REMOTE SENSING IN STRAWBERRY PRODUCTION

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Introduction

California grew approximately 90% of the nations strawberries in 2008 with a farm gate value over $1.5 billion. Approximately 50% of this crop is grown in the central coastal production area (Watsonville and Salinas), where production costs are in excess of $30,000 per acre each year. Historically production has relied on preplant soil fumigation with mixtures of methyl bromide and chloropicrin to manage soilborne pests and ensure the high yields required for economic viability. With the phase out of methyl bromide due to its ozone depletion potential there has been a shift in the fumigation practices of growers and a need for tools that can help the grower assess the efficacy of alternative fumigation practices as well as improve crop management practices to optimize returns. Remote sensing was evaluated for its ability to measure plant growth parameters on the ground and to see if there was a correlation between NDVI and crop yield.

Trials in Commercial Fields

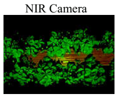
Data Collection:

- Size and reflectance data –subplots in 11-33 locations in the field for each treatment block.
  - Plant size data was collected with a Tetracam ADC digital camera
  - Reflectance data collected approximately every 6 weeks of the harvest season with an ASD Handheld Spectroradiometer for 20 plants in each subplot where yield data was collected and with a CropScan MSR-16 in all subplots on a monthly basis during the harvest season. Reflectance data is collected immediately after harvest to minimize interference from the fruit.
- Aerial Images (0.5 meter spatial resolution)
  - Images taken with a DuncanTech MS-3100 CIR equipped with a green (530-570 nm), red (640-680 nm) and near infrared (768-832 nm) filters
  - To normalize images for analysis, a 56% and 12% reflectance calibration tarp was deployed on the days that images were collected. The images were calibrated to the tarps prior to data analysis.
  - All data collection areas were georeferenced to the images by GPS.
  - An 8-class NDVI was calculated for each image using Imangine.

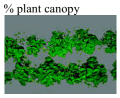
Nondestructive measurement of plant biomass

- Plant size data collected by analysis of digital images taken with a camera that records images in the NIR spectra. This system has been calibrated by destructive sampling and the % of the picture taken up by the plant (% canopy coverage) was found to correlate well with leaf area (r^2=0.82 and above depending on the cultivar) and biomass (r^2=0.87 and above, data not shown). Due to an increase in canopy density over time the relationship between % canopy coverage and leaf area is linear to approximately 80% canopy coverage. Because of different canopy architecture the calibration curves of cultivars are different.

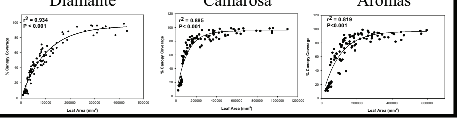
Picture with NIR Camera



Color analysis for % plant canopy



Diamante / Camarosa / Aromas

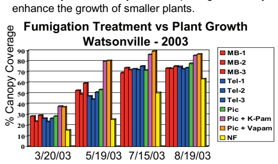


Relationship between plant growth and subsequent yield

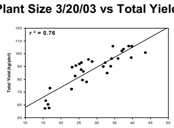
Plant growth during the season can be accurately measured using a near infrared camera mounted on a frame over the bed top (there is a good correlation between % canopy coverage and fresh and dry weight of the plant as well as leaf area; r^2 > 0.90).

- Plants grow at different rates in response to fumigation treatments and a correlation was found between plant size at the early stages of the fruit production cycle and subsequent yield. This should **not** be interpreted to mean that growers should be encouraged to produce larger plants, only that under the best management practices used within a field smaller plants will yield less than larger plants.
- The ability to accurately measure plant growth early in the season may provide time for the growers to modify fertility management to enhance the growth of smaller plants.

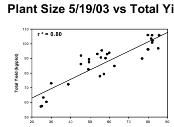
Fumigation Treatment vs Plant Growth Watsonville - 2003



Watsonville 2003 Plant Size 3/20/03 vs Total Yield



Watsonville 2003 Plant Size 5/19/03 vs Total Yield



Determining the relationship between remote sensing data and plants in the ground

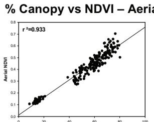
To better understand how the aerial data obtained with remote sensing relate to the plants in the ground, data was extracted from the images and compared to physical data collected on the ground for the same locations.

- Multiple sites were precisely located in the field by GPS
  - Data on plant canopy coverage and canopy reflectance was collected from these locations at the same time aerial images were collected
  - The aerial images were georeferenced and the NDVI data extracted from the specific locations in the field (from the pixel representing the GPS point and each adjacent pixel).

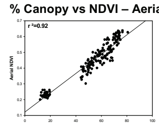
<u>Results</u>

- There was a good correlation between plant size (% canopy coverage) and NDVI collected from the aerial image.
  - Due to background problems with green plastic the correlation was weaker early season until the canopy filled in the bed top.
- There was a good correlation (r^2 = 0.754 and above) between plant size (% canopy coverage) and NDVI collected on the ground with a spectroradiometer and between NDVI from ground based measurements and aerial images (r^2 = 0.737 and above) (data not shown).
  - This correlation does not always hold true once the % canopy coverage is greater than 80% (the relationship between leaf area and % canopy coverage is no longer linear and the increase in leaf density in the plant will cause an increase in the NDVI).
  - The NDVI also will decrease if the plant vigor cycles down.
  - A reduction in plant vigor due to disease, mite infestations, irrigation problems or management decisions regarding fertilization may also cause a reduction in NDVI for some regions of the field as well.

