Precision Agriculture: Emerging Technologies for Management of High-quality Production

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Center for Precision and Automated Agricultural Systems
Washington farmers produce over 300 different commodities
WASHINGTON AGRICULTURE
A GLOBAL IMPACT

Top Trading Partners
Source: World Trade Atlas, CY16

<table>
<thead>
<tr>
<th>Country</th>
<th>Value (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CANADA</td>
<td>$1.3B</td>
</tr>
<tr>
<td>JAPAN</td>
<td>$1.2B</td>
</tr>
<tr>
<td>CHINA</td>
<td>$611M</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>$564M</td>
</tr>
<tr>
<td>SOUTH KOREA</td>
<td>$432M</td>
</tr>
</tbody>
</table>

Top 10 Commodities in Washington
2016

<table>
<thead>
<tr>
<th>Rank</th>
<th>Commodity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>APPLES</td>
<td>$2.389 billion</td>
</tr>
<tr>
<td>2</td>
<td>MILK</td>
<td>$1.097 billion</td>
</tr>
<tr>
<td>3</td>
<td>POTATOES</td>
<td>$813 million</td>
</tr>
<tr>
<td>4</td>
<td>CATTLE</td>
<td>$704 million</td>
</tr>
<tr>
<td>5</td>
<td>WHEAT</td>
<td>$656 million</td>
</tr>
<tr>
<td>6</td>
<td>CHERRIES</td>
<td>$502 million</td>
</tr>
<tr>
<td>7</td>
<td>HAY</td>
<td>$478 million</td>
</tr>
<tr>
<td>8</td>
<td>HOPS</td>
<td>$382 million</td>
</tr>
<tr>
<td>9</td>
<td>GRAPES</td>
<td>$359 million</td>
</tr>
<tr>
<td>10</td>
<td>PEARS</td>
<td>$233 million</td>
</tr>
</tbody>
</table>
Precision Agriculture

- Producing more with less (www.cema-agri.org)

- Global Position System
  - Guidance, Navigation

- Site-Specific
  - Measure, Analyze
  - Yield Mapping

- Sensors and Remote Sensing
  - Measure, Analyze

- Variable Rate Technology
  - Manage
Producing more with less (www.cema-agri.org)
Decision Agriculture

- ‘Big’ data-driven farming
- Digital Agriculture

Source: Tzounis et al. (2017)
Industry 4.0

1st
Mechanization, water power, steam power

2nd
Mass production, assembly line, electricity

3rd
Computer and automation

4th
Cyber Physical Systems

https://en.wikipedia.org/wiki/Industry_4.0
Why Precision/Decision Ag

- **Food security**
  - Population vs Production
  - Global climate change
  - Agriculture production (efficient?)

**Mean Temperature Departure from Average**
For Five Warmest Years on Record

<table>
<thead>
<tr>
<th>Rank</th>
<th>Year</th>
<th>Departure from average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2012</td>
<td>+3.3F</td>
</tr>
<tr>
<td>2</td>
<td>2015</td>
<td>+2.4F</td>
</tr>
<tr>
<td>3</td>
<td>2006</td>
<td>+2.2F</td>
</tr>
<tr>
<td>4</td>
<td>1998</td>
<td>+2.2F</td>
</tr>
<tr>
<td>5</td>
<td>1934</td>
<td>+2.1F</td>
</tr>
</tbody>
</table>

Global agricultural productivity
GAP report 2015, Global Harvest Initiative
Fertilizer use in kg per hectare of arable land, 2014

Fertilizer products cover nitrogenous, potash, and phosphate fertilizers (including ground rock phosphate). Animal and plant manures are not included.

Source: World Bank – WDI
Feast or Famine

Nearly half the people on the planet wouldn’t be alive if not for the abundant food made possible by nitrogen fertilizer. Yet its benefits have not reached everyone. In sub-Saharan Africa, where 239 million people go hungry in a year, crops fail as soil is stripped of nutrients, and farmers can’t afford to buy fertilizer. Elsewhere overuse pollutes waterways and releases greenhouse gases.

JEROME N. COOKSON AND LAWSON PAPKER, NGM STAFF
SOURCE: PAUL C. WEST, INSTITUTE ON THE ENVIRONMENT, UNIVERSITY OF MINNESOTA
Why Precision/Decision Ag

Pesticide use per hectare of cropland, 1990
Average pesticide application per unit of cropland, measured in kilograms per hectare.

Pesticide use per hectare of cropland, 2006
Average pesticide application per unit of cropland, measured in kilograms per hectare.

Pesticide use per hectare of cropland, 2008
Average pesticide application per unit of cropland, measured in kilograms per hectare.

Pesticide use per hectare of cropland, 2014
Average pesticide application per unit of cropland, measured in kilograms per hectare.

