Remote estimation of leaf area index (LAI) with unmanned aerial vehicle (UAV) imaging for different rice cultivars throughout the entire growing season

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Research Article

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Abstract

Background: Rice is one of the most important grain crops worldwide. The accurate and dynamic monitoring of leaf are index (LAI) provides important information to evaluate rice growth and production.

Methods: This study explores a simple method to remotely estimate LAI with Unmanned Aerial Vehicle (UAV) imaging for a variety of rice cultivars throughout the entire growing season. 48 different rice cultivars were planted in the study site and field campaigns were conducted once a week. For each campaign, several widely used vegetation indices (VI) were calculated from canopy reflectance obtained by 12-band UAV images, canopy height was derived from UAV RGB images and LAI was destructively measured by plant sampling.

Results: The results showed the correlation of VI and LAI in rice throughout the entire growing season was weak, and for all tested indices there existed significant hysteresis of VI vs. LAI relationship between rice pre-heading and post-heading stages. The model based on the product of VI and canopy height could reduce such hysteresis and estimate rice LAI of the whole season with estimation errors under 24%, not requiring algorithm re-parameterization for different phenology stages.

Conclusions: The progressing phenology can affect VI vs. LAI relationship in crops, especially for rice having quite different canopy spectra and structure after its panicle exsertion. Thus the models solely using VI to estimate rice LAI are phenology-specific and have high uncertainties for post-heading stages. The model developed in this study combines both remotely sensed canopy height and VI information, considerably improving rice LAI estimation accuracy at both pre- and post-heading stages. This method can be easily and efficiently implemented in UAV platforms for various rice cultivars during the entire growing season with no rice phenology and cultivar pre-knowledge, which has great potential for assisting rice breeding and field management studies at a large scale.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Figures

