

SPECTRAL VEGETATION INDICES FOR ESTIMATING GROWTH OF WINTER WHEAT GENOTYPES

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INTRODUCTION

Fast growing population



Growing food demand



Wheat as a staple cereal crop

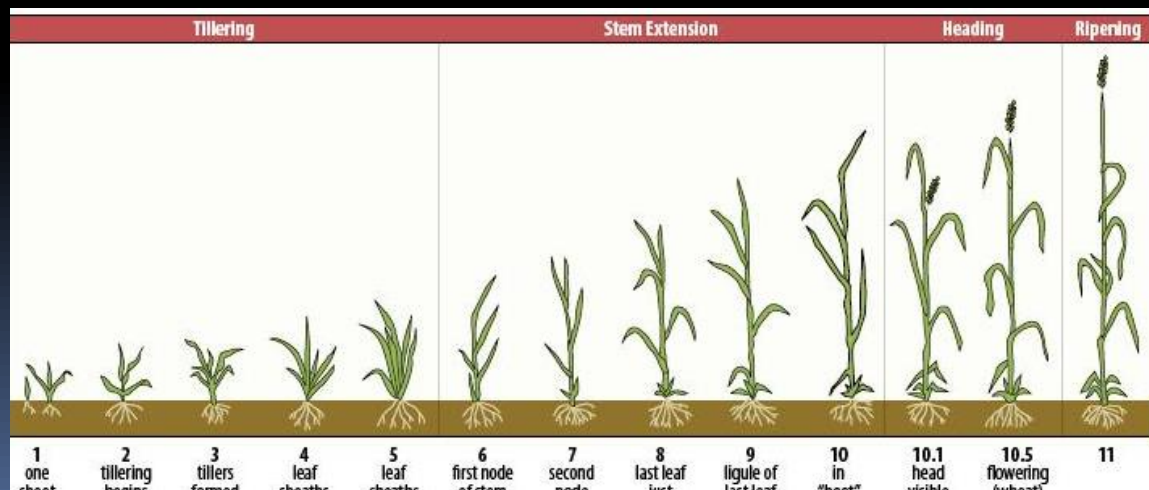


Wheat Breeding



INTRODUCTION

- The process of monitoring the growth and performance of wheat genotypes for better yield under various agro-climatic conditions and stresses can be labor intensive especially when done several times during the growing season (at different growth stages).



The Feekes scale of wheat development.

