Utilizing Canopy Light Interception/yield Data to Improve Management in Almond

Project No.: 19-HORT13-Lampinen

Project Leader: Bruce Lampinen, Dept. of Plant Sciences, UC Davis, One Shields Avenue, Davis, CA 95616

Project Cooperators and Personnel:
Brian Bailey, Ali Pourreza, Astrid Volder, Shrini Upadhyaya, Sam Metcalf, Tran Nguyen, and Loreto Contador - UC Davis
Greg Browne, USDA-ARS
Kamyar Aram, UCCE Contra Costa/Alameda Counties
Kari Arnold, UCCE Stanislaus County
Mae Culumber, UCCE Fresno County
David Doll, UCCE Merced County
Roger Duncan, UCCE Stanislaus County
John Edstrom, UCCE Emeritus Colusa County
Elizabeth Fichtner, UCCE Tulare County
Phoebe Gordon, UCCE Madera County
Brent Holtz, UCCE San Joaquin County
Dani Lightle, UCCE Butte/Glenn/Tehama Counties
Luke Milliron, UCCE Butte/Glenn/Tehama Counties
Franz Neiderholtzer, UCCE Yuba/Sutter Counties
Katherine Pope, UCCE Sacramento/Solano/Yolo Counties
Mohammad Yaghmour, UCCE Kern County

A. Summary

A mobile platform for measuring midday canopy light interception and a sensor suite for measuring leaf/canopy temperature as a means of assessing plant water status has been developed.

The mobile platform was used extensively for mapping midday canopy light interception in almond orchards again in season. Data collected with the mobile platform suggests that there are a number of potential uses for this technology. The first is for providing a baseline for assessing how an orchard is performing relative performance to other orchards of similar age and variety. Another is for separating out the effects of rate of canopy growth from productivity per unit canopy light intercepted in different selections or varieties. A third potential use is for assessing the efficacy of different fumigants by again separating out the effects of canopy size from productivity per unit light intercepted. A fourth use is for evaluating the impacts of different pruning regimes on canopy growth, light interception and productivity per unit light intercepted. This technology also allows the elimination of canopy size differences from any type of trial.

B. Objectives *(300 words max.)*

Objective 1- Continue to provide support to various other research projects with the goal of understanding the relationship between management practices and productivity. This objective is ongoing with new projects included every year.

Objective 2- Rewrite the iPAR app to ensure it’s future availability (this will include creating a PC based version for batch processing of images).

Objective 3- Work to integrate the iPAR app with Brian Bailey's modelling work (several years)

Objective 4- Work to assess the possibility of using airborne (drone) based imagery as a quicker means of estimating PAR interception in collaboration with Alireza Pourreza (several years)

C. Annual Results and Discussion *(This is the core function of this report)*

Objective 1 - Complete the collection of light interception and yield data for the orchards that have been followed for 5-6 years to get a final data set to help separate out alternate bearing effects from overall yield trends as well as to assess what happens to this relationship as orchards age. Data collected with the Mule lightbar in from 2009-2019 are shown in Figure 1. The line in the top graph in Figure 1 indicates the line about which the best orchards can alternate (about 50 kernel pounds per 1% PAR intercepted). The bottom graph in Figure 1 shows the average regression line through all the data which results in about 40 kernel pounds per 1% PAR intercepted. These results suggest the best orchards can produce about 4000 kernel pounds per acre at 80% interception and the average orchard about 3200 kernel pounds at 80% PAR interception. Because of the large number of points in the graphs in Figure 1, the data is presented broken up by orchard age in Figure 2. You can see that the orchard ages that have a substantial number of points above the optimal line are from 5-13 years of age. The reason for this are still not clear and this is one of the things we plan to investigate further.

The data collected with the mobile platform lightbar has many potential uses. One possible use is to help interpret data from pruning and spacing trials. Figure 3 shows the midday canopy

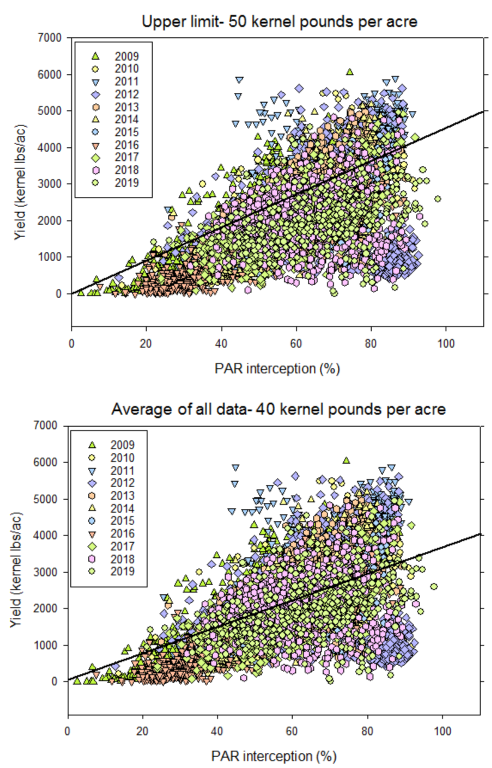

Fig. 1. Midday photosynthetically active radiation (PAR) interception for all data from 2009 to 2019 with the optimal line about with the best orchards can alternate in top figure and the average line for all orchards in bottom figure.

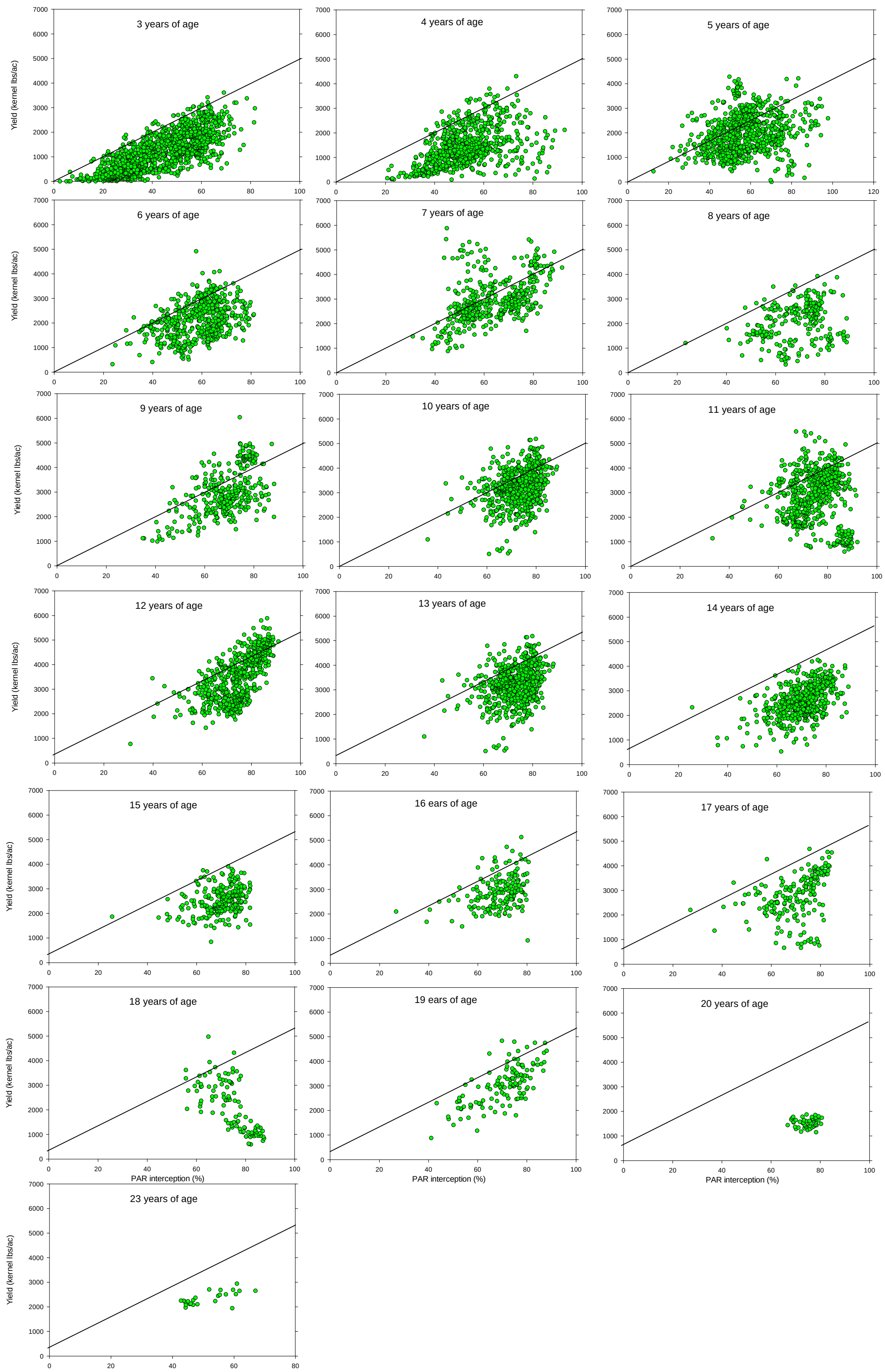

Fig. 2. Midday canopy PAR interception versus yield for 2009 to 2019 separated by orchard age.

light interception over years 5 to 17 for a spacing, rootstock and pruning trial in Stanislaus County. These data suggest that the decline in PAR interception (and corresponding yield) that

