Spectral Vegetation Indices for Estimating Growth of Winter Wheat Genotypes.

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INTRODUCTION

Global population has been estimated to increase by 40 percent in the next 40 years, reaching approximately 10.7 billion in the year 2050. This comes with the challenge of keeping up with the global food demand with such a great increase. Wheat is known as one the world's most important cereal and a staple food for over one third of the world's population. Global wheat demand in 2010 reached an estimated 666 million metric tons (MMT), and global wheat consumption would exceed 880 MMT by 2050 (Wiegand, 2011). Wheat production can be enhanced through the development of improved cultivars with wider genetic base capable of producing better yield under various agro-climatic conditions and stresses. In the US Southern Great Plains (SGP), drought stress is one of the most important factors for reducing yield in winter wheat. The selection of drought tolerant and high yielding wheat cultivars is a critical strategy for wheat management under water-limited conditions. Remotely sensed data have been useful in monitoring physiological response to early growth conditions and plant adaptations to environmental changes and also differentiate genotypes for yield potential and water relations. However, little information is known for the genotypic differences in spectral parameters and their relationship, to warrant its use as an indirect selection tool. Therefore, the **objective** of this study is to evaluate genetic variability in early growth of twenty wheat genotypes (10 Texas A&M genotypes and other 10 SGP genotypes) under two water regimes (rainfed and irrigated conditions), using GreenSeeker®, digital photography (percent ground cover - %GC) and vegetation indices (VIs) estimated from aerial imagery.

MATERIALS AND METHODS

- Location: Texas A&M AgriLife Research Experiment Station, Bushland, TX (Fig. 1).
- Experimental design: Randomized complete block design with three replications. .
- 2014-2015 growing season.

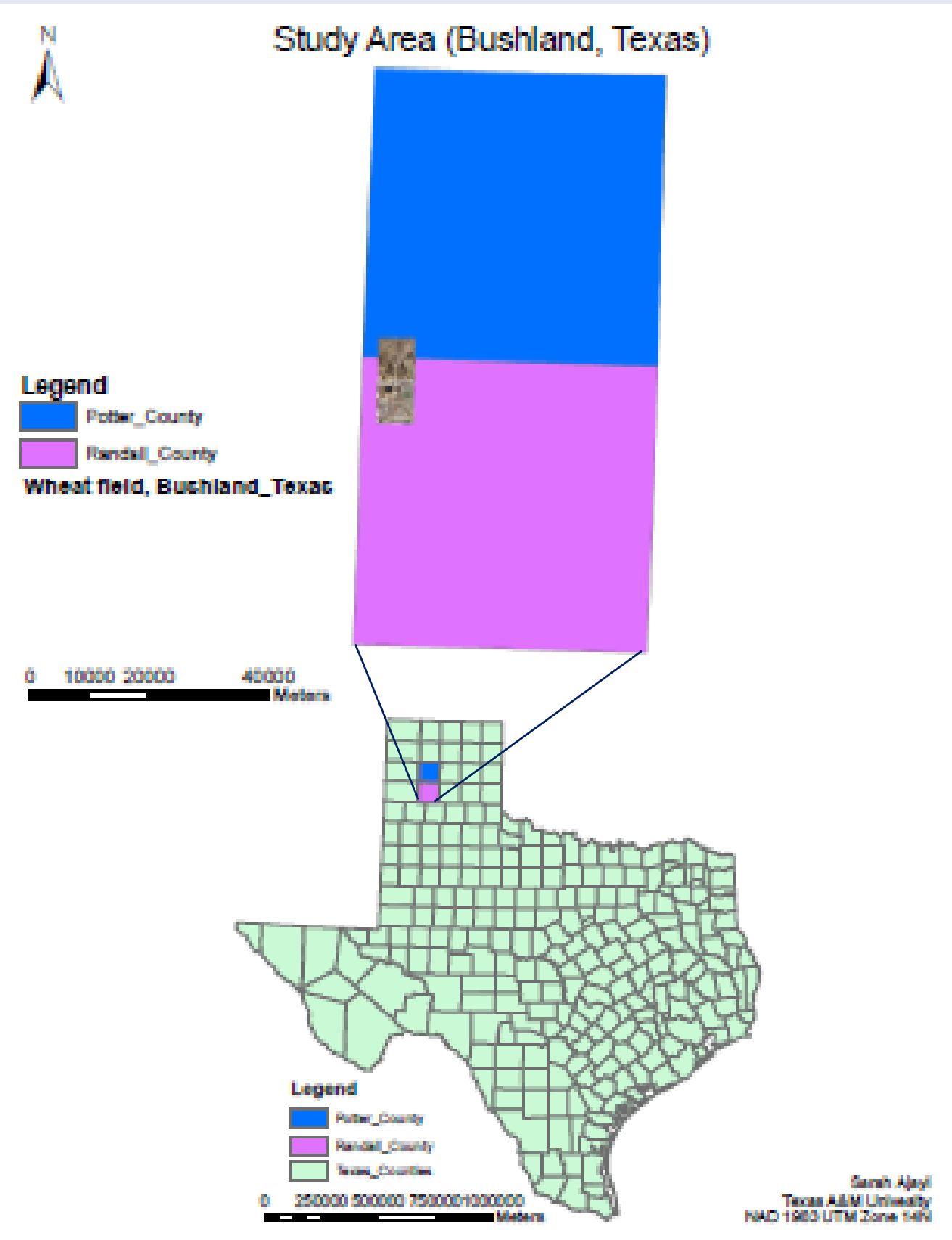


Figure 1. Study area.

