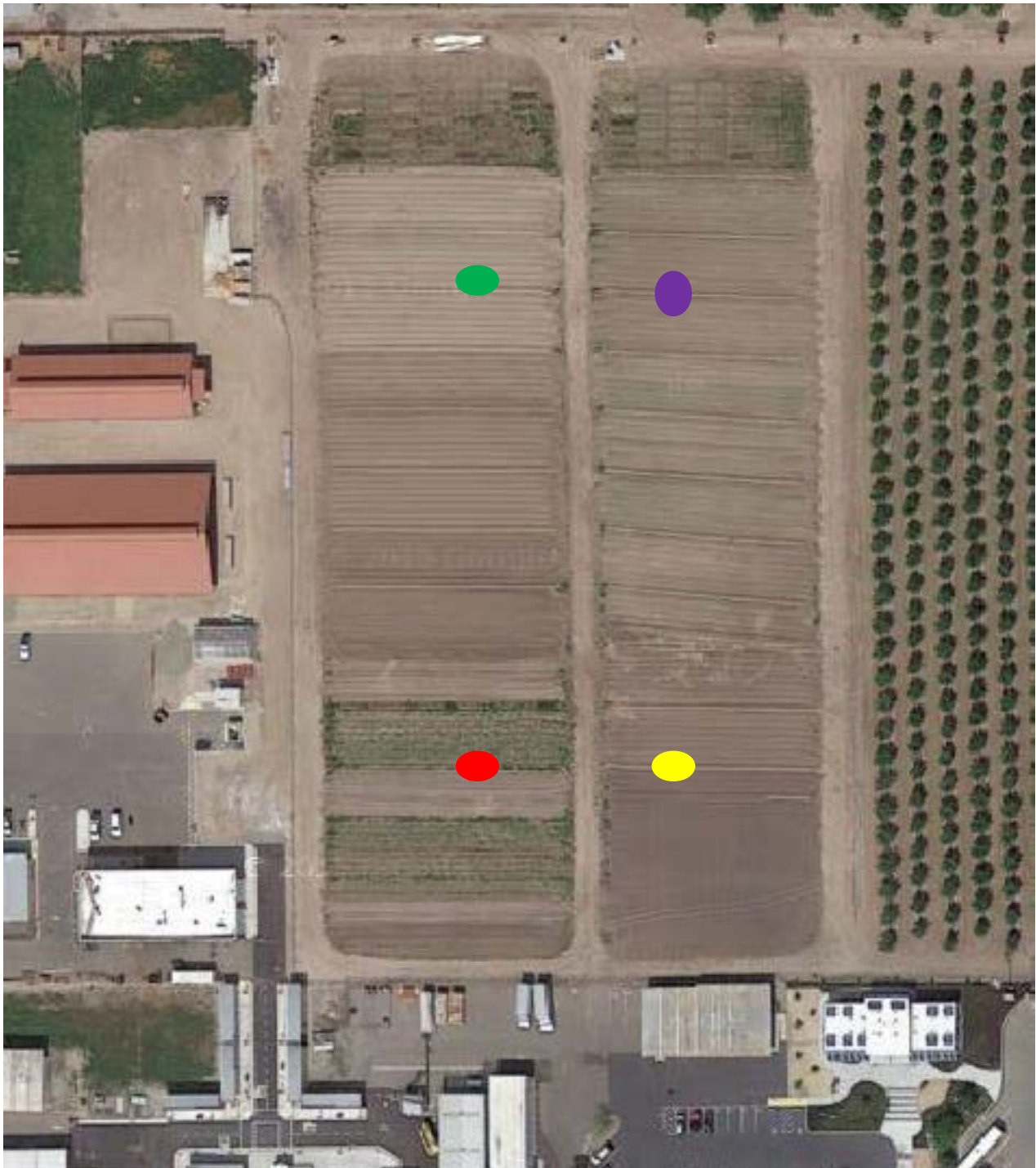
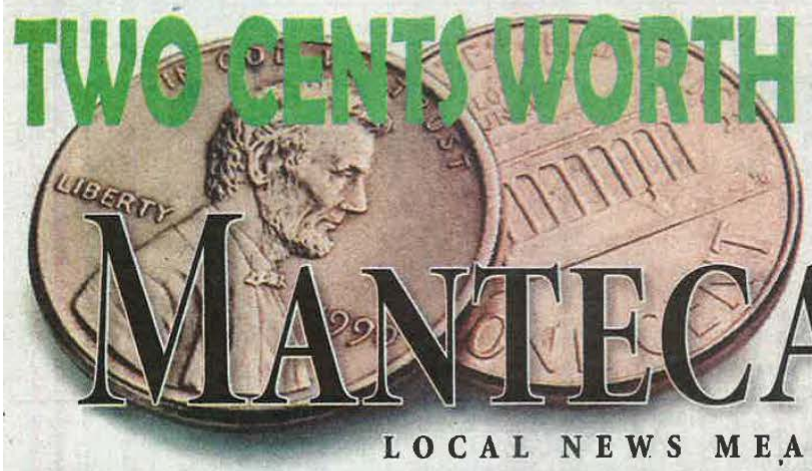
Ground Truthing Effort