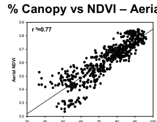
Diamante – White Plastic % Canopy vs NDVI – Aerial



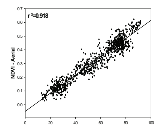
Diamante – Silver Plastic % Canopy vs NDVI – Aerial



Diamante – Green Plastic % Canopy vs NDVI – Aerial



Camarosa – Brown Plastic % Canopy vs NDVI – Aerial



Comparing changes in NDVI of aerial images of production fields

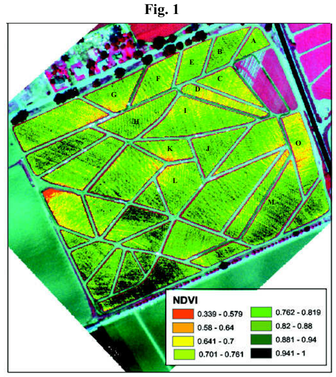
Images with a 0.5 m spatial resolution were taken of production fields at periodic intervals during the fruit production season and analyzed to give an 8-class NDVI image.

- Images in Fig. 1 and 2 were taken on 6/3 and 7/14/04, respectively. The mean values of the NDVI for each block were calculated and listed on the bottom of the figures.
- Note how values can change from the earlier picture to the latter (increasing for blocks C and O, decreasing for blocks G and H)

To measure the extent of change in NDVI from one image to the next:

- Georeferenced images were overlaid and aligned.
- For each pixel the NDVI values in the earlier image were subtracted from the later image.
- This new value was referred to as the Strawberry Vegetation Difference Index (SVDI) and an 8-class SVDI was then generated to provide a visual representation of changes in the NDVI in different regions of the field (Fig. 3).
  - This value can be useful for evaluating the effects of specific treatments on plant growth or vigor
  - Currently evaluating how this change relates to strawberry yield.

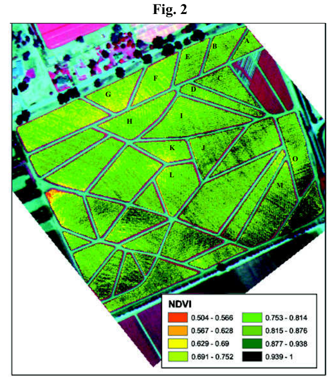
Fig. 1



<u>Average block NDVI values</u>

A = 0.78	F = 0.77	K = 0.76
B = 0.82	G = 0.78	L = 0.79
C = 0.74	H = 0.80	M = 0.85
D = 0.72	I = 0.78	N = 0.85
E = 0.78	J = 0.81	O = 0.73

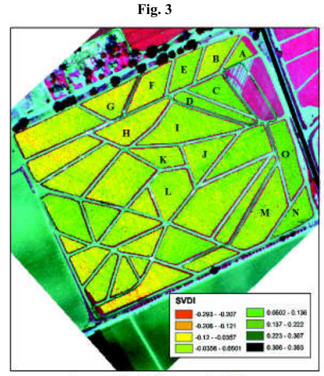
Fig. 2



<u>Average block NDVI values</u>

A = 0.83	F = 0. 76	K = 0. 78
B = 0.83	G = 0. 75	L = 0. 81
C = 0. 84	H = 0. 78	M = 0. 89
D = 0. 81	I = 0. 81	N = 0. 95
E = 0. 82	J = 0. 85	O = 0. 85

Fig. 3



<u>Average block differences in NDVI</u>

A = 0.045	F = -0.0130	K = 0.014
B = 0.005	G = -0.030	L = 0.021
C = 0.101	H = -0.023	M = 0.035
D = 0.098	I = 0.031	N = 0.094
E = 0.044	J = 0.038	O = 0.127

Additional research that is needed

Correction factors to eliminate interference from soil and plastic

Images taken of the production field include reflectance from the plants under study as well as soil in the furrow bottoms and, during early season before the plant canopy fills in, plastic on the bed top. Reflectance from the soil and plastic can compromise the accuracy of the vegetation index (especially when the plants are small) so studies are needed to evaluate correction factors to reduce this potential interference (0.25 m spatial resolution images were taken parallel with the beds to allow collection of data from the plants on the bed top only).

- There was a good correlation (r^2=0.809) between the NDVI for the bed tops only in the 0.25 m image and 0.5 m images of the entire field, although the values were approximately 31% higher for the bed tops.
- Multiplying the NDVI for the 0.5 m images by 1.29 gave a vegetation index equal to the values observed in the 0.25 m image. Investigations are needed to re-evaluate the field data for the 0.5 m images to see if applying this correction factor improves the utility of the NDVI in assessing plant health and production.

Determining if there is a correlation between changes in NDVI over time and plant productivity

It would be very helpful for the growers to be able to identify changes in the vegetation index associated with future reductions in fruit production so they could modify their production practices to maintain yield (for example, fertilizer application). From a price support and marketing standpoint it also would be helpful to be able to predict what the fields will produce in the coming weeks. Data on crop yield was collected at the same time aerial images were taken and the data needs to be further analyzed to determine if there is a correlation that would be helpful to the growers.

Determining if there is another vegetation index that would better reflect plant vigor and productivity

An ASD Handheld Spectroradiometer has been used to collect reflectance data on a monthly basis from 20 plants per treatment rep. The data needs to be analyzed to determine the best correlation between this data and strawberry yield. This would allow for development of a vegetation index that would more reflect accurately plant vigor and yield potential.

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