Data Collection

- Aerial Imagery
- Manned aircraft (Fig. 2a) using the Tetra Mini MCA (Multiple Camera Array - Fig. 2b).
- With Spectral Range: 450 - 1000nm (nanometers); Spatial Resolution: 223 mm; Flight height: 5000 – 6500 feet Above Ground level; Scanning time: 1 frame/second; and each frame produced 12-band images.
- Growth stages: After-emergence, tillering, late-jointing and heading.
- Digital Photographs
- Digital camera was used to take plot pictures to observe ground cover (GC) using Photoshop.
- GreenSeeker ® sensor
- Instrument that recorded NDVI values; using 660 and 770nm.

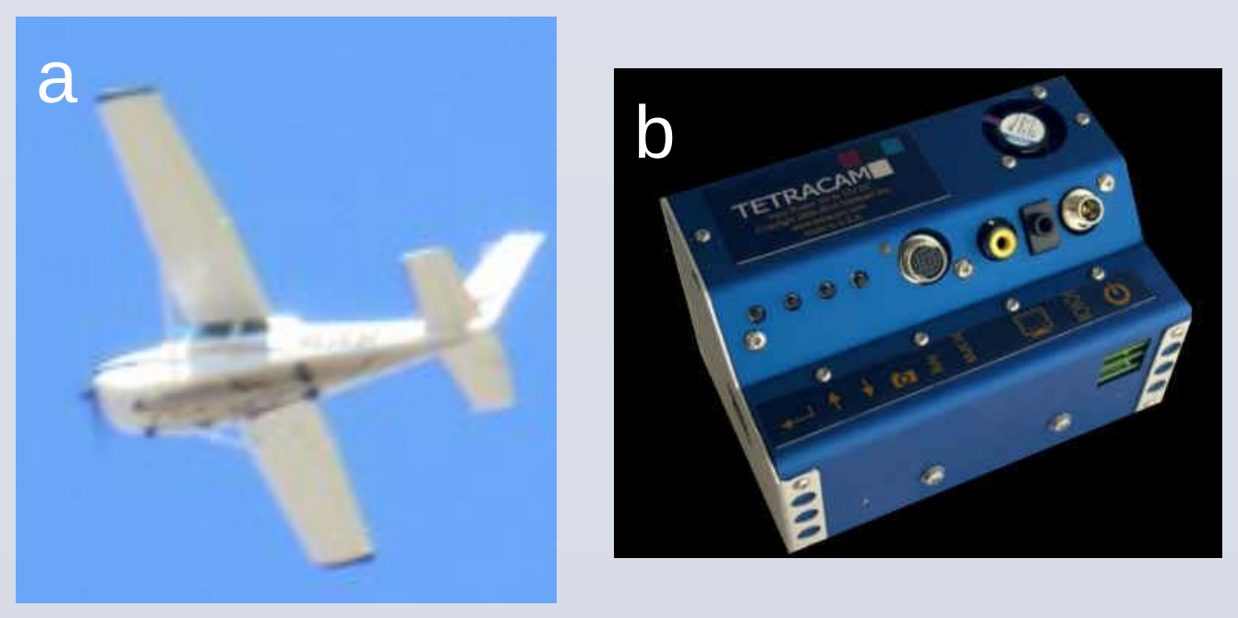


Figure 2. (a) Aircraft used in the study, and (b) the MCA camera used for collecting aerial images.

Image Analysis (Fig. 3)

- The raw aerial images were georeferenced to map projection – NAD 1983 UTM Zone 14N.
- Spectral Vegetation Indices (VI) calculated include: Normalized Difference Water Index (NDWI), NDVI and Perpendicular VI (PVI) used to estimate percent GC (Fig. 4a-c).
- $PVI = (NIR\_DC – RED\_DC(a_1) – a_0)/\sqrt{1+(- a_1)^2}$
- $GC = PVI_{plot}/PVI_{FC}$

Where a_0 = Intercept; a_1 = Slope; NIR = Near Infrared; DC = Digital count; and FC = Full canopy.