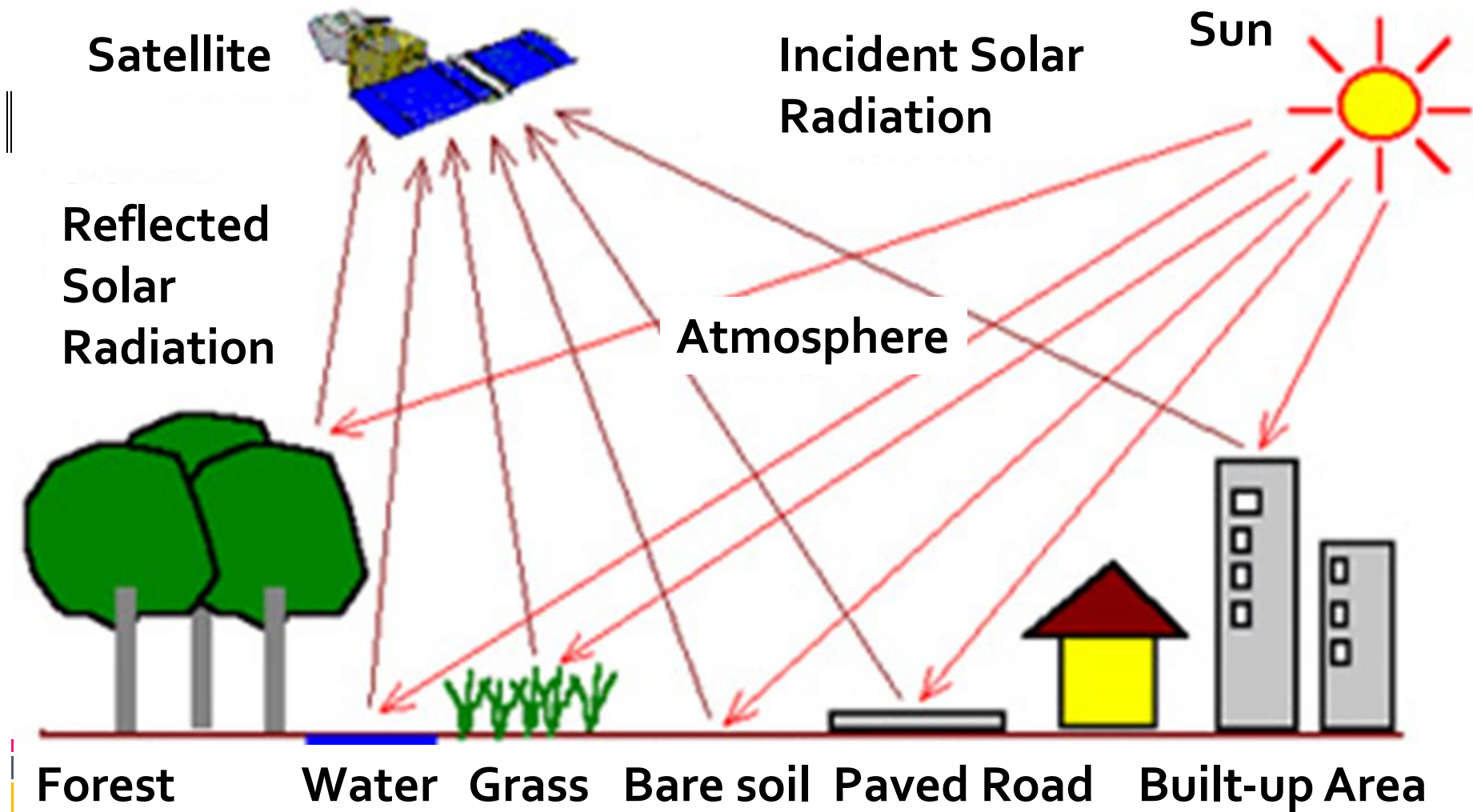
Smith, 2009

9/20/2016

Remote Sensing Methods

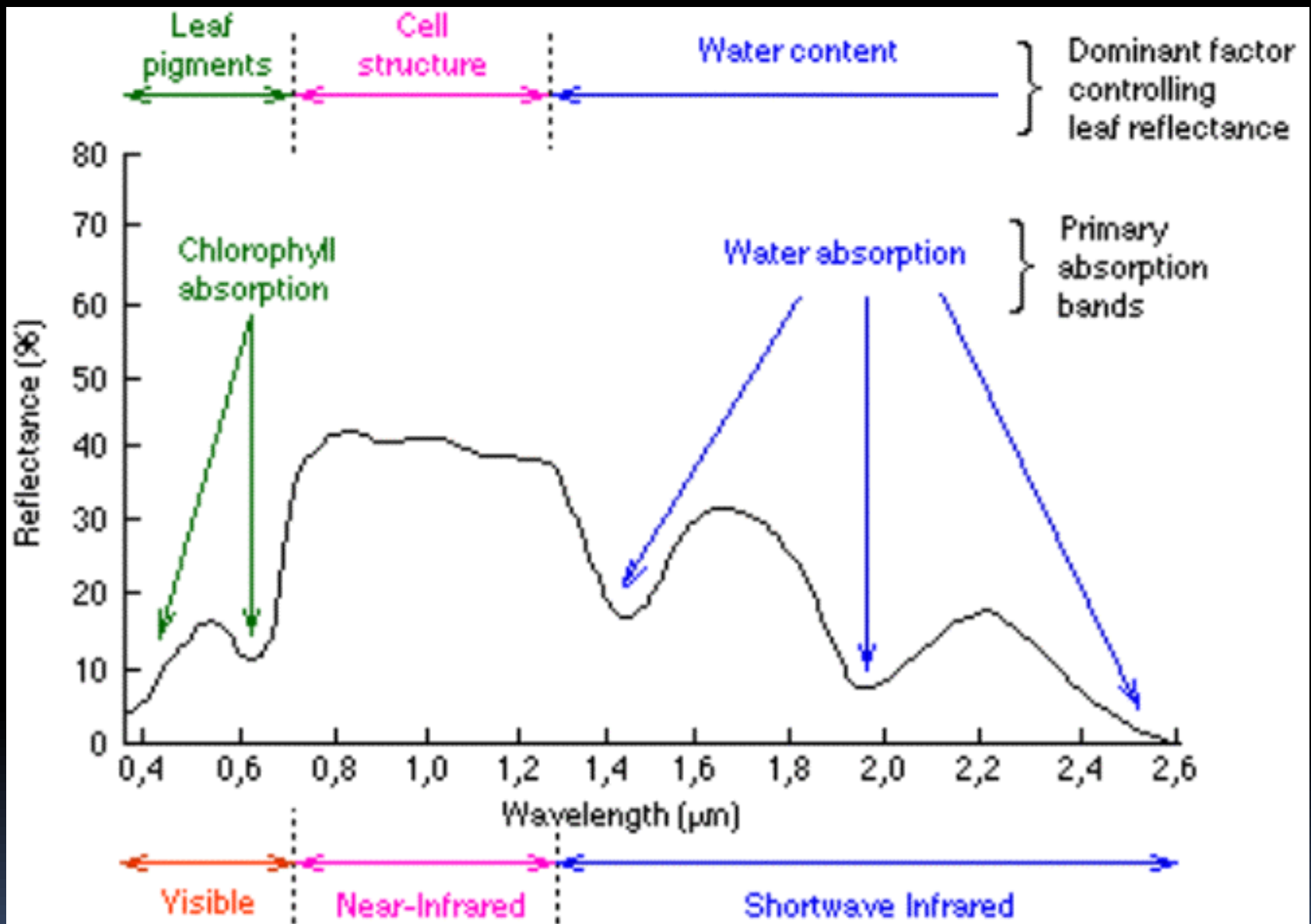
- Quick
- Objective
- Non-destructive
- Simultaneous measurements
- Reduced cost and time
- Automated approach to identify best plant variety of interest





Spectral signatures of natural and human-made materials

(Sanderson, 2000)



Dominating factor controlling leaf reflectance (Hoffer, 1978).

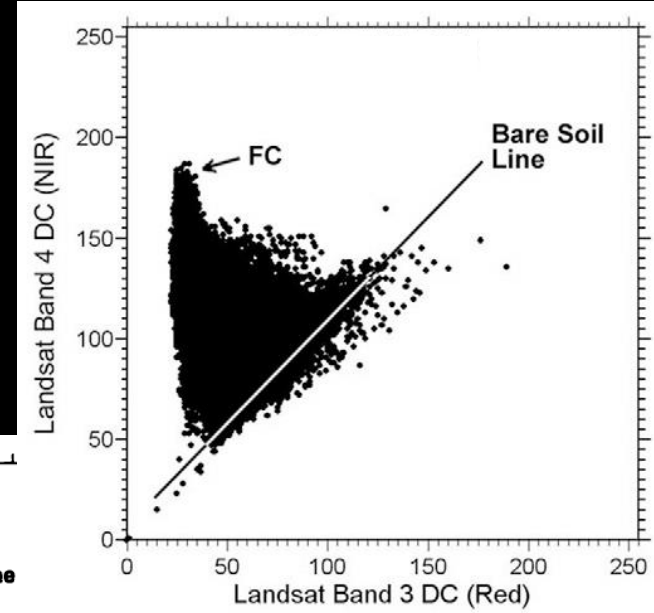
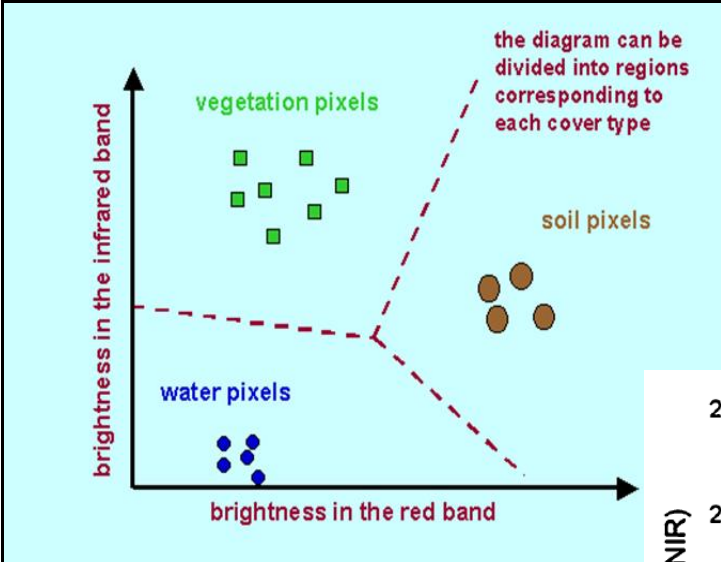
Vegetation Index

- A number generated by mathematical equations and transformations using remote sensing bands.
- May have some relationship to the amount of vegetation and its characteristics in a given image pixel.
 - Some examples are NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), SAVI (Soil Adjusted Vegetation Index), **PVI (Perpendicular Vegetation Index)**.