Source: UN Food and Agricultural Organization (FAO)
Why Precision/Decision Ag

29

Number of pesticides in the average American's body

Source: Centers for Disease Control and Prevention
COUNTERTHINK
"THE MANY 'CIDES OF MODERN FOOD PRODUCTION"

FUNGICIDES

CONCEPT-MIKE ADAMS

PESTICIDES

ART-DAN BERGER

HERBICIDES

GENOCIDE

WWW.NATURALNEWS.COM
Crop Losses

“Fruits and vegetables, too good to be wasted”

Apple sunburn & related: 6-30%

Sweet cherry split & related: ~90%

Postharvest rots & related: ~7.5%
Produce more: healthy beings?

\[ \text{Yield} \approx f(\text{Genetics, Environment, Farming Practices}) + \epsilon \]
Remote sensing: Drones, Satellites...
Remote sensing: Drones, Satellites…

- Landsat (30 m)
- Sentinel (10 m)
- Rapideye (5 m)
- Planet (3 m)
- Small UAS (9 cm)
Remote sensing: Drones, Satellites…

Landsat (30m)

Soil Patterns

(Planet Scope, 3x3m)
Advances in Optical Sensors

- RGB
- Multispectral
- Hyperspectral
- Light Detection & Ranging (LiDAR)
- Thermal imaging
Sensing Platforms

Handheld

Ground-based

Aerial
Remote sensing: Drones, Satellites...

- Platforms
- Customized sensors
- Geospatial mapping solutions (Service providers)

Integration with ‘Low-orbiting satellites’ data

Source: PlanetLabs.com
UAS Imaging

Crop Emergence, Winter survival, Spring stand, Yield potential

Nursery inventory (Assurance & Insurance)

Hail damage (Assurance & Insurance)

Crop Lodging (Assurance & Insurance)
Blueberry/ Cherry frost/freeze damage control
Apple sunburn/heat stress

Monitoring is critical
Novel Wireless Sensor Networks for Real-time Crop Management

https://doi.org/10.1016/j.agrformet.2018.02.013
Novel Wireless Sensor Networks for Real-time Crop Management

2.7 °C

4.8 °C
How plants communicate?

Biotic Stress: Methyl salicylate, C₆ aldehydes and alcohols

Climate: Isoprenoids, Terpenoids
Smart Application Technologies: Why?

Transition → to modern tree architectures
Variable Rate Sprayers

Chen, Zhu & Ozkan (2012)

Orchards

www.durand-wayland.com

Nursery & Orchards

Five-port nozzle manifold

PWM solenoid valves

Controller

Laptop computer

Laser sensor

Chen, Zhu & Ozkan (2012)

Olive

RTK-GPS Antenna

Control unit

Section 3

Section 2

Section 1

3 Electro-valves

Ultrasonic sensor

Pe´rez-Ruiz, Aguer´a, Gil & Slaughter (2010)

Citrus

Khot, Ehsani et al. (2013, 2014)
Precision Sprayer
Mid-sized UAS

Surgical spraying in WA tree-fruit

Grapevine surgical spraying
Dr. Ken Giles, UC Davis (www.spectrum.ieee.org)

Surgical applications in row & field crops

DP-14 (Source: Dragonfly Pictures, Inc.)
USDA SCRI: SSCDS - An efficient, sustainable and safer spray technology for perennial fruit (2016-2019)

Transition → to modern spray system
USDA SCRI: SSCDS- An efficient, sustainable and safer spray technology for perennial fruit (2016-2019)

Transition ➔ to modern tree architectures ➔ to Solid Set Canopy Delivery System

SSCD optimization and testing in apple
Challenges: Precision & Decision Agriculture

Input  ===  Output

4C’s
Issues:
  o Correction for sunlight/shadow variations
  o Metadata standards (sensors, flight)
  o Image quality standards
Cloud Connectivity

Issues:
- Network connectivity
- Data security/ownership
- ?

Source: Tzounis et al. (2017)
Cloud Connectivity 2020

How long would it take to download the two-hour-long "Guardians of the Galaxy"?

- **3G**: 384 Kbps (2001) - 26 hours
  - Fly from New York to Sydney, including check-in times

- **4G**: 100 Mbps (2009) - 6 minutes
  - Run a quick mile

- **5G**: 10 Gbps (2020) - Ask, "Is it downloaded yet?"

What you could do while waiting:

- Fly from New York to Sydney
- Catch up on Facebook

Microsoft

www.cnet.com
Artificial Intelligence

- Camera (emoji’s)
- Language translator
- Monitor user behavior
- Security
- Voice assistance

8-core architecture
5 trillion operations per second
Core ML runs up to 9x faster than A11 Bionic
Issue: MRLs [Maximum Residue Limits]

Solution: Alternate spray materials/technologies

Biopesticides Sprayer

- THYME
- NEEM

Ozonated Water

Highly refined petroleum oils

OMRI Listed®

For Organic Use

www.freshplaza.com
Thank you!

CONTACT:
Lav Khot, lav.khot@wsu.edu, Ph. 509-786-9302
- **Producing more with less** (www.cema-agri.org)

- **Doing the right thing, in the right place, the right way, at the right time** (Pierce & Frye, 1998)

- **Satellite farming or site specific crop management** based on observing, measuring and responding to inter and intra-field variability in crops (Wiki; Singh et al., 2008)