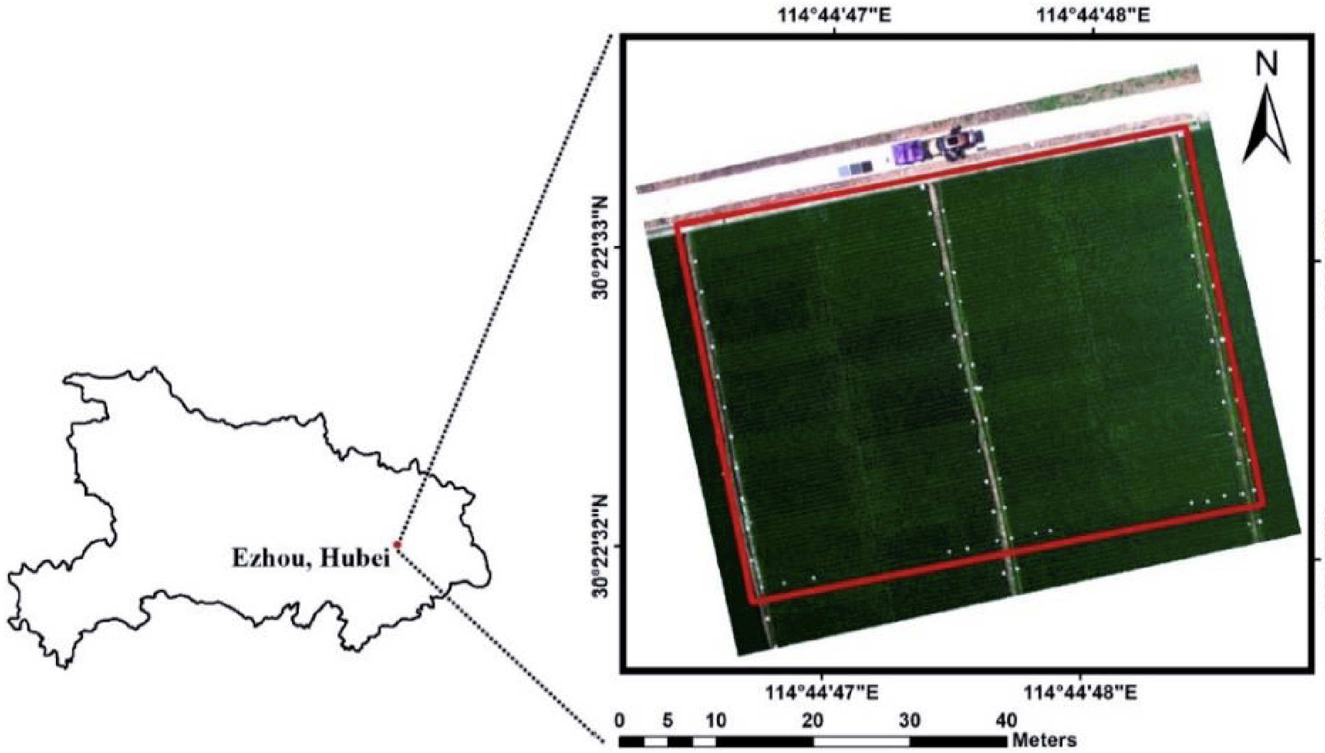

Figure 1

Study Area of 48 rice cultivars in Hubei, China. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area o bbnhjr of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