Vegetation Index cont'd

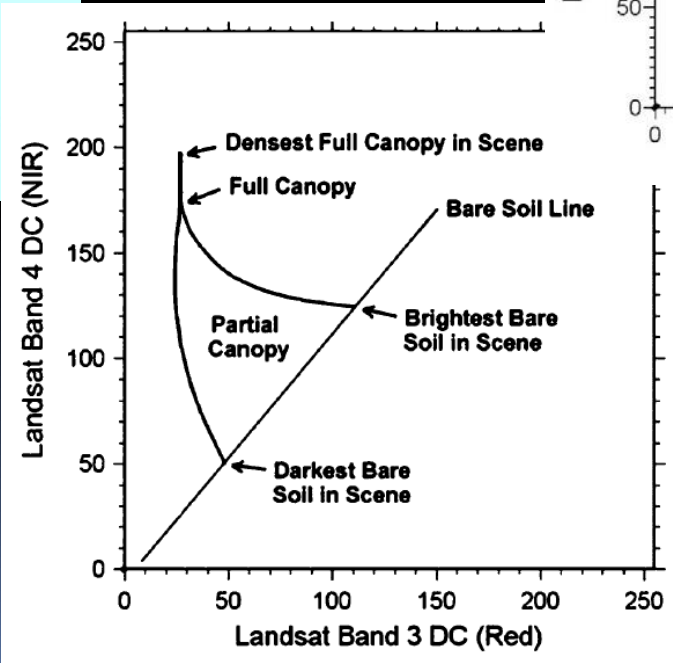
$$PVI = (NIR_DC - RED_DC(a_1) - a_0) / \sqrt{1 + (-a_1)^2}$$

Where PVI= Perpendicular Vegetation Index, a_0 = Intercept, a_1 = Slope, DC = Digital count, GC = Ground cover, FC = Full canopy.



Richards and Wise, 2001

$$GC = PVI_{plot} / PVI_{FC}$$



Rajan and Maas, 2009

OBJECTIVE

- Evaluate genetic variability in growth and performance of twenty wheat genotypes under two water regimes (rainfed and irrigated conditions), using spectral vegetation indices (SVI) estimated from aerial imagery, and from GreenSeeker[®] sensor, and percent ground cover (%GC) estimated from digital photos.

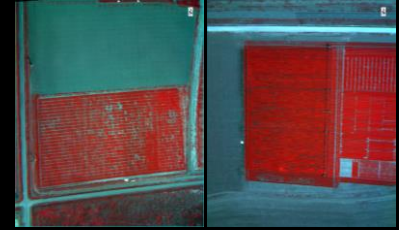
Materials and Methods

- **Location: Texas A&M AgriLife Research Experiment Station, Bushland, TX.**
- **Experimental design: Randomized complete block design with three replications.**
- **2014-2015 growing season.**

Data Collection

○ Aerial Imagery

- Involves taking of photographs of the ground from an elevated position, usually the camera is not supported by a ground-based structure.
- Analyzed using ENVI and ArcMap.



○ Digital Photographs

- Involves the use of a digital camera to take pictures of the ground surface.
- To measure the percent ground cover (analyzed using Adobe Photoshop CS6).



○ GreenSeeker[®] sensor

- Instrument that records NDVI values. It uses 660 and 770nm.

Aerial Imagery – Tetra Mini MCA (Multiple Camera Array)

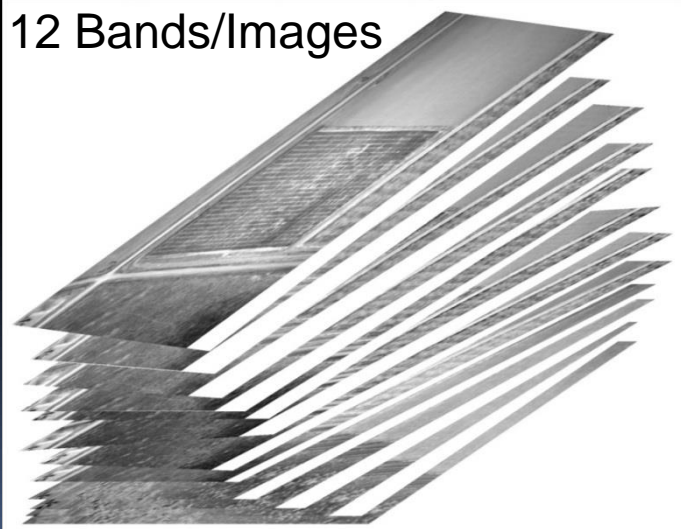
Spectral Range 450-1000 nm
Spatial Resolution 222.89 mm
Scanning Time 1 frame/second
Flight height 5000 – 6500 feet Above Ground Level