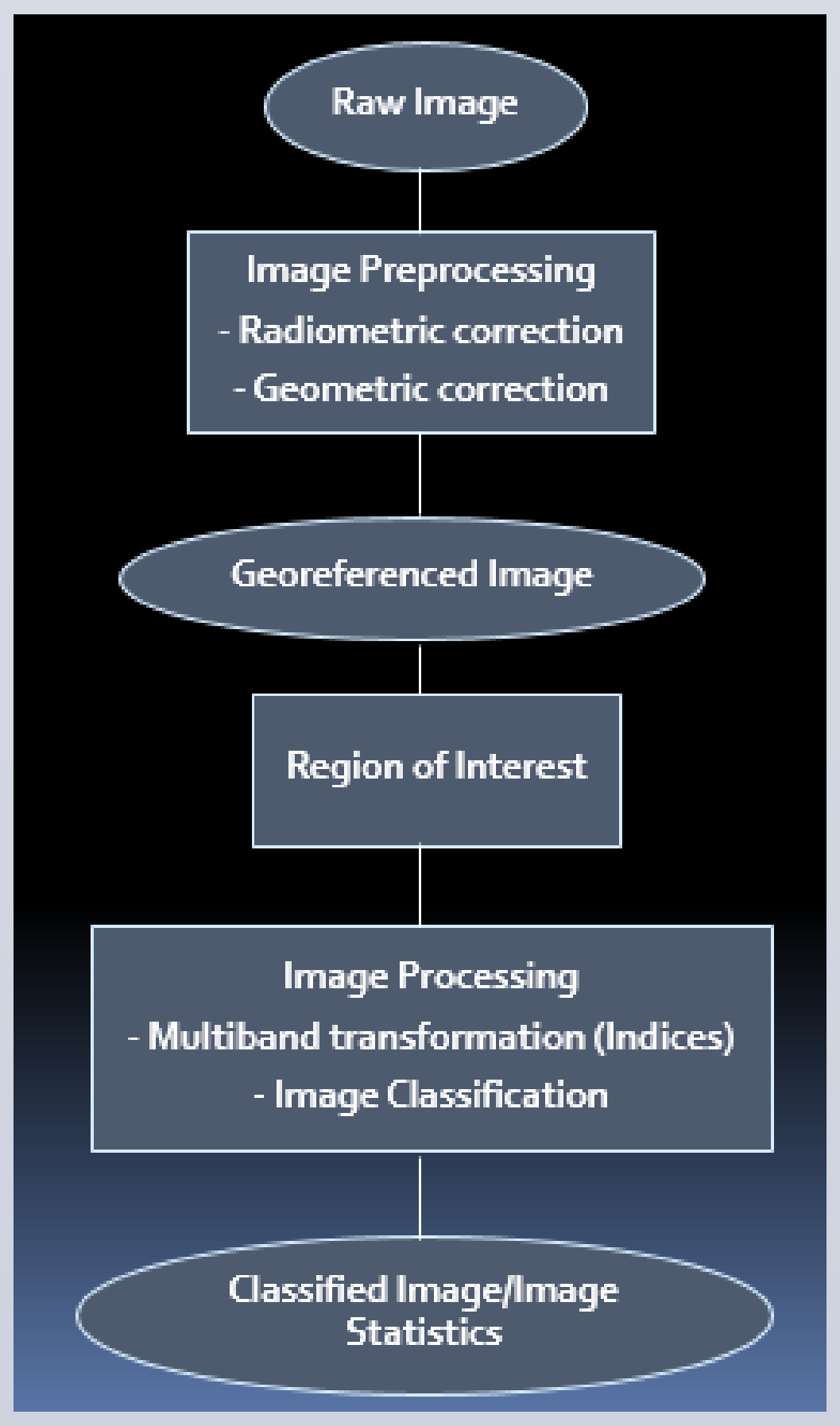

Raw Image

Image Preprocessing
- Radiometric correction
- Geometric correction

Georeferenced Image

Region of Interest

Image Processing
- Multiband transformation (Indices)
- Image Classification

Classified Image/Image Statistics

Figure 3. Flow chart of aerial image analysis.

- Regions of Interest for this study are 60 plots highlighted in Figures 5-7.
- Images were classified based on the indices to produce NDWI maps, NDVI maps, and GC maps.