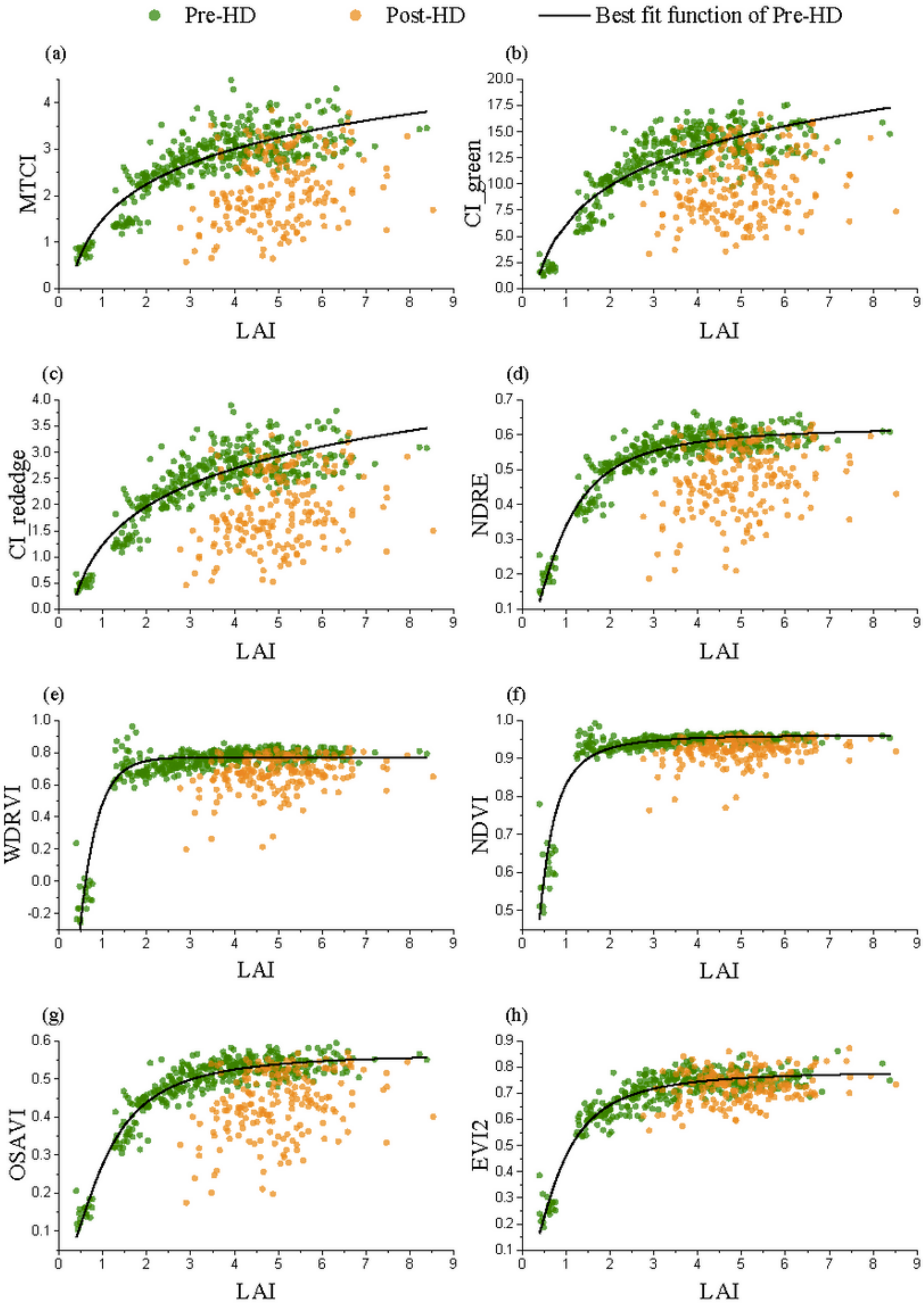

Figure 2

The variation of LAI plotted with (a) MTCI, (b) CIgreen, (c) CIred edge, (d) NDRE, (e) WDRVI, (f) NDVI, (g) OSAVI and (h) EVI2 in rice during the entire growing season. For all tested VIs, samples of post-heading (Post-HD) stages were deviated from the LAI vs. VI relationship of pre-heading (Pre-HD) stages.

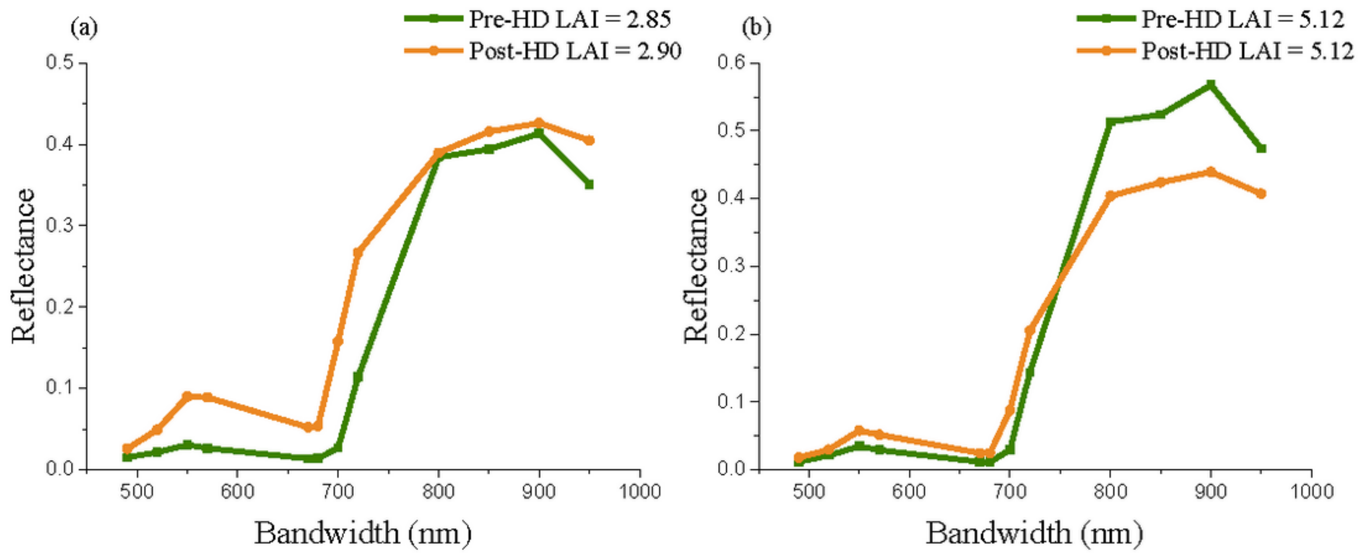

Figure 3

The canopy spectra of two samples with similar LAI values, (a) LAI around 2.9 and (b) LAI around 5, in pre-heading (Pre-HD) and post-heading (Post-HD) stages.

