APPLICATION OF THERMAL IMAGING OF WHEAT CROP TO ESTIMATE CANOPY COVERAGE UNDER DIFFERENT MOISTURE STRESS CONDITIONS

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ABSTRACT

Thermal imaging cameras determine the temperature of the object by non-contact measurements and give temperature reading for each pixel of the image. This proximal remote sensing technique work with the same principle of spot pyrometers. Thus the thermal image directly gives the temperature of the crop canopy and provides a better distinctibility between the two classes i.e., leaf and soil using image classification techniques. In this study thermal imaging was used to determine the canopy coverage using image classification analysis. As a further application of this technology, an attempt was made to estimate the canopy coverage of the wheat crop grown under different moisture stress conditions. Thermal Images were analyzed with five different supervised image classification techniques namely Maximum likelihood, Mahalanobis, Minimum distance to mean, Parallelepiped and Support Vector Machine methods using ENVI - image analysis software. Results showed that the best estimation of canopy coverage was possible using Support Vector Machine method, due to its higher overall classification accuracy and Kappa coefficient. This is further supported by the statistical analysis based on the comparison with instrument (plant canopy analyser) observed LAI and digital image derived canopy coverage In general Support Vector Machine method estimated the wheat crop canopy coverage from the thermal image meaningfully with high R^2 value of 0.915 and with low values of RMSE and MBE. Thus the present study clearly showed that thermal image analysis could be applied as a non-destructive, rapid, proximal remote sensing technique to characterize the crop canopy temperature and estimate the canopy coverage of the wheat crop grown under moisture stress conditions.

Key word: canopy coverage, proximal remote sensing, LAI

Introduction

Wheat crop is often affected by biotic and abiotic stress factors. One of the strategies for better production is to maintain a good crop condition. Crop condition is regularly monitored in terms of the percentage of ground that has been covered by the healthy vegetation (Schirrmann, et al., 2016). Thermal imaging cameras determine the temperature of the object by non-contact measurements. They work with the same principle of spot pyrometers, as they detect infrared radiation and convert it into a temperature reading. However, thermal cameras give temperature reading for each pixel of the image. Thus the thermal image directly gives the temperature of the crop canopy (Krishnan, 2014) and provides a better distinctibility between the two classes i.e., leaf and soil using image classification techniques. Supervised method of image classification provides a better opportunity to classify whole image into corresponding class unit (Lillesand et al., 2014). Thus thermal imaging can be used for determining the canopy coverage. Leaf area index (LAI), is an important biophysical parameter that determine extent of solar radiation, a plant can absorb for photosynthesis and thus biomass (Bréda et al., 2003). Canopy coverage over the ground varies with the applied moisture stress and has been regarded as one of the important parameter to monitor crop status index (Banerjee et al., 2015). Direct LAI measurement is time taking, labor intensive, destructive and produce error in its estimation. It has observed that by Image classification, accurate estimation of LAI can be obtained from digital images in a non-destructive mode (Liu et al., 2013). . The present study was undertaken to estimate canopy coverage by thermal imaging of wheat crop canopy under different moisture stress levels and to compare with the digital imaging and those derived from canopy analyser.

Methodology

The experiment was conducted in the experimental farm of Indian Agricultural Research Institute, New Delhi situated at 77.12°E longitude, 28.35°N latitude, and at an altitude of 228.16 m over the mean sea level. The climate of the study site is semi-arid with dry hot summer and mild winters. The crop period of wheat is from middle of November to first week of April in the winter seasons (locally called the *Rabi* season). Wheat crop were grown under four different level of moisture stresses I1, I2, I3, I4 (based on the IW/CPE ratio of 1.0, 0.8, 0.6 and 0.4 respectively). The wheat crop under I1 treatment was exposed in optimum irrigation condition where I4 was the stressed treated plant where irrigation was given only at CRI stage.

For deriving the canopy coverage of the wheat crop thermal and digital images were taken at regular interval throughout the crop growing season using Testo 890-1 thermal camera. Images were taken under optimum weather condition so that weather effect can be minimized during the image accusation. Both thermal and digital images were taken in single shot of the wheat crop grown under moisture stress condition. Later image classification was done using ENVI4.8 image classification software. Five different supervised image classification method like Maximum Likelihood method, Support Vector Machine method, Mahalanobis method, Minimum Distance method, and Parallelepiped method were used for classifying the thermal and digital images for deriving canopy coverage of the wheat crop grown under moisture condition.

Instrumental value of LAI for wheat crop grown under different stress condition was obtained using LAI-2200 (LICOR inc., Nebraska).Thermal and digital images were obtained at different growth stages of the crop. This image classification based LAI was compared with instrumental LAI to get Modelling Efficiency (ME) for each supervised image classification method. Classification accuracy of each image classification methods in terms of overall accuracy, user's accuracy, producer's accuracy and Kappa coefficient (K) was also found out.