(@Manteca MUSD self-funded)

These are rough approximations for where the soil moisture readings were taken at. **Green** is Compost, **purple** is Biochar and compost, **Red** is control, and **yellow** is Biochar.



2/14/2017



TWO CENTS WORTH

You never know when it will pay off big for someone

▶ See DENNIS WYATT, **Page A4**

HERE'S TO BEATING CANCER

Doctors Hospital Relay for Life team plans wine tasting

▶ See YOUR WEEKEND, **Page A7**

MANTECA BULLETIN

LOCAL NEWS MEANS THE WORLD TO US

Today:

65/55

Tomorrow:

65/55

www.MantecaBulletin.com THURSDAY, FEBRUARY 5, 2015 Vol. 107, No. 30 PRICE 50¢

Major water saving initiative

Biochar field test underway at school farm

By DENNIS WYATT
THE BULLETIN

There's black gold sitting in a pile at the Manteca Unified School District farm.

It's the stuff that California farmers dream of — an organic substance that can yield water savings between 10 to 20 percent, reduce the need for fertilizer, provide bigger yields, reverse the depletion of soil, and can even reduce ammonia smells and manure leeching issues at dairies.

For the next two years the black gold known as biochar will be part of the first extensive field test of its kind in the world's most productive farming region — the San Joaquin Valley.

Pacific Biochar is partnering with the Manteca Unified School District as well as working with the City of Manteca to see how well greenhouse lab results involving biochar mixed with soil translate when applied in fields.

If successful, the Manteca Unified field tests could entice farmers to employ biochar to improve their bottom line while reducing the use of California's most precious and critical resource — water.

"Biochar has been proven to reduce water use and retain more nutrients," noted Josiah Hunt of Pacific Biochar.

Biochar is as old as plant life and fire itself. It is a

SEE **WATER,** PAGE A8

WHAT'S INSIDE

WATER CRISIS

▶ State suspends minimum flow requirements for Stanislaus River in bid to conserve water. See **AROUND TOWN**, Page A2.

Josiah Hunt pours water into a fistful of biochar to demonstrate its superior water retention properties.

DENNIS WYATT/The Bulletin

8-FOOT WALL IN SOUTH MANTECA

MURDER

UCMER

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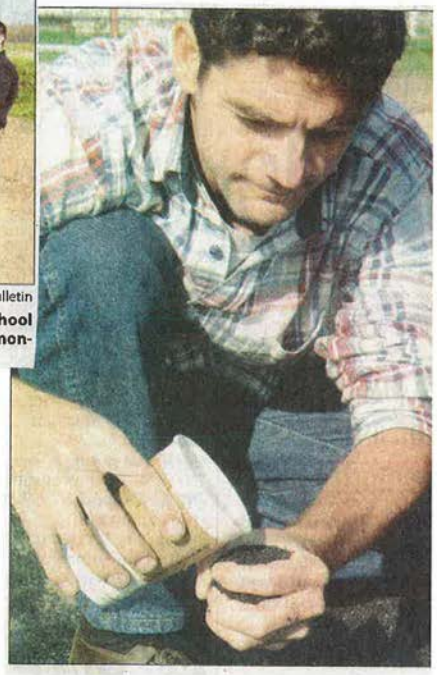

DENNIS WYATT/The Bulletin

TOP PHOTO: Josiah Hunt, left, of Pacific Biochar stands by a pile of bicohar at the school farm while explaining its properties. RIGHT PHOTO: Josiah Hunt gets ready to demonstrated water retention effectiveness with a fist full of biochar and a cup of water.