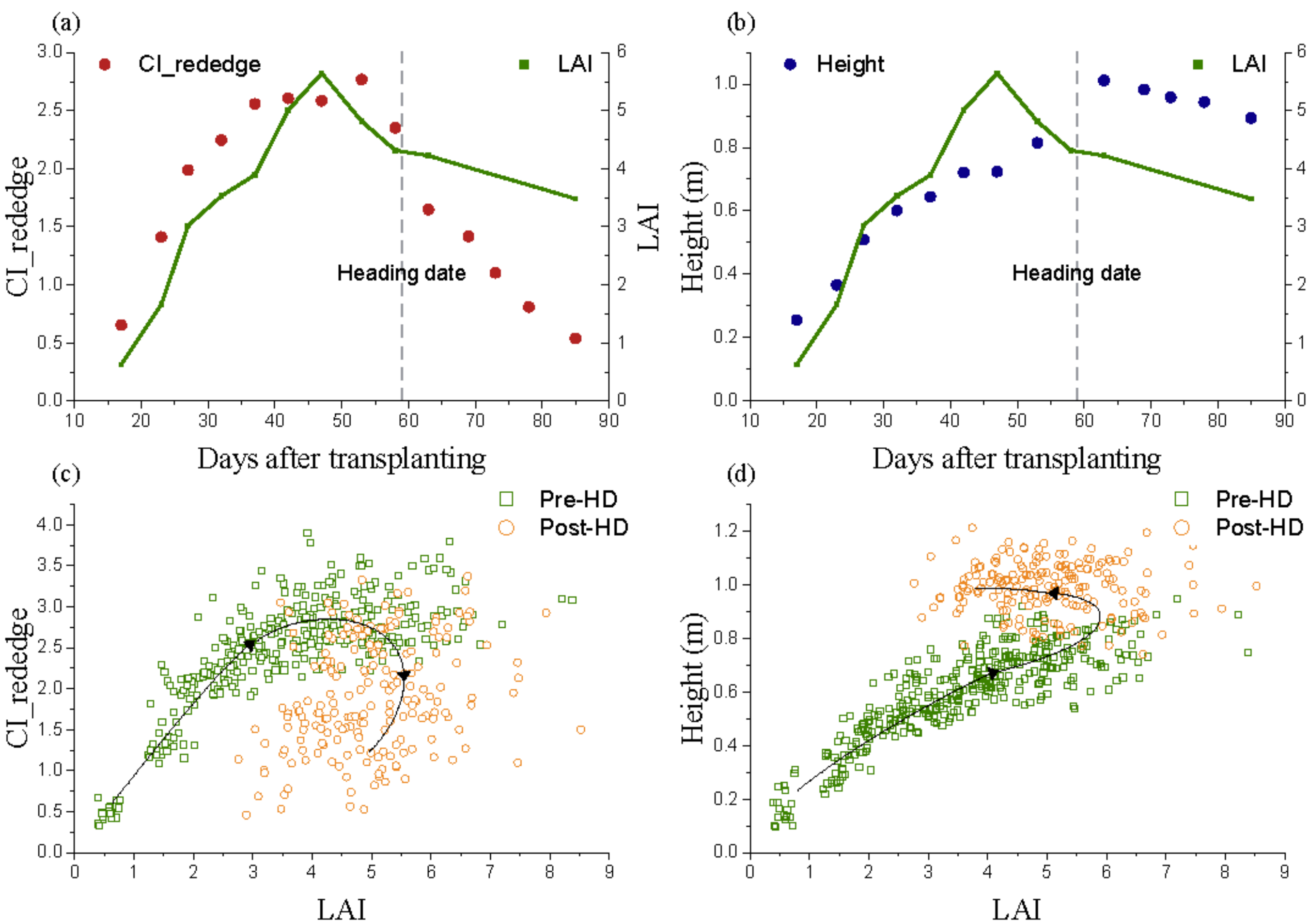

Figure 4

Temporal behaviors of measured LAI vs. (a) CIred edge and (b) canopy height, and the LAI variation plotted with (c) CIred edge and (d) canopy height during the rice entire growing season.