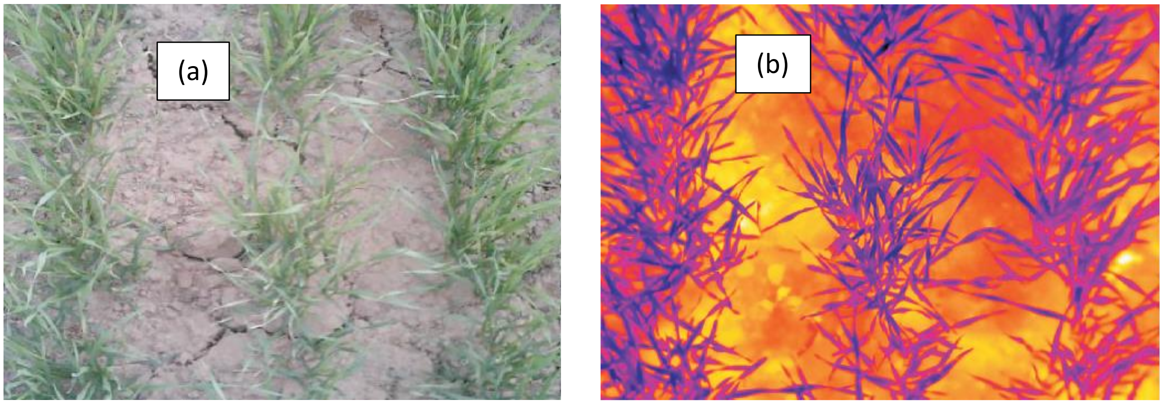

Fig. 1. Image analysis: (a) Optical Image (b) Thermal Image

Result

Thermal image classification based canopy coverage estimation performed best in predicting canopy coverage as compare to digital image classification based canopy coverage. In both the cases Support vector machine (SVM) method performed well in predicting canopy coverage with R^2, 0.9157 and 0.814 for thermal and digital image respectively (Fig 1). Parallelepiped method was found to be the poor performer in prediction efficiency for both thermal and digital image classification for canopy coverage with R^2, 0.797 and 0.606 respectively (Table1). Similarly, modelling efficiency was found to be highest for SVM and least for parallelepiped method for both thermal and digital image classification for canopy coverage estimation. The methods used in this study for image processing are widely used in, image analysis studies (Lillesand et al., 2014), however they are rarely applied in field based studies (Liu et al., 2013). Although, classification accuracy for different classification methods was found to be statistically at par but maximum overall accuracy and Kappa coefficient were found for SVM method and least for parallelepiped method for both thermal and digital image. So, as a non-destructive, less laborious, less erroneous and accurate estimation of canopy coverage, ENVI supervised thermal image classification using Support vector machine method can be used for large scale application. Therefore instead of spot pyrometer, thermal imaging can be used not only for canopy temperature determination (Krishnan, 2014) but also for canopy coverage estimation in wheat crop grown under different moisture stress conditions.

Table 1 Evaluation of canopy coverage estimation of wheat crop from thermal and digital image analysis using different statistical tools (pooled data of I1, I2, I3, and I4)

S No	Methods	Statistical Parameters							
		ME		R^2		RMSE		MBE	
		Digital	Thermal	Digital	Thermal	Digital	Thermal	Digital	Thermal
1	Support Vector Machine	0.68	0.84	0.81	0.91	0.81	0.57	0.46	0.31
2	Maximum Likelihood	0.60	0.77	0.73	0.87	0.91	0.70	0.44	0.45
3	Mahalanobis	0.31	0.72	0.72	0.81	1.20	0.76	0.89	0.47
4	Minimum Distance to Mean	0.19	0.63	0.71	0.82	1.30	0.87	1.01	0.53
5	Parallelepiped	0.44	0.64	0.60	0.79	1.08	0.87	0.57	0.53

Conclusion

Thus the results clearly showed that the best estimation of canopy coverage was possible using Support Vector Machine method, due to its higher overall classification accuracy and Kappa coefficient. This is further supported by the statistical analysis based on the observed LAI. In general Support Vector Machine method estimated the wheat crop canopy coverage from the thermal image meaningfully with high R^2 value and low values of RMSE and MBE than those derived from the digital image. Thus the present study clearly showed that thermal image analysis could be applied as a non-destructive, rapid, less erroneous technique to characterize the crop canopy temperature and also estimate the canopy coverage of the wheat crop grown under moisture stress conditions.

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