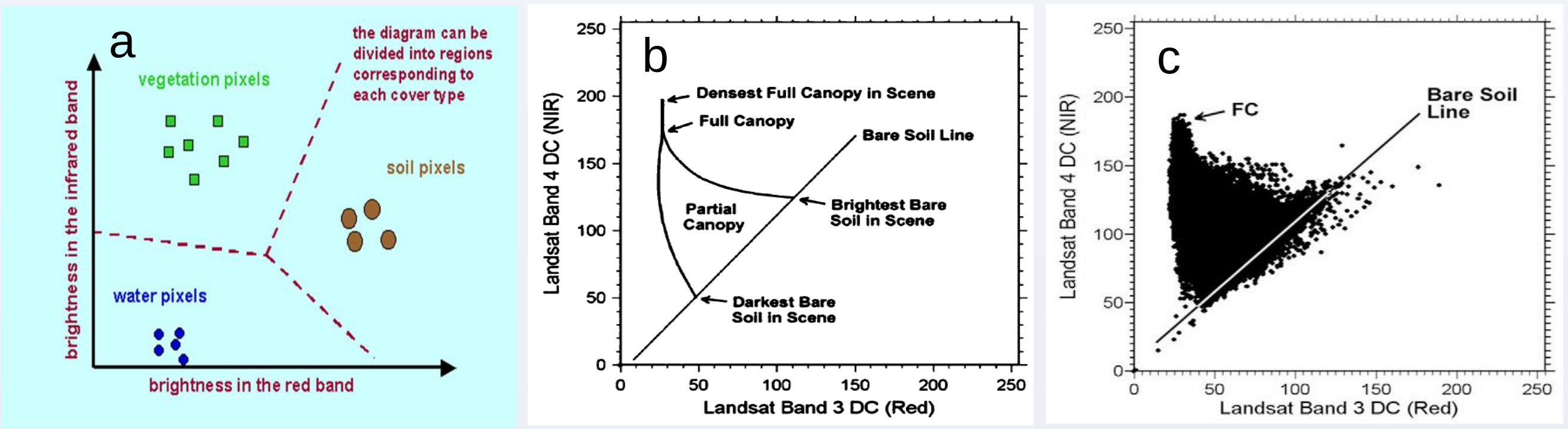


Figure 4. Diagrammatic representations of the features of (a) the distribution of points in a NIR-Red scatterplot (Richard and Wise, 2001); (b) Including the bare soil line and full canopy point; and (c) Scatterplot of pixel DC values in the NIR and red spectral bands extracted from a Landsat-5 Thematic Mapper image (Rajan and Maas, 2009).