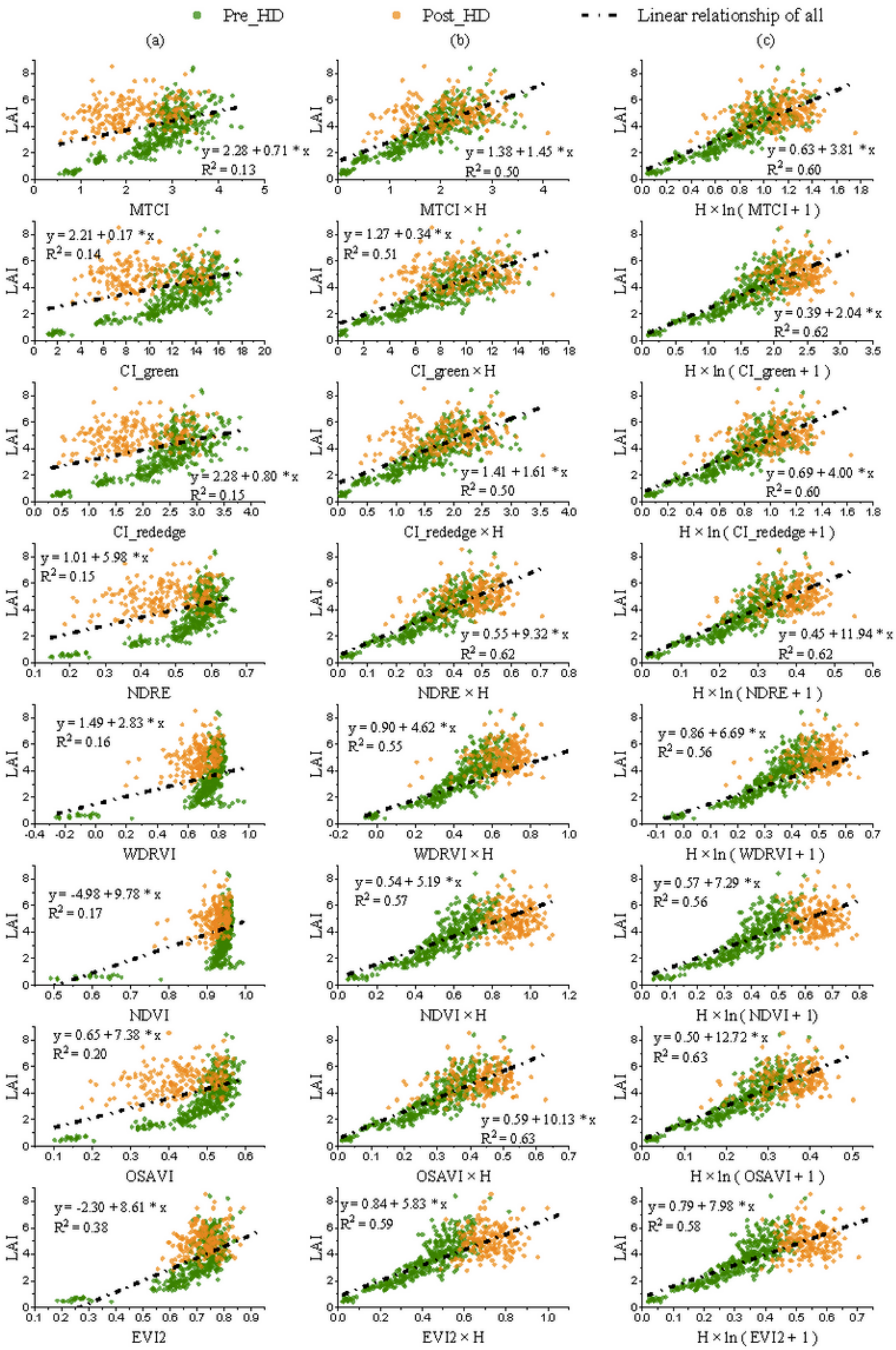

Figure 5

Three models, (a) LAI vs. VI, (b) LAI vs. H×VI and (c) LAI vs. H×ln(VI+1), were tested for rice LAI estimation throughout the entire growing season for eight tested indices.