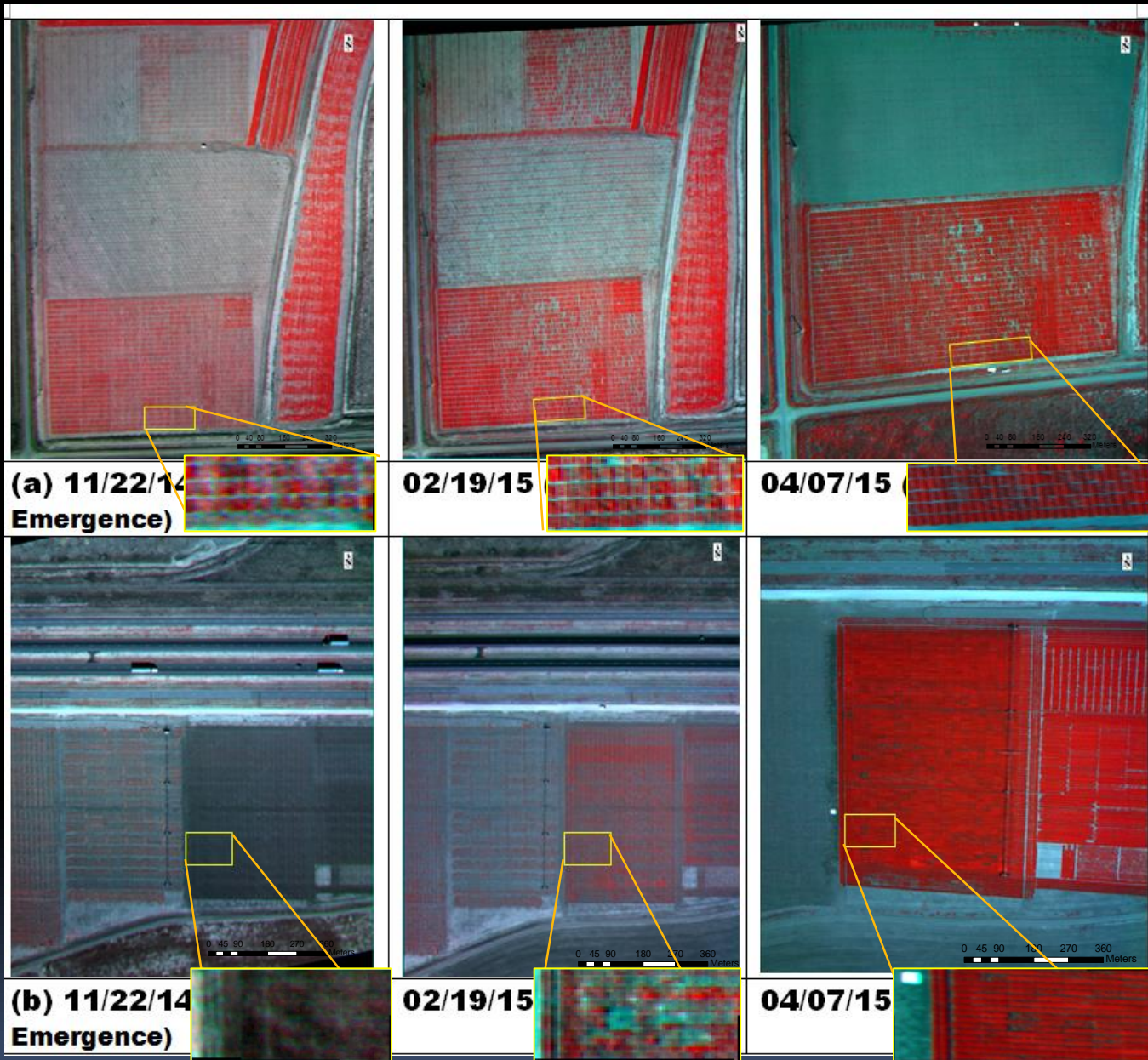


Spectral Resolution

12 Bands/Images

| Bands | Wavelength in nm |
|-------|------------------|
| B1 | 460-470 |
| B2 | 490-590 |
| B3 | 530-540 |
| B4 | 580-590 |
| B5 | 626-640 |
| B6 | 684-694 |
| B7 | 710-720 |
| B8 | 756-766 |
| B9 | 785-800 |
| B10 | 830-850 |
| B11 | 870-880 |
| B12 | 930-950 |

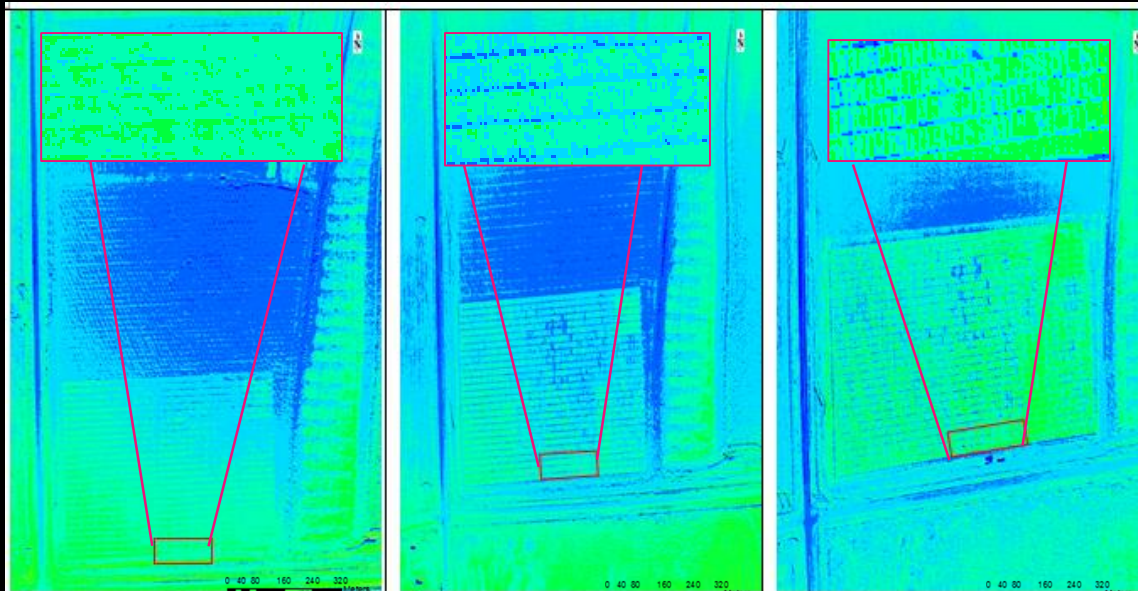




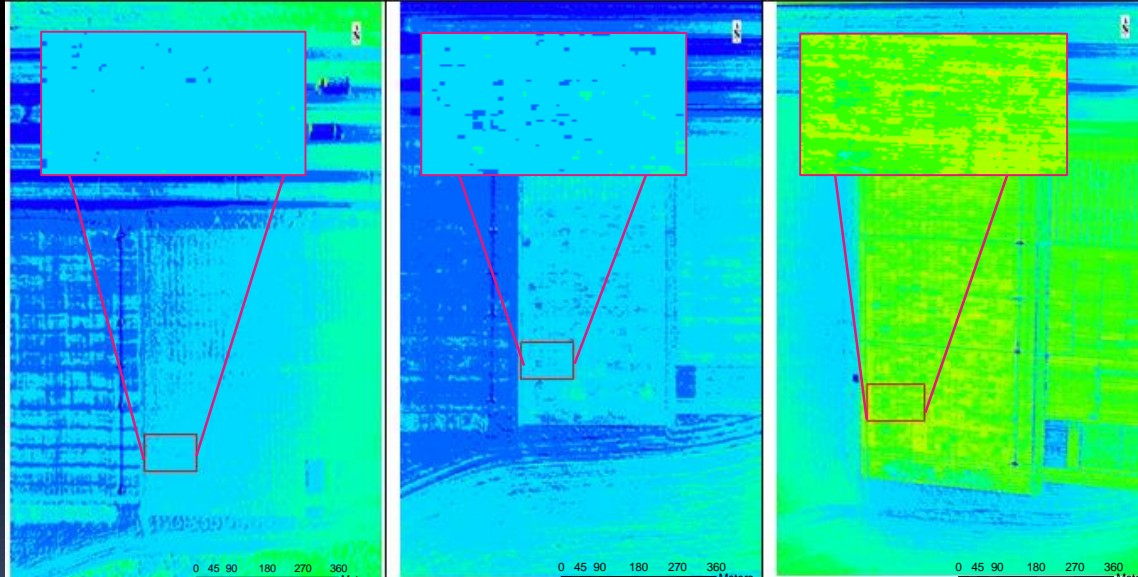
Aerial Images of Rainfed (a) and Irrigated (b) fields in Bushland, TX; displayed in color infrared.

| NAME | NDWI | |
|-------------|---------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 0.391 | 0.240 |
| TAM 105 | 0.372 | 0.236 |
| TAM 110 | 0.381 | 0.243 |
| TAM 111 | 0.375 | 0.246 |
| TAM 112 | 0.394 | 0.241 |
| TAM 114 | 0.396 | 0.240 |
| TAM 304 | 0.388 | 0.241 |
| TAM 113 | 0.388 | 0.240 |
| TX99A0153-1 | 0.389 | 0.238 |
| Dumas | 0.381 | 0.241 |
| Jagalene | 0.386 | 0.245 |
| Hatcher | 0.382 | 0.247 |
| PlainsGold | | |
| Byrd | 0.380 | 0.249 |
| Winterhawk | 0.387 | 0.243 |
| Iba | 0.393 | 0.244 |
| Endurance | 0.384 | 0.254 |
| Duster | 0.374 | 0.239 |
| Billings | 0.381 | 0.229 |
| Jagger | 0.381 | 0.241 |
| Fuller | 0.378 | 0.242 |
| LSD | NS | NS |

| NAME | NDWI | |
|-------------|---------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 0.292 | 0.234 |
| TAM 105 | 0.320 | 0.249 |
| TAM 110 | 0.328 | 0.238 |
| TAM 111 | 0.331 | 0.228 |
| TAM 112 | 0.321 | 0.267 |
| TAM 114 | 0.331 | 0.269 |
| TAM 304 | 0.338 | 0.256 |
| TAM 113 | 0.341 | 0.236 |
| TX99A0153-1 | 0.335 | 0.255 |
| Dumas | 0.323 | 0.242 |
| Jagalene | 0.314 | 0.245 |
| Hatcher | 0.299 | 0.255 |
| PlainsGold | | |
| Byrd | 0.329 | 0.259 |
| Winterhawk | 0.323 | 0.215 |
| Iba | 0.312 | 0.213 |
| Endurance | 0.329 | 0.214 |
| Duster | 0.318 | 0.229 |
| Billings | 0.315 | 0.217 |
| Jagger | 0.318 | 0.226 |
| Fuller | 0.319 | 0.255 |
| LSD | NS | 0.024*** |

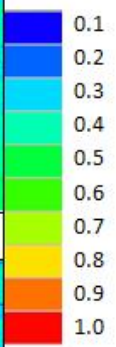


(a) 11/22/14 NS 02/19/15 NS 04/07/15 NS



(b) 11/22/14 NS 02/19/15 *** 04/07/15 **

NDWI



Blue colors show less water content

Yellow/Red colors indicate more water content

| NAME | NDWI | |
|-------------|---------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 0.458 | 0.602 |
| TAM 105 | 0.455 | 0.606 |
| TAM 110 | 0.457 | 0.630 |
| TAM 111 | 0.444 | 0.582 |
| TAM 112 | 0.441 | 0.597 |
| TAM 114 | 0.457 | 0.595 |
| TAM 304 | 0.437 | 0.586 |
| TAM 113 | 0.448 | 0.603 |
| TX99A0153-1 | 0.449 | 0.617 |
| Dumas | 0.445 | 0.601 |
| Jagalene | 0.450 | 0.593 |
| Hatcher | 0.444 | 0.584 |
| PlainsGold | | |
| Byrd | 0.478 | 0.591 |
| Winterhawk | 0.447 | 0.561 |
| Iba | 0.452 | 0.561 |
| Endurance | 0.462 | 0.545 |
| Duster | 0.471 | 0.599 |
| Billings | 0.412 | 0.556 |
| Jagger | 0.455 | 0.598 |
| Fuller | 0.459 | 0.599 |
| LSD | NS | 0.032** |

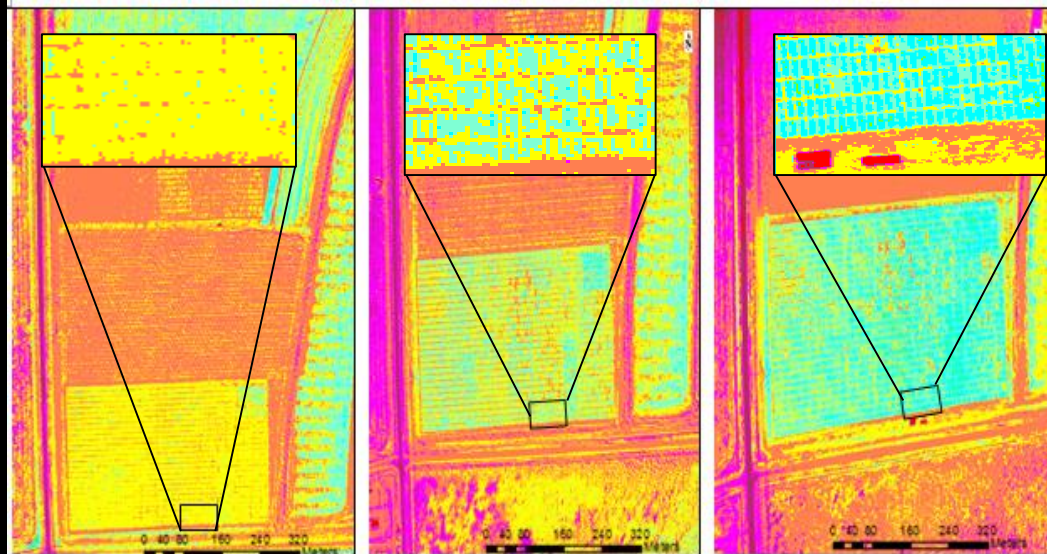
NDWI (Normalized Difference Water Index) maps of Rainfed (a) and Irrigated (b) fields in Bushland, TX.

† NS: No significance; *, **, and *** significant at 0.05, 0.01, and <.0001, respectively

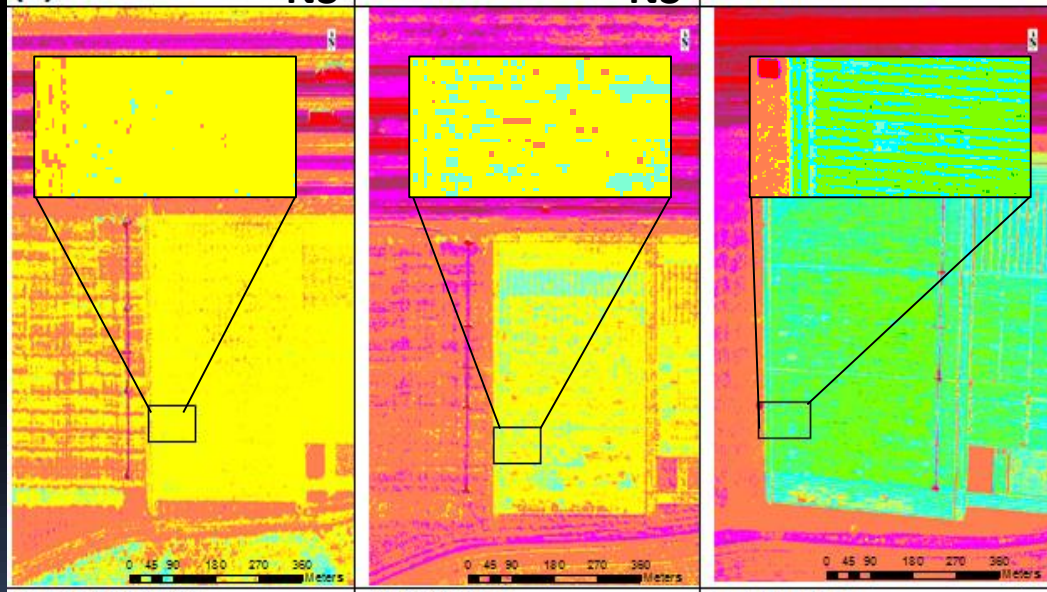
9/20/2016

| NAME | NDVI_aerial | |
|-------------|-------------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 0.466 | 0.233 |
| TAM 105 | 0.425 | 0.231 |
| TAM 110 | 0.453 | 0.228 |
| TAM 111 | 0.450 | 0.226 |
| TAM 112 | 0.465 | 0.227 |
| TAM 114 | 0.474 | 0.230 |
| TAM 304 | 0.475 | 0.230 |
| TAM 113 | 0.447 | 0.228 |
| TX99A0153-1 | 0.477 | 0.233 |
| Dumas | 0.451 | 0.230 |
| Jagalene | 0.453 | 0.229 |
| Hatcher | 0.446 | 0.227 |
| PlainsGold | | |
| Byrd | 0.475 | 0.235 |
| Winterhawk | 0.455 | 0.225 |
| Iba | 0.478 | 0.224 |
| Endurance | 0.464 | 0.234 |
| Duster | 0.469 | 0.228 |
| Billings | 0.446 | 0.220 |
| Jagger | 0.469 | 0.230 |
| Fuller | 0.478 | 0.229 |
| LSD | NS | NS |

| NAME | NDVI_aerial | |
|-------------|-------------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 0.486 | 0.453 |
| TAM 105 | 0.528 | 0.473 |
| TAM 110 | 0.523 | 0.460 |
| TAM 111 | 0.532 | 0.461 |
| TAM 112 | 0.516 | 0.494 |
| TAM 114 | 0.543 | 0.491 |
| TAM 304 | 0.591 | 0.477 |
| TAM 113 | 0.551 | 0.464 |
| TX99A0153-1 | 0.537 | 0.475 |
| Dumas | 0.549 | 0.462 |
| Jagalene | 0.518 | 0.460 |
| Hatcher | 0.506 | 0.481 |
| PlainsGold | | |
| Byrd | 0.550 | 0.485 |
| Winterhawk | 0.544 | 0.432 |
| Iba | 0.523 | 0.430 |
| Endurance | 0.548 | 0.423 |
| Duster | 0.543 | 0.449 |
| Billings | 0.532 | 0.440 |
| Jagger | 0.520 | 0.453 |
| Fuller | 0.528 | 0.479 |
| LSD | NS | 0.025*** |



(a) 11/22/14 NS 02/19/15 NS 04/07/15 *



(b) 11/22/14 NS 02/19/15 *** 04/07/15 *

NDVI

Red colors indicate bare soil

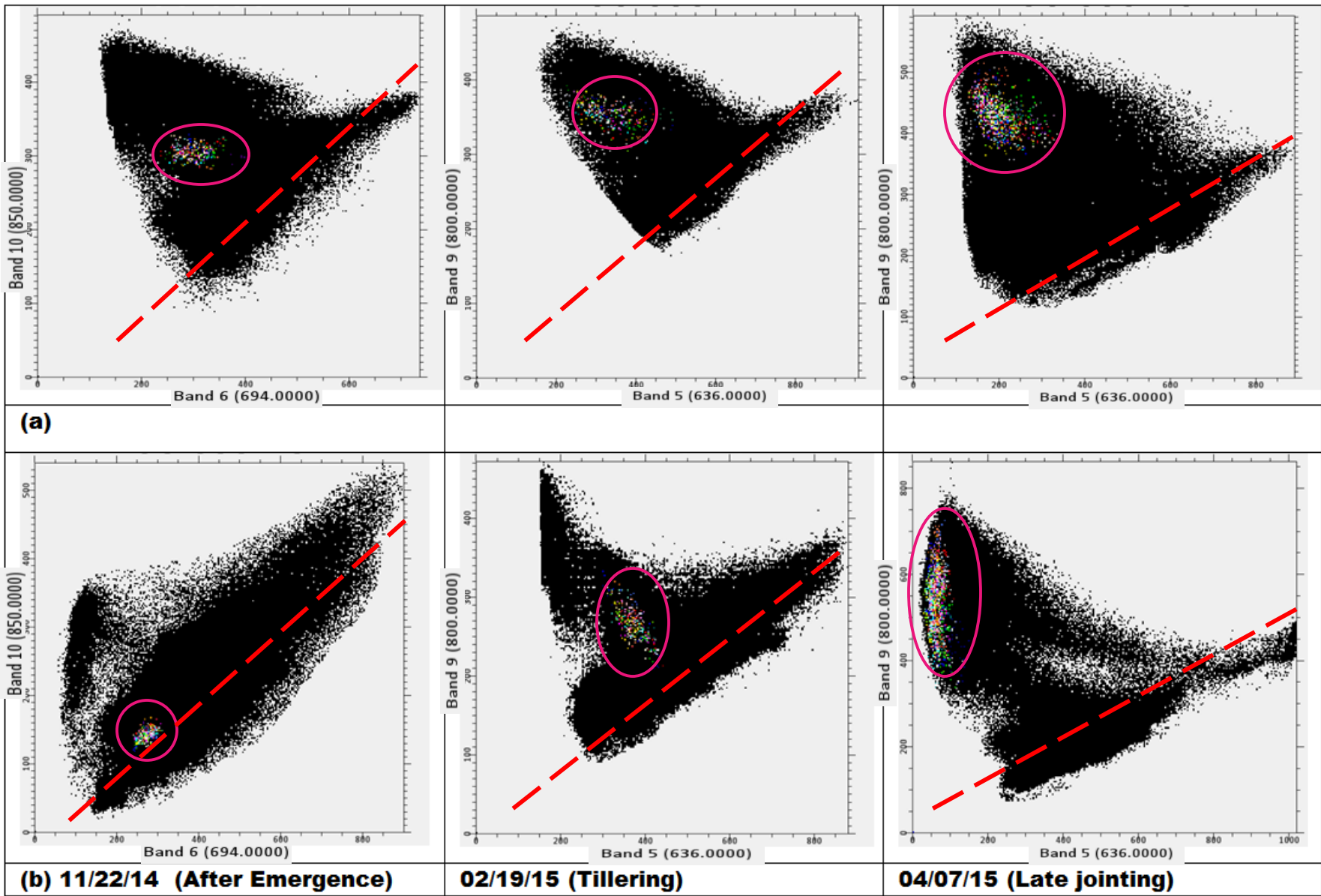
Green colors indicate the densest vegetation canopy

- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1.0

| NAME | NDVI_aerial | |
|-------------|-------------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 0.674 | 0.779 |
| TAM 105 | 0.673 | 0.786 |
| TAM 110 | 0.681 | 0.802 |
| TAM 111 | 0.694 | 0.759 |
| TAM 112 | 0.670 | 0.776 |
| TAM 114 | 0.694 | 0.766 |
| TAM 304 | 0.681 | 0.770 |
| TAM 113 | 0.667 | 0.772 |
| TX99A0153-1 | 0.689 | 0.786 |
| Dumas | 0.655 | 0.784 |
| Jagalene | 0.653 | 0.771 |
| Hatcher | 0.677 | 0.790 |
| PlainsGold | | |
| Byrd | 0.697 | 0.774 |
| Winterhawk | 0.658 | 0.752 |
| Iba | 0.658 | 0.758 |
| Endurance | 0.698 | 0.757 |
| Duster | 0.677 | 0.781 |
| Billings | 0.632 | 0.768 |
| Jagger | 0.671 | 0.771 |
| Fuller | 0.687 | 0.772 |
| LSD | 0.035* | 0.025* |

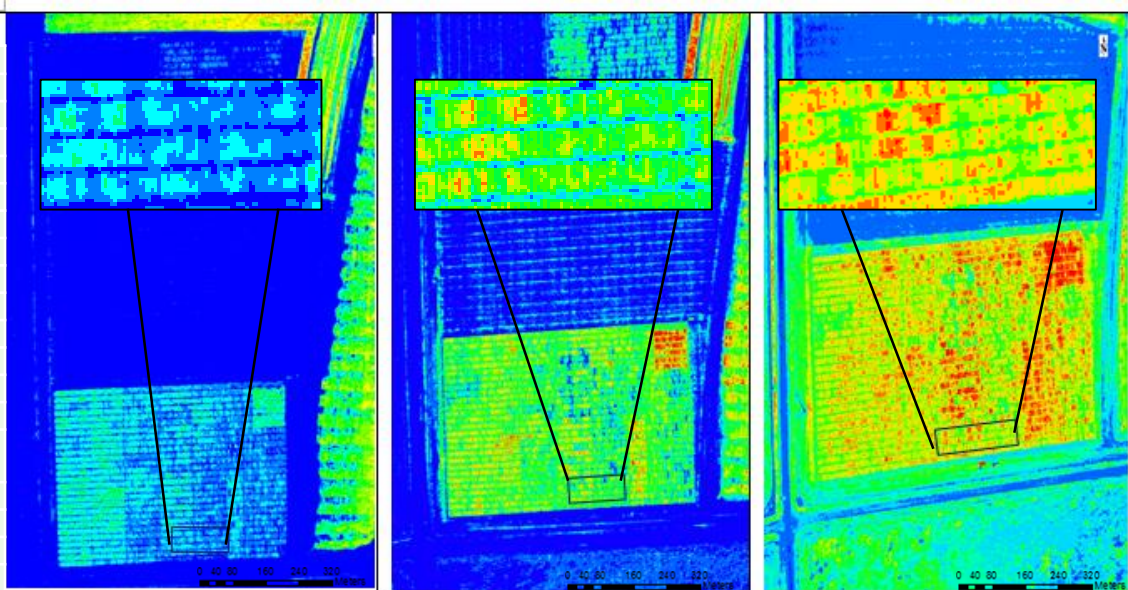
NDVI (Normalized Difference Vegetation Index) maps of Rainfed (a) and Irrigated (b) fields in Bushland, TX

† NS: No significance; *, **, and *** significant at 0.05, 0.01, and <.0001, respectively

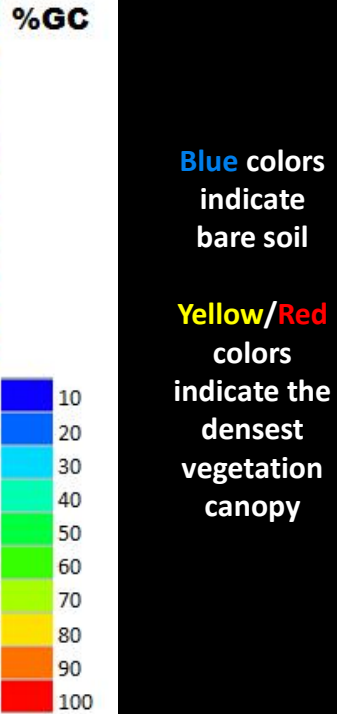


NIR-Red Scatter plots used to calculate PVI (Perpendicular Vegetation Index), showing the 60 plots for the 20 wheat genotypes in color under Rainfed (a) and Irrigated (b) fields in Bushland, TX.

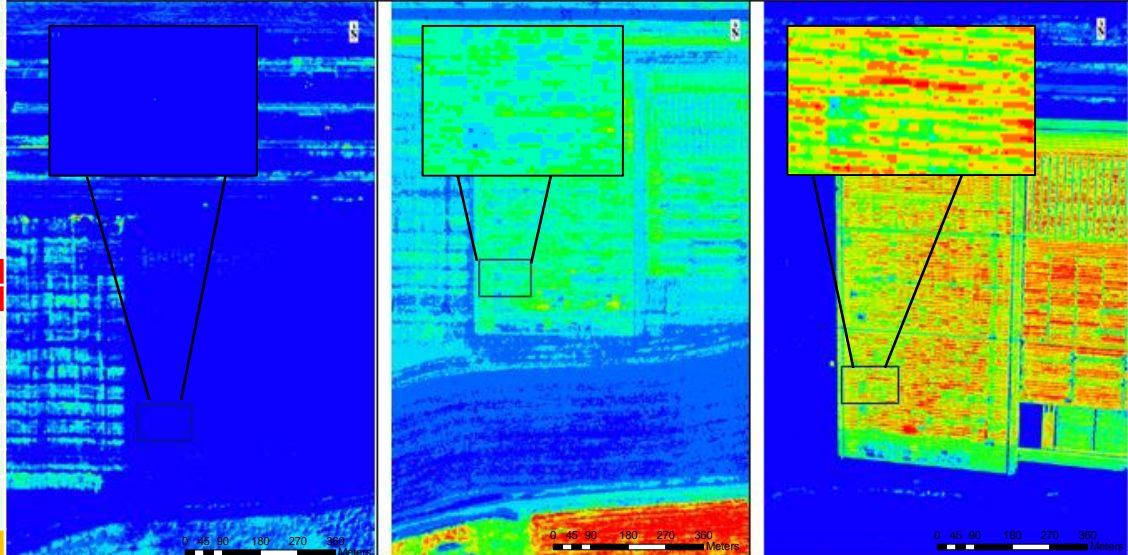
| NAME | %GC_PVI | |
|-------------|---------------|-----------|
| | Rainfed | Irrigated |
| TAM W-101 | 27.274 | 2.613 |
| TAM 105 | 33.088 | 2.451 |
| TAM 110 | 25.271 | 2.657 |
| TAM 111 | 26.784 | 1.264 |
| TAM 112 | 30.108 | 2.992 |
| TAM 114 | 31.684 | 2.105 |
| TAM 304 | 28.523 | 2.728 |
| TAM 113 | 28.644 | 2.792 |
| TX99A0153-1 | 28.746 | 2.341 |
| Dumas | 21.568 | 1.975 |
| Jagalene | 28.129 | 1.414 |
| Hatcher | 26.902 | 2.083 |
| PlainsGold | | |
| Byrd | 30.656 | 2.609 |
| Winterhawk | 25.565 | 2.913 |
| Iba | 24.135 | 2.683 |
| Endurance | 28.716 | 2.835 |
| Duster | 28.659 | 2.684 |
| Billings | 27.777 | 2.840 |
| Jagger | 32.582 | 3.049 |
| Fuller | 28.032 | 2.006 |
| LSD | 4.7154** | NS |



(a) 11/22/14 ** 02/19/15 * 04/07/15 ***



| NAME | %GC_PVI | |
|-------------|---------------|-----------------|
| | Rainfed | Irrigated |
| TAM W-101 | 54.502 | 35.618 |
| TAM 105 | 56.056 | 40.048 |
| TAM 110 | 56.402 | 39.356 |
| TAM 111 | 58.597 | 34.632 |
| TAM 112 | 59.088 | 47.107 |
| TAM 114 | 59.553 | 44.599 |
| TAM 304 | 57.602 | 41.396 |
| TAM 113 | 61.429 | 37.818 |
| TX99A0153-1 | 48.443 | 42.829 |
| Dumas | 42.650 | 34.321 |
| Jagalene | 49.050 | 34.973 |
| Hatcher | 48.812 | 43.427 |
| PlainsGold | | |
| Byrd | 63.843 | 44.030 |
| Winterhawk | 51.021 | 26.651 |
| Iba | 49.560 | 29.932 |
| Endurance | 57.059 | 28.450 |
| Duster | 52.312 | 36.984 |
| Billings | 40.864 | 32.469 |
| Jagger | 57.370 | 34.543 |
| Fuller | 54.455 | 41.965 |
| LSD | 12.709* | 7.458*** |



(b) 11/22/14 NS 02/19/15 *** 04/07/15 **

| NAME | %GC_PVI | |
|-------------|---------------|----------------|
| | Rainfed | Irrigated |
| TAM W-101 | 64.594 | 74.025 |
| TAM 105 | 73.893 | 81.202 |
| TAM 110 | 69.540 | 79.014 |
| TAM 111 | 72.900 | 79.436 |
| TAM 112 | 68.330 | 90.845 |
| TAM 114 | 79.113 | 83.916 |
| TAM 304 | 70.782 | 76.443 |
| TAM 113 | 61.100 | 74.397 |
| TX99A0153-1 | 69.347 | 74.621 |
| Dumas | 62.941 | 79.743 |
| Jagalene | 70.338 | 80.655 |
| Hatcher | 69.899 | 94.481 |
| PlainsGold | | |
| Byrd | 74.914 | 87.035 |
| Winterhawk | 67.701 | 75.925 |
| Iba | 66.860 | 76.761 |
| Endurance | 77.093 | 74.226 |
| Duster | 69.371 | 80.463 |
| Billings | 65.885 | 78.870 |
| Jagger | 65.822 | 77.940 |
| Fuller | 72.576 | 81.806 |
| LSD | 6.177*** | 9.698** |

Percent Ground cover (%GC) maps of Rainfed (a) and Irrigated (b) fields in Bushland, TX.

† NS: No significance; *, **, and *** significant at 0.05, 0.01, and <.0001, respectively 9/20/2016

Relationship between the Percentage ground cover (%GC) estimated from digital photos (dp) and PVI, NDVI obtained from GreenSeeker (gs) and Aerial (A) images, under (a) Rainfed and (b) Irrigated fields at tillering stage.

| Rainfed | | |
|----------------|----------------|----------------|
| Variable 1 (X) | Variable 2 (Y) | R ² |
| %GC_dp | NDVI_gs | 0.49** |
| %GC_dp | %GC_PVI | 0.66*** |
| %GC_dp | NDVI_A | 0.01 |
| NDVI_gs | NDVI_A | 0.002 |
| %GC_PVI | NDVI_gs | 0.46** |

| Irrigated | | |
|----------------|----------------|----------------|
| Variable 1 (X) | Variable 2 (Y) | R ² |
| %GC_dp | NDVI_gs | 0.88*** |
| %GC_dp | %GC_PVI | 0.79*** |
| %GC_dp | NDVI_A | 0.78*** |
| NDVI_gs | NDVI_A | 0.87*** |
| %GC_PVI | NDVI_gs | 0.95*** |

† NS: No significance; *, **, and *** significant at 0.05, 0.01, and <.0001, respectively

CONCLUSIONS

- TAM genotypes were mostly similar (in Parameters – NDVI and %GC) while Other genotypes showed more genotypic variations due to the wide genetic background, especially at tillering and late-jointing stages.
- Significant relationships provide the possibility of using the estimated parameters (%GC_PVI, NDVI) as an indirect tool to screen large numbers of wheat genotypes.
- Repeat field study: with consistent field data collection at specific growth stages, and yield data.

Acknowledgment

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