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Interactive comment on "Assessing shadow effects on Photochemical Reflectance Index (PRI) for the water stress detection in winter wheat" *by* Xin Yang et al.

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1. This study collected PRI data within a window between 1000 and 1400h. Unfortunately, wheat PRI can change dramatically between 1000 and 1400h. Magney et al. (2016) demonstrated that PRI can vary by a factor of 4 between 1000 and 1400h, particularly later in the growing season when water stress is at its peak. This is likely problematic for the current study. It would have been helpful for the authors to conduct an experiment of how the PRI in their wheat plots changes over the course of the data collection period. This information is fundamental to determining whether it is valid to group data across 1000-1400h, or whether the data must be binned in a more

time-specific manner before analyzed.

Thanks for the suggestion. PRI changes diurnally driven by the xanthophyll cycle and also changes seasonally driven by the variations in pigment pool sizes (e.g. carotenoid/chlorophyll). Since this study focused on evaluating seasonal water stress, we conducted the experiment during the noon. Although we did not conduct the diurnal measurements, we recorded the time when each hyperspectral image was taken. Thus, if the major revision was allowed, we can filter the data to make sure all the data used for analyses were collected within an hour.

2. There is more of a continuum of light values, rather than two distinct classes of sunlit canopy vs. shaded canopy. As a result, the analysis is flawed because it is trying to capture a process that responds to a continuum (of incident PAR, specifically) using a binary shadow/non-shadow classification. The biological process in question is nonlinear, and the method is oversimplified.

We agreed with the reviewer's opinion that PRI is related to the irradiance, but it is hard to measure the irradiance received by each leaf, and thus to analyze the difference between the sunlit and shaded leaves provides a feasible way to evaluate the impact of the vertical illumination distribution and mixed pixels issue. From a remote sensing perspective, shadow or shade is inevitable in a pixel, and we usually assume the contribution of vegetation and shade to the reflectance of the pixel is linear (Dennison and Roberts 2003; Tane et al. 2018). The shade fraction may vary from pixel to pixel depending on the viewing zenith angle, solar angle, and the vegetation fraction. Therefore, this study aimed to evaluate the impact of shade fractions on the assessment of seasonal water stress using PRI. Although the incident PAR is continuously distributed within the canopy, sunlit leaves and shade have contrasting illumination in a pixel. Several studies have analyzed the differences of PRI in sunlit leaves and shaded leaves, and the sunlit leaves are usually selected/defined as the top of the canopy leaves that receive high irradiance, and the shaded leaves are selected/defined as the leaves at the bottom of the canopy that receive low irradiance(Gamon and Berry 2012; Takala

and Mõttus 2016). Takala and MõttusâĂŤ(2016) picked the darkest and brightest top-of-crown pixel in the aerial photo, based on the broadband reflectance factor value as the samples of sunlit and shaded leaves. Instead of manually picked the sunlit and shaded leaves, we classified the hyperspectral images into sunlit and shaded leaves, which have distinct spectra. If manually selecting the darkest and brightest leaves was more appropriate than classification, we would like to make a change accordingly.

3. The variants of PRI selected for this study are influenced by both long term (constitutive) and short term (facultative) plant physiological processes, and the influences of long term vs. short term pigment pools cannot be isolated from each other. See Gamon and Berry (2012) for more detail.

We agreed with the reviewer that PRI is influenced by both constitutive and facultative plant physiological processes, and these two processes are hard to be isolated from each other. Although we did not measure the xanthophyll cycle, we did measure the chlorophyll and carotenoid content. And our analyses showed that PRI was strongly related to the ratio of chlorophyll to carotenoid (not shown in the study). If the major revision was allowed, we would add the analysis of the correlation between PRI and pigment pool sizes. We would also like to try to use the difference between the PRI of sunlit leaves (brightest pixels) and shaded leaves (darkest leaves) to minimize the constitutive effects. Although the difference between the PRI of sunlit and shaded leaves is different from the delta PRI proposed by Gamon and Berry (2012) and Magney et al. (2016), the PRI of shaded leaves may be a proxy for the PRI at epoxidation state, since shaded leaves do not experience de-epoxidation of xanthophyll cycle as the sunlit leaves do. Also Hwang found that the ratio of PRI in sunlit canopy (backward direction MODIS images) to PRI in shaded canopy (forward direction images) provided better correlations with drought signal. The test of the difference between the PRI of sunlit and shaded leaves in the water stress assessment may provide insights into the applications of multi-angle aerial or satellite images in monitoring crop water stress.

4. The light (PAR) incident on the plants was not measured or considered in the anal-

yses.

Thanks for the reviewer's comment. We did not realize the importance of PAR in the analyses of PRI, as our focus was on the difference between PRI in sunlit and shaded leaves and their correlations with RWC. The weather station near the study site takes PAR measurements. And also the DN value in near infrared bands of the gray panel can be used as the proxy of PAR. We will evaluate the relationship between PRI and PAR for pots under different levels of water stress, if the major revision was allowed.

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