RESULTS

- NDWI values under Irrigated field conditions presented significant variation among the twenty genotypes at tillering and late-jointing stages (Fig. 5a). Rainfed field showed no genotypic variation (Fig. 5b).

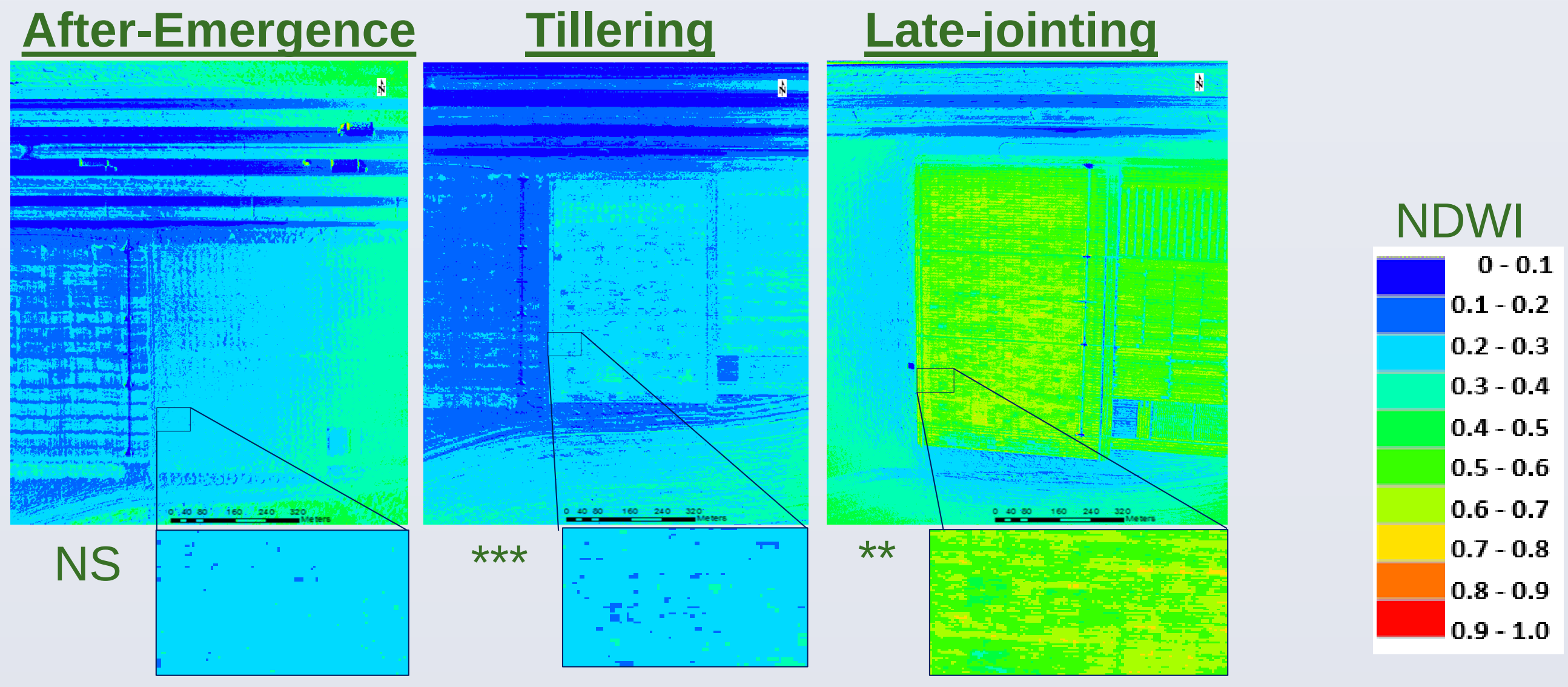
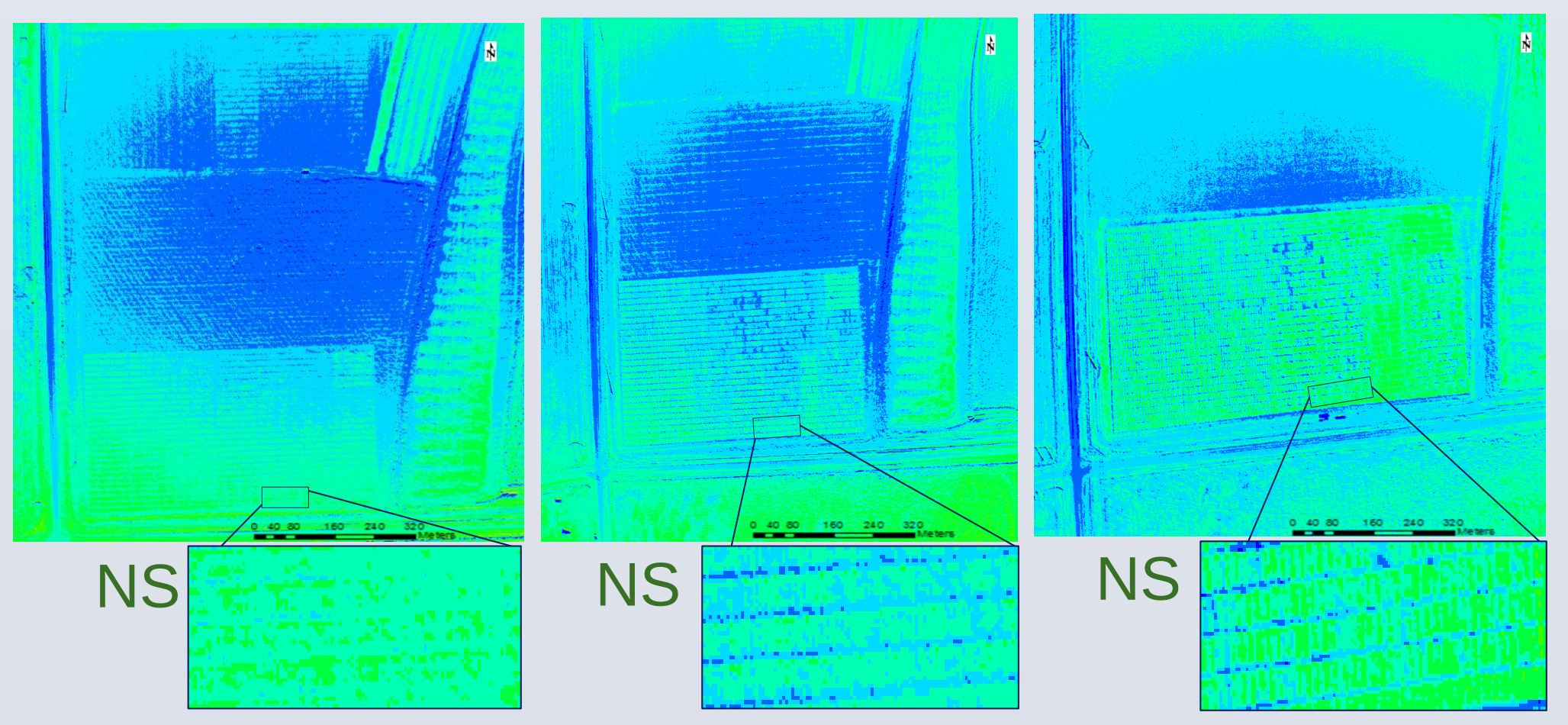


