# Evaluating a Three-Dimensional Model of Incident Radiation in Maize Canopy

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## Introduction

The knowledge of three-dimensional (3D) radiation distribution in crop canopy is pivotal for understanding and modeling of plant eco-physiological processes (Chelle & Andrieu 1999; Sinoquet *et al*. 2000; Dauzat *et al*. 2006). A 3D model for simulating the distribution of incident radiation (3DIRM) in crop canopy is evaluated in this paper.

## The modelling scheme

The static virtual canopy was reconstructed by representing organ surfaces as little triangular facets positioned according to the 3D digitized data by Fastrak digitizer (Polhemus, USA). Parallel projection and Z-buffer algorithms (Chelle & Andrieu 1999; Espana *et al*. 1999; Maddonni *et al*. 2000) were utilized to simulate the sunfleck area ratio and the intensity of solar beam radiation to every facet in canopy. A sub-model, named as DSHP (Dividing Sky Hemisphere with Projecting), was set up for computing the incident diffuse radiation in crop canopy (Wang *et al*., 2006). The total incident radiation in canopy could be calculated by just summing up the solar beam and incident diffuse radiation to each canopy facet.

## Evaluating the model with field experiment

A mast was built for supporting an AccuPAR ceptometer (Decagon Devices Inc. USA) to measure the 3D PAR distribution in maize canopy and an additional point PAR sensor, LI-190SA, to simultaneously measure the incoming PAR above canopy. The field measurements were carried out in maize canopies in the early filling stage near Beijing in 2002 (Wang *et al*., 2006).

Based on the assumption that the intensity of beam PPFD (Photosynthetically photon flux density) was much higher than sky diffuse PPFD under sunshine conditions, when an AccuPAR sensor registered PPFD in canopy more than beam PPFD that had been estimated from the global PPFD measured by the LI-190SA above canopy, then this sensor point was considered to be sunfleck. Sunfleck area ratio was set to be the ratio of the number of sunfleck sensors and the total sensor number for each height. The sensors with PPFD lower than beam PPFD was set to be umbrage. The average total and diffuse PPFD was calculated by averaging the PPFD values among all the AccuPAR sensors and only the umbrage sensors at each height.

In model evaluation, the simulated incident diffuse PPFD was slightly lower than the measured diffuse PPFD that included incident diffuse PPFD and secondary scattering PPFD by canopy elements, with a mean error of ME (Mean Error) =20.78 μmol $m^{-2}$ $s^{-1}$ (Refer to Wang *et al*. 2006) for detailed information). The simulated total incident PPFD ($PPFD_{sim}$) and sunfleck area ratio ($FR_{sim}$) were consistently close to the measured results ($PPFD_{obs}$ and $FR_{obs}$ respectively) with correlation equations of $PPFD_{sim}$=1.026$PPFD_{obs}$ (μmol $m^{-2}$ $s^{-1}$) with $R^2$=0.95 ($n$=74), and $FR_{sim}$=0.810$FR_{obs}$+4.10 (μmol $m^{-2}$ $s^{-1}$) with $R^2$=0.96 ($n$=74).

## Discussion

The 3DIRMS model achieved incident PAR (Photosynthetically active radiation) and sunfleck area estimation very close to the measurement. DSHP sub-model generated obvious errors with neglecting secondary scattering in canopy in diffuse PAR estimation. Nevertheless diffuse PAR only occupied a small proportion of total PAR in crop canopy during sunny daytime, thus DSHP sub-model can be an usful tool for incident diffuse radiation simulation in crop canopy.

It is difficult to carry out a 3D radiation measurement *in situ* in a real crop canopy. We hope the methodology of 3D measurement of PAR in maize canopy for evaluating a 3D radiation model introduced in this paper is referential to related studies.

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