WATER

FROM PAGE A1

fine-grained charcoal made from biomass — biological material such as agricultural waste. It is an organic carbon free of fossil fuel products, geological carbon, and plastics.

As soon as next week, Manteca Unified students under the direction of school farm instructor Cole Dutter will plant four one-acre plots for the two-year field test. The control plot will have native soil. The other three will use biochar — one with biochar only, one with biochar inoculated with microorganisms, and one with biochar mixed with the soil as well as being inoculated and mixed 4 to 1 with compost.

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Students will raise crops for school lunch program

The students will plant different crops throughout the year including cabbage, peas, cauliflower, broccoli spinach, and carrots among others. Food harvested will be used in the school lunch programs. The dozen students will work five days a week and be paid minimum wage. The fields will be fallow only one month — June.

They will meticulously collect and record a variety of data ranging from moisture readings to the weight of plants produced.

There is a growing collection of research in greenhouses and labs that show biochar can deliver the results that Hunt describes. It has been used successfully in an area of Australia where researchers have reduced water use and increased yields in soil similar to the Veritas sandy loam at the school farm. He recently returned from Vietnam where he assisted on a project that tied biochar production into a farming operation to generate energy to process crops as well as to help increase yields and conserve water.

"This is important," Hunt said of the field test. "It will show what it (biochar) can do in the San Joaquin Valley, the world's greatest farming region."

Biochar could prove a game changer especially as California enters its fourth year of a severe drought. Much of the San Joaquin Valley is experiencing extreme overdrafting of aquifers while a shortage of water — both surface and underground — has forced farmers to keep fields fallow and to rip out orchards as they no longer have adequate water to keep trees alive let alone produce crops.

Hunt showed the absorption quality of the biochar by grabbing a fist full and slowly pouring a coffee cup of water into the opening of his hand. After 40 seconds, the first drops of water starting seeping out from the bottom of his fist.

Other tests have shown when biochar is mixed with soil in dairy cattle pens it reduces the leeching of ammonia that poses a danger to water sources as well as reducing smell. That manure with biochar was then tilled into a pasture enhancing grass growth and again reducing leeching issues.

They are planning quarterly open houses at the school farm to show farmers and the community firsthand their results.

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Manteca's interest is in protecting, expanding agricultural employment

Economic Development Manager Don Smail noted the city's interest is in protecting agricultural jobs, generating new jobs with the goal to ultimately secure a biochar conversion facility for Manteca, to reduce water use, improve air quality, to possibly reduce pollution issues connected with fertilizer, and to yield more food production per acre.

The city's economic development strategy was refined several years ago to targeting employment opportunities in agricultural related ventures given Manteca's strategic location in the world's richest farming region and ready access to rail, freeway, airport and sea port to move farming goods. Agriculture is the No.1 employer in San Joaquin County.

Five of the top 10 counties in the United States for agricultural production are within two hours of Manteca while two of the remaining five counties are within 3.5 hours. (The top seven counties for farm production based on the 2012 United States Department of Agricultural report are from California. They are in descending order: Fresno, Tulare, Kern, Monterey, Merced, San Joaquin, and Stanislaus.)