Figure 5a. NDWI (Normalized Difference Water Index) maps of Irrigated fields.



Blue colors show less water content

Yellow/**Red** colors indicate more water content

Figure 5b. NDWI (Normalized Difference Water Index) maps of Rainfed fields.

- NDVI values under Irrigated field conditions presented significant variation among the twenty genotypes at tillering and late-jointing stages (Fig. 6a). The genotypes varied in their NDVI values under dryland fields, only at late-jointing stage (Fig. 6b).

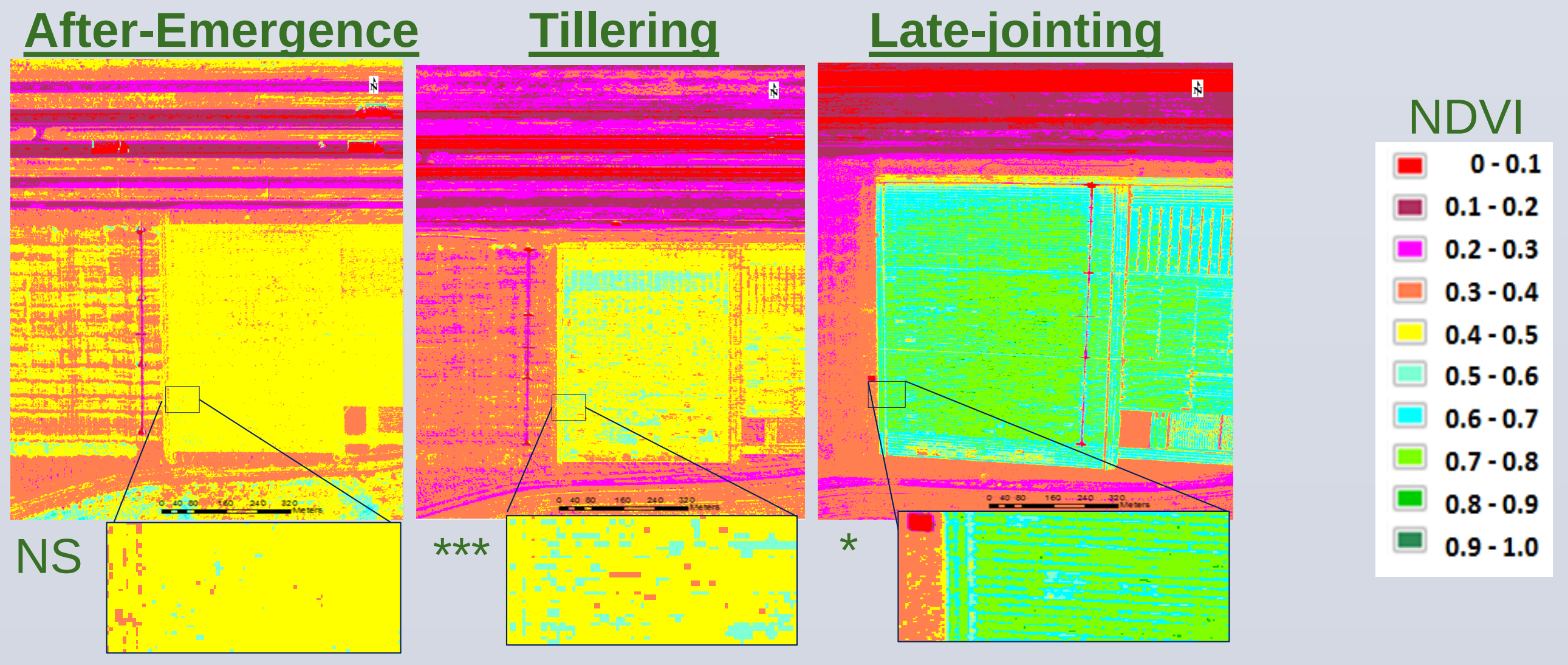
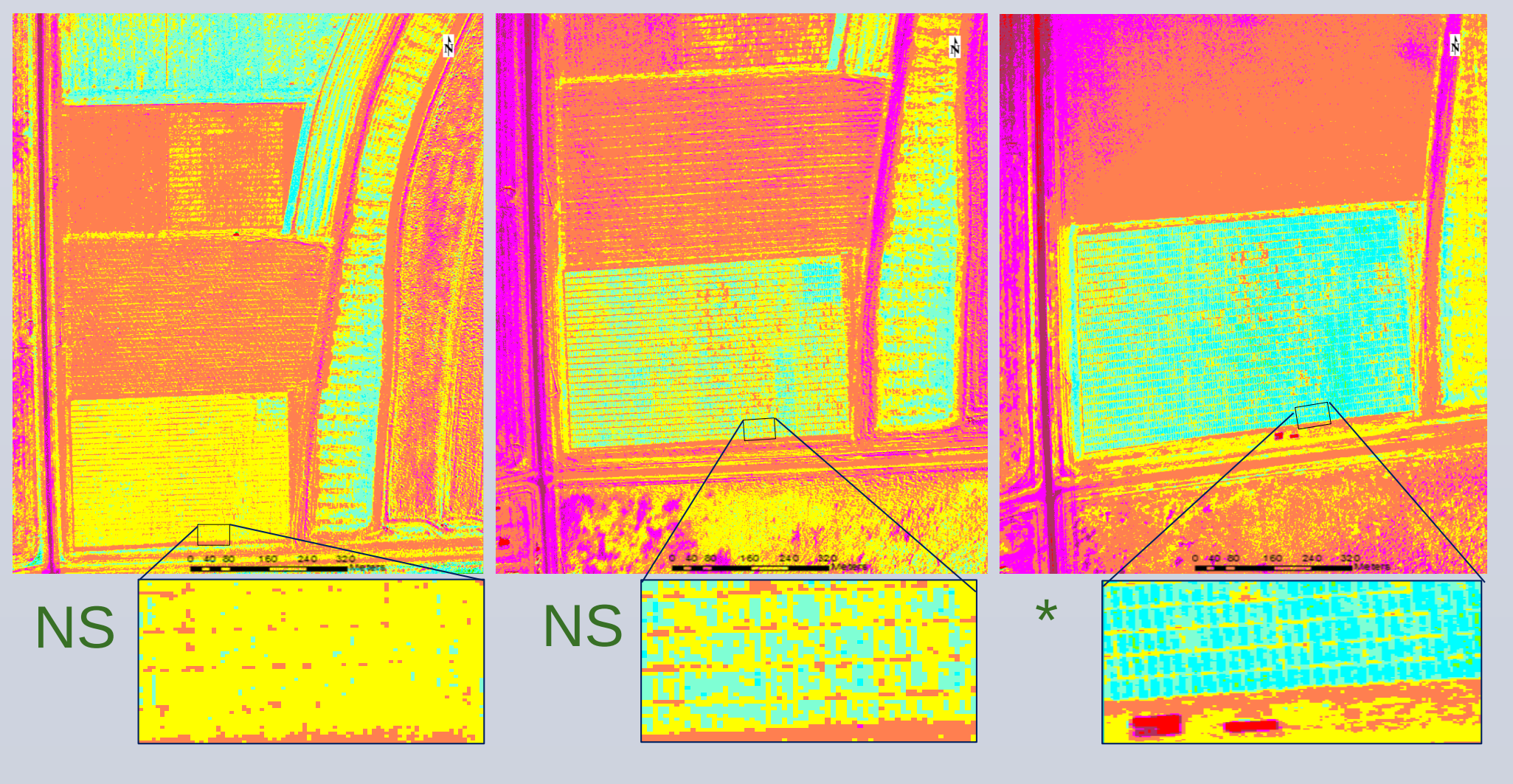


Figure 6a. NDVI (Normalized Difference Vegetation Index) maps of Irrigated fields.



