REMOTE SENSING APPLICATIONS FOR AGRICULTURE

the anticipated promise and the present reality

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QUICK INTRO

- Background
  - 1992-1996: used color and NIR aerial photos for grassland ecology studies
  - 1996-1999: assisted organization of first precision farming workshop for Colorado State Coop Extension
    - Preliminary work with Space Imaging for agricultural applications of 3 meter resolution imagery from their first IKONOS satellites
  - 2001-2004: evaluated IKONOS imagery and 12-band digital airborne system (<12” resolution) for invasive weed detection/mapping
  - 2014-present: original collaborator in “Unmanned Flight Initiative” program at Cal Poly (Aerospace Engineering)
    - Evaluation of hyperspectral data for detecting and monitoring moisture stress in vineyards, development of Decision Support System (DSS)

DigitalGlobe WorldView-4
Resolution: 0.31m pan, 1.24m indiv
Spectra: Blue, Green, Red, NIR
Revisit: 1-5 days

Disadvantages of satellites

1. Low spatial and spectral resolution
2. Long or inconvenient revisit times
3. Clouds
4. Cost

REMOTE SENSING: WHERE ARE WE?

- Very high quality imaging systems
  - Resolution (optical systems capable of ~3cm at 122m [400 ft] AGL)
  - Commercial spectral ranges now extends from ultraviolet through LWIR (long-wave infrared, aka thermal)
  - Multispectral, hyperspectral, NIR, and Thermal systems commercially available (waiting for hyperspectral systems to extend beyond SWIR)
    - Multispectral, NIR, and Thermal systems readily available for UAS
    - Smallest hyperspectral systems weigh 8-15 lbs
- Substantial advancements in automation of image georegistration (placement in coordinate space)

REMOTE SENSING: WHERE ARE WE?

- Interpretation of image data (the part that matters)
  - Limited progress since 1972 (NDVI)
    - NDVI is a mathematically simple technique for qualitatively discriminating between areas that are densely covered with actively growing vegetation, and those that aren't
      - Little reflected red light and lots of reflected NIR light (indications of healthy vegetation) produces values approaching 1.0
        - $NDVI = (NIR - VIS)/(NIR + VIS)$
    - It performs that basic operation reasonably well – but comparing image data from different locations or across different dates is problematical
    - Numerous attempts have been made to improve on the NDVI to make it more sensitive to smaller variations and quantitatively comparable across sites. Results have been mixed.

REMOTE SENSING: WHERE ARE WE?

- Basic Physics Problem
  - While meaningful measurements can be made of a number of plant physiology parameters when a pure canopy is present and light is well controlled, those conditions do not usually occur in the field
  - Most image pixels are 'mixed,' meaning that the values of each band in a pixel is a weighted average of all the elements that contribute to it
  - This has been tough to overcome

			Weighted
Element	Reflectance	Proportion	Value
canopy	14	50%	7
road	156	15%	23.4
soil	102	20%	20.4
dry grass	118	15%	17.7
		Wtd Avg:	68.5

REMOTE SENSING: WHERE ARE WE?

- What do we WANT from the imagery?
  - Indications of…
    - Crop Biomass/Yield levels
    - Crop Quality (chemical composition)
    - Stress
      - Disease indications
      - Nutrient deficiency
      - Pest
        - Disease/Nutrient/Pest ID
        - Area affected
      - Water

All these and more are areas of very active research. A number of useful discoveries have been made, just few that have translated into useful field tools as yet.

REMOTE SENSING: WHERE ARE WE?

- What do we currently GET from the imagery?
  - Identification of areas that are 'different'
    - It is still usually more effective to use aerial images to identify potential problems, and then go scout them to determine why
      - …as opposed to using the imagery to attempt to determine what is occurring
    - Acquiring images during key periods, especially when plants may be especially subject to stress, can be usefully revealing

CAL POLY VINEYARD WATER STRESS PROJECT – UAS / HYPERSPECTRAL

- (1) agricultural water use is a growing concern
- (2) many vineyards use irrigation systems which can be adapted to respond to fine-scale differences in water needs
- (3) trellis-grown vines produce narrow canopies that imaging systems on piloted aircraft have not yet achieved high enough resolution to deliver pure vine canopy data, as a UAS-borne imager might be able to do

CAL POLY VINEYARD WATER STRESS PROJECT – UAS / HYPERSPECTRAL

Yamaha RMAX

Gas engine
1 hr endurance
50 lb payload

CAL POLY VINEYARD WATER STRESS PROJECT – UAS / HYPERSPECTRAL

Chorro Creek vineyard

CAL POLY VINEYARD WATER STRESS PROJECT – UAS / HYPERSPECTRAL

Corning SHARK hyperspectral unit

60 bands, 400-800 nm
~15 lbs
GSD <1 ft

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- Ultimate goal, if system proves successful
  - Explore developing a Decision Support System (DSS) for vineyard operations
  - European Vite.net example (Rossi et al., 2013)
    1. an integrated system for real-time monitoring of the vineyard components (air, soil, plants, pests, and diseases)
    2. a web-based tool that analyses these data by using advanced modelling techniques and then provides up-to-date information for managing the vineyard in the form of alerts and decision supports.

CAL POLY VINEYARD WATER STRESS PROJECT – UAS / HYPERSPECTRAL

- The goals of vite.net:
  i. maintain the natural resource base of the vineyard for future grape production;
  ii. improve the economic viability of the crop through better management of resources and through reduction of certain inputs (e.g., chemicals, water, etc.);
  iii. demonstrate good environmental performance to customers, neighbors, and the general community;
  iv. meet industry, community, and government expectations about environmental management;
  v. maintain or gain access to certain markets, especially those with high environmental standards.