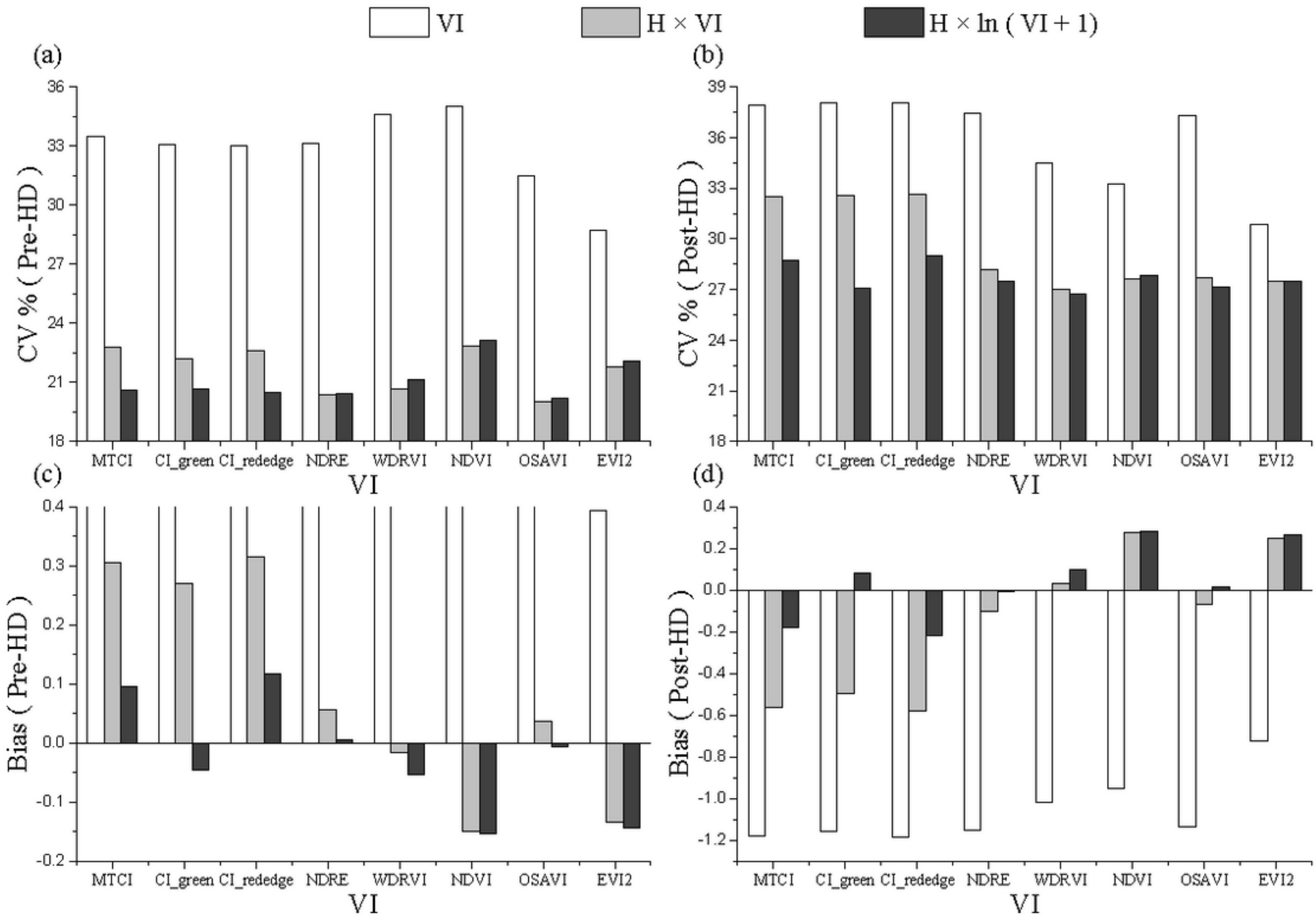

Figure 6

Using one algorithm during entire rice growing seasons for LAI estimation based on VI, H×VI and H×ln (VI+1) models with (a) coefficient of variation (CV) for pre-heading stages, (b) CV for post-heading stages, (c) Bias for pre-heading stages and (d) Bias for post-heading stages.

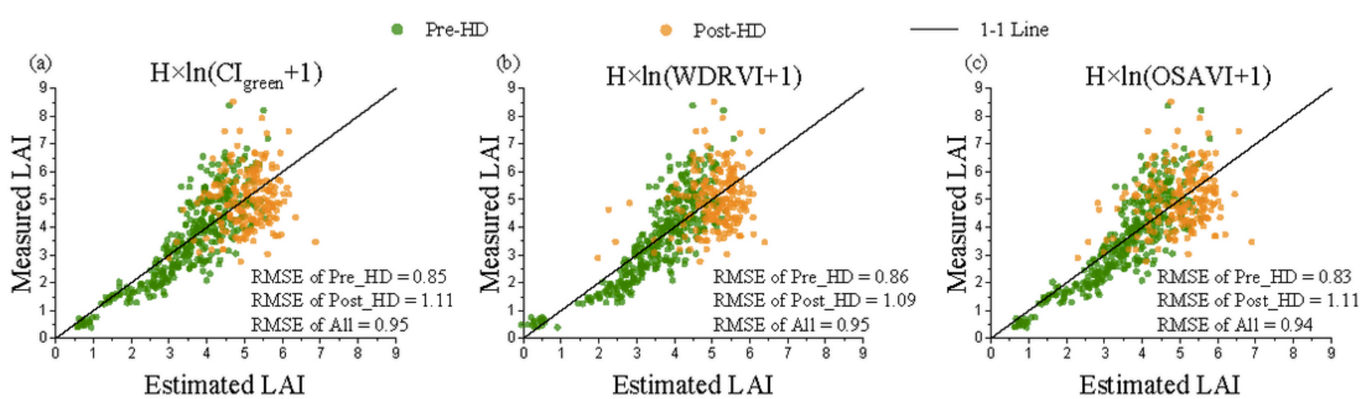

Figure 7

Comparison of estimated and measured LAI based on H×ln(VI+1) model using (a) CIgreen, (b) WDRVI and (c) OSAVI.