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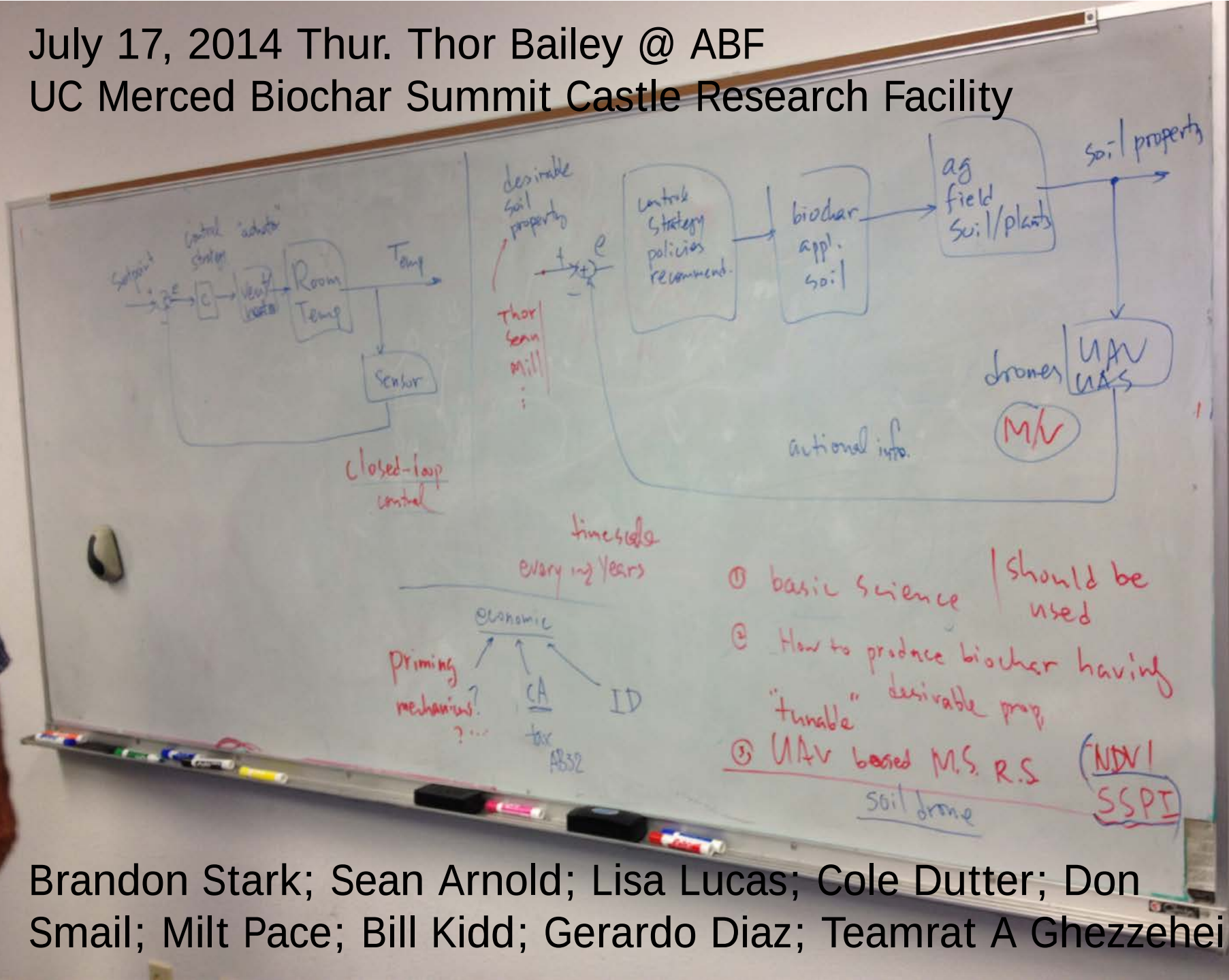
2/14/2017

July 17, 2014 Thur. Thor Bailey @ ABF
UC Merced Biochar Summit Castle Research Facility



Brandon Stark; Sean Arnold; Lisa Lucas; Cole Dutter; Don Smail; Milt Pace; Bill Kidd; Gerardo Diaz; Teamrat A Ghezzehei