Red colors indicate bare soil

Green colors indicate the densest vegetation canopy

Figure 6b. NDVI (Normalized Difference Vegetation Index) maps of Rainfed fields.

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

- PVI values were calculated using the NIR-Red scatterplots and then used to estimate %GC; dividing PVI for each plot by PVI for full canopy, to produce the %GC maps (Fig. 7a-b)

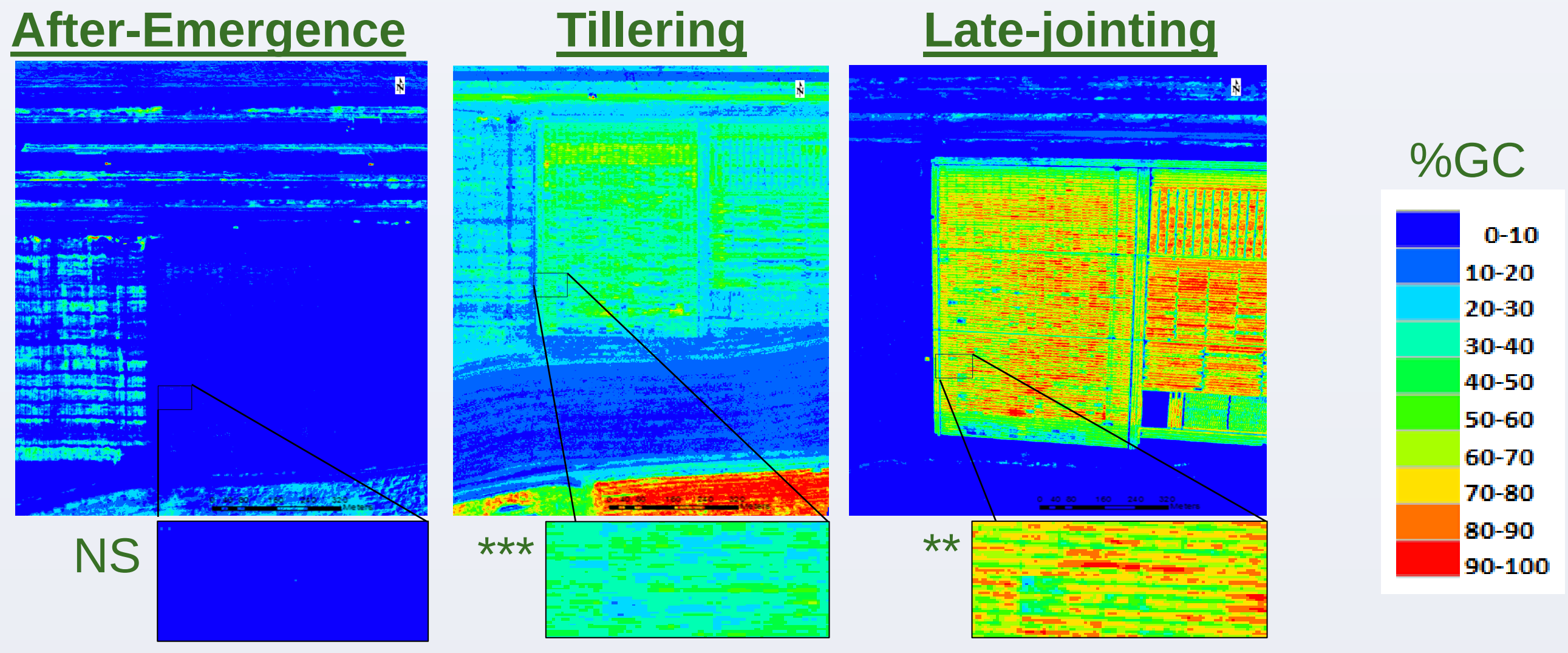
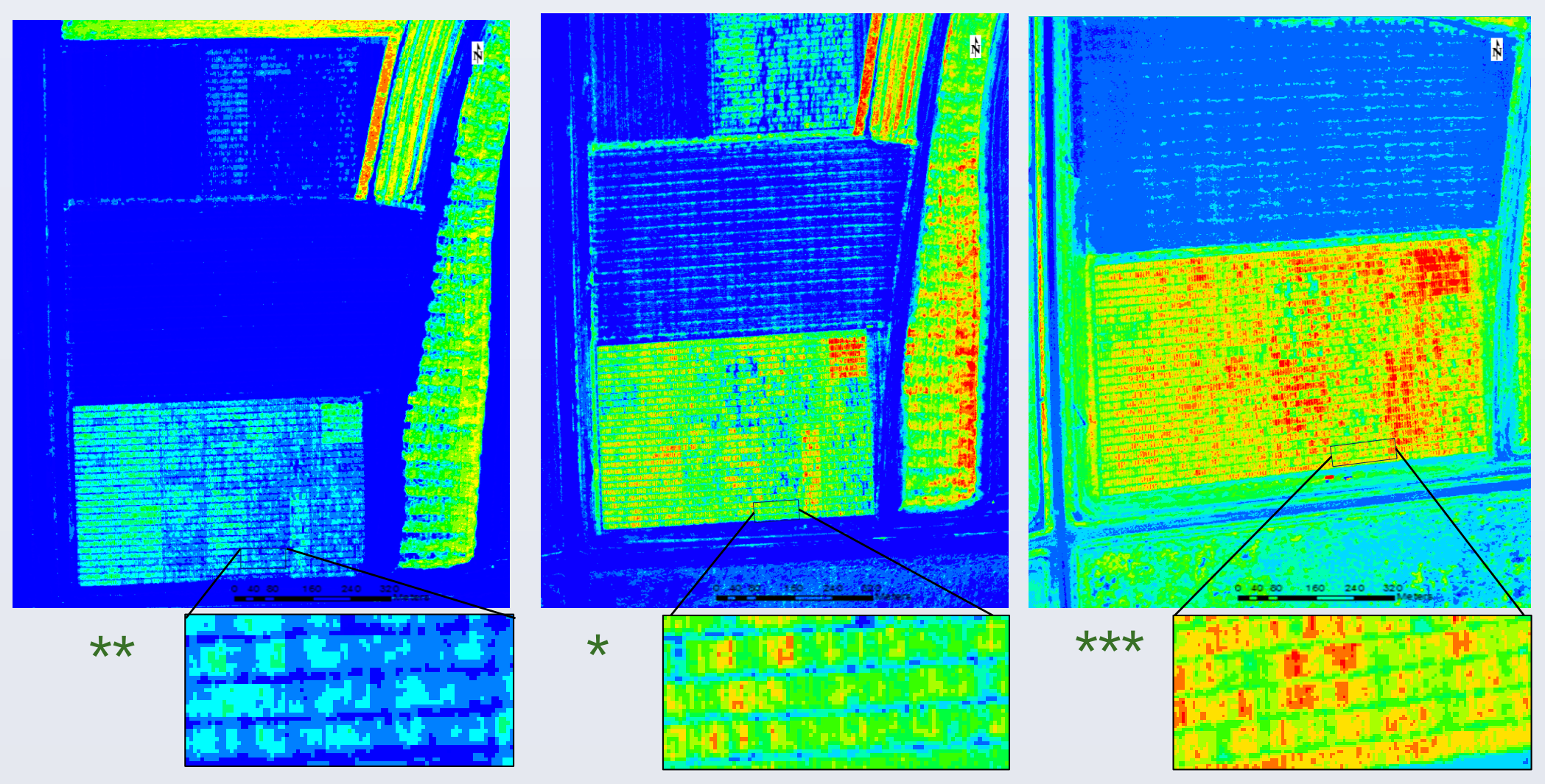