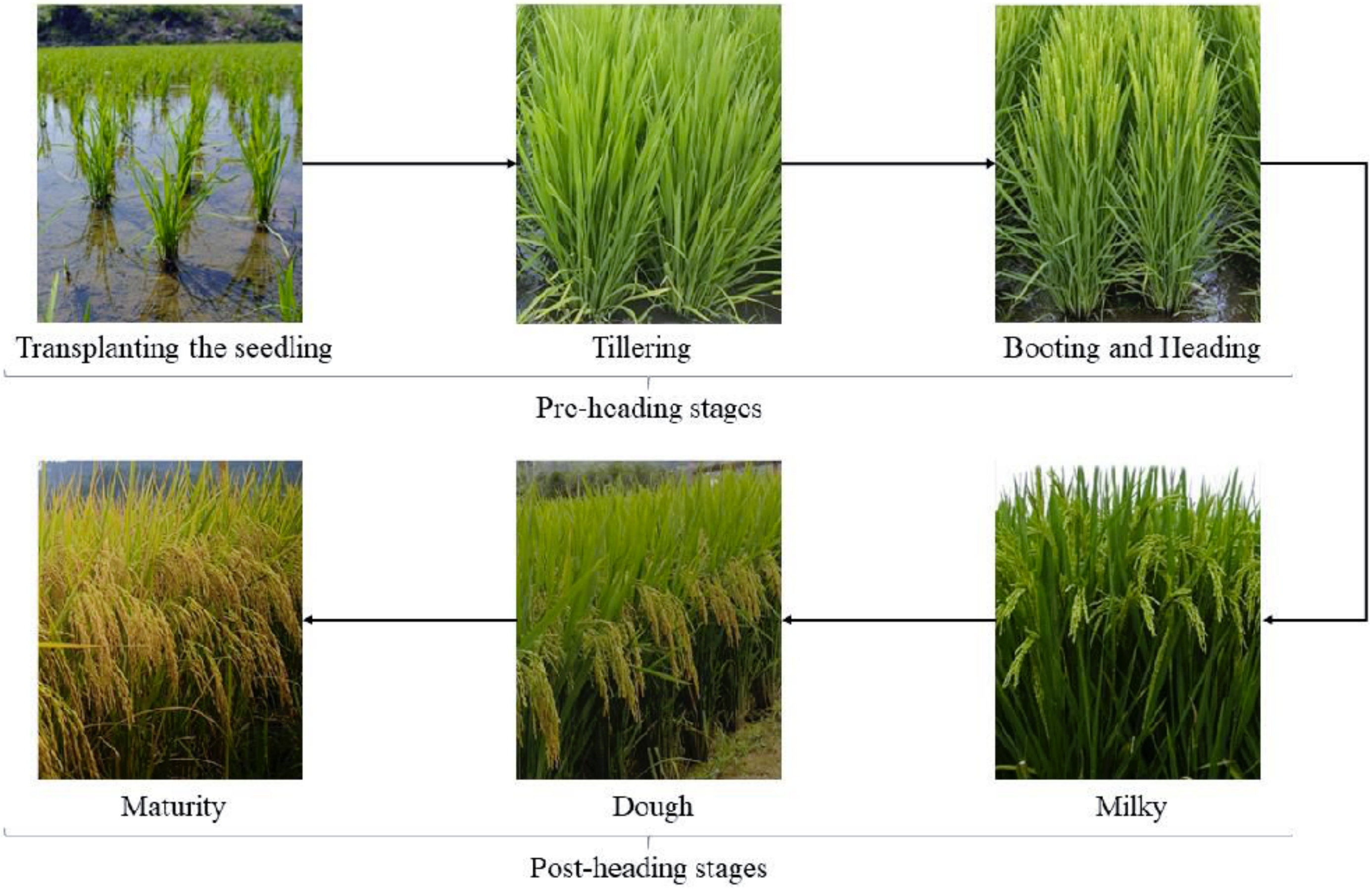

Figure 8

Phenology stages of rice growth cycle.