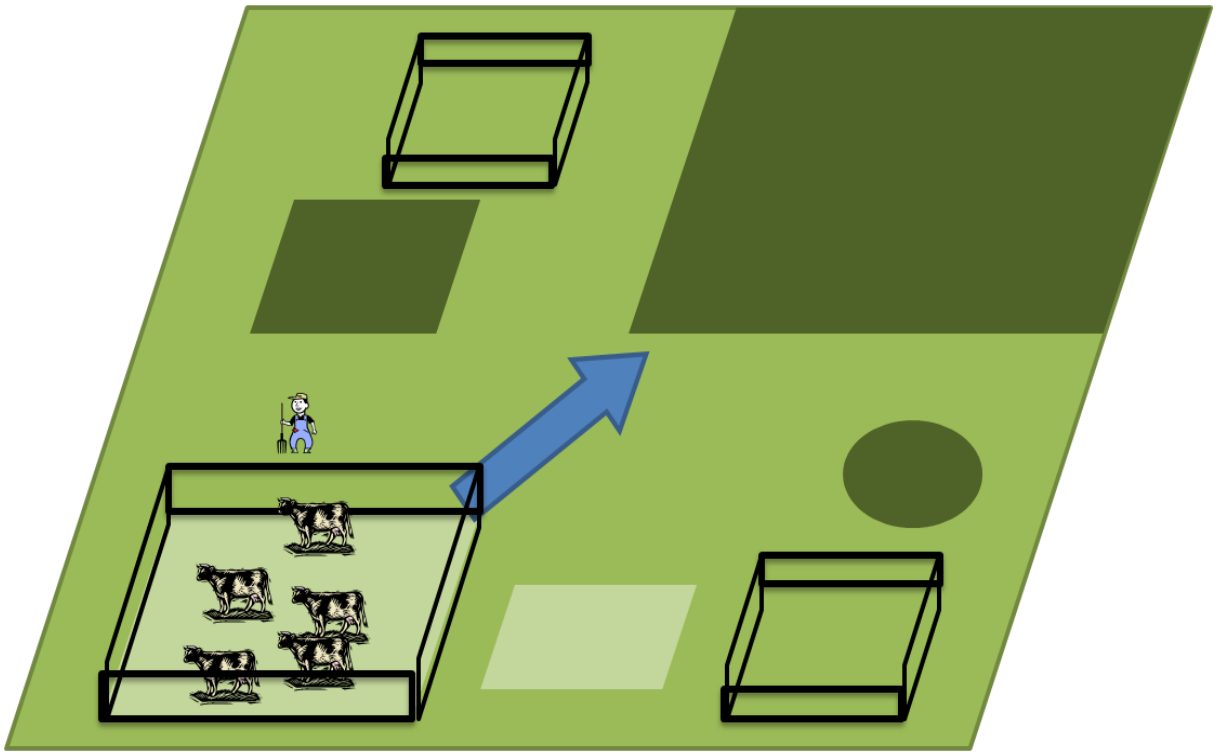
Time to Prime It
More research, more trials

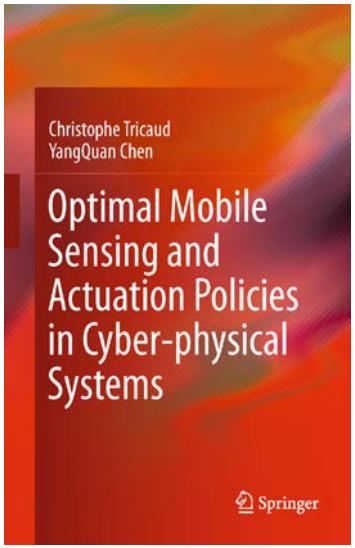
Thank you for your attention!

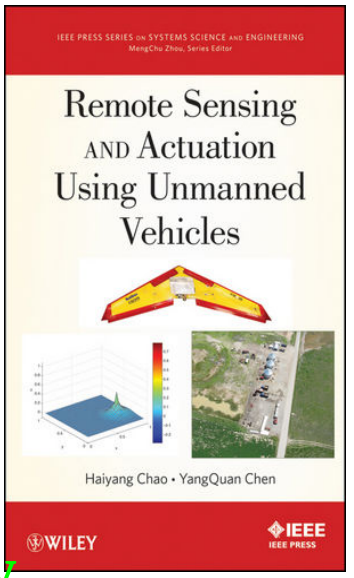
- Q/A

- Call for public support
  - **UC Multi-campus Synergy on CIDERS: California Institute of Data-drone Engineering and Services**
  - **WATERSTAR initiative**

Agriculture in 2100s: when no more synthetic fertilizers available







Data to Decision to Action to Data

Cyber-Physical Systems for Sustainability