Figure 7a. Percent Ground cover (%GC) maps of Irrigated fields.



Blue colors indicate bare soil

Yellow/**Red** colors indicate the densest vegetation canopy

Figure 7b. Percent Ground cover (%GC) maps of Rainfed fields.

- Irrigated field showed highly significant relationships among all the VIs and %GC. However, poor relationships were recorded using the NDVI_A values with the other parameters under rainfed condition (Table 1).

Table 1. Relationship between the ground cover (%GC) estimated from digital photos (dp) and PVI, NDVI obtained from GreenSeeker® (gs), NDVI and NDWI estimated from Aerial (A) images, under Irrigated and Rainfed fields at tillering stage.

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***
NDWI	NDVI_A	0.94***
NDWI	NDVI_gs	0.87***

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**
NDWI	NDVI_A	0.63***
NDWI	NDVI_gs	0.02

DISCUSSION

- Genotypic variations (NDWI, NDVI, and %GC) were recorded among the genotypes due to their wide genetic background, at tillering and late-jointing stages mostly, but rarely at the after-emergence stage.
- Significant relationships (R^2: 46%-95%) provide the possibility of using the estimated parameters (%GC_PVI, NDVI, and NDWI) as an indirect selection tool.
- Some challenges included are:
  - Image resolution
  - Interval between dates of aerial and field data collected; more than +/-2 days.
  - Over or under estimation of % GC (using PVI, and digital photos) may be due to different sections of the plot captured for analysis, especially under Rainfed fields.
  - Lack of yield data due to hailstorm damage.

SUMMARY

- All the remote sensing tools utilized for this study present the potential use for high-throughput phenotyping to support wheat breeders in screening efficiently for drought-tolerant and high yielding genotypes from a large number of early-generation lines and advanced wheat genotypes.
- Future work will involve more consistent field data collection at specific growth stages; additional field data collection to relate with the VIs, such as leaf area index, canopy temperature (to estimate crop water stress index), and yield.

References

- Weigand, C. 2011. Wheat import projections towards 2050. US Wheat Associates, USA.
- Rajan, N., and Maas, S. J. 2009. Mapping crop ground cover using airborne multispectral digital imagery. Precision agriculture, 10(4), 304-318.
- Richard J. and Wise P. 2001. Looking Back to Earth. National Museum of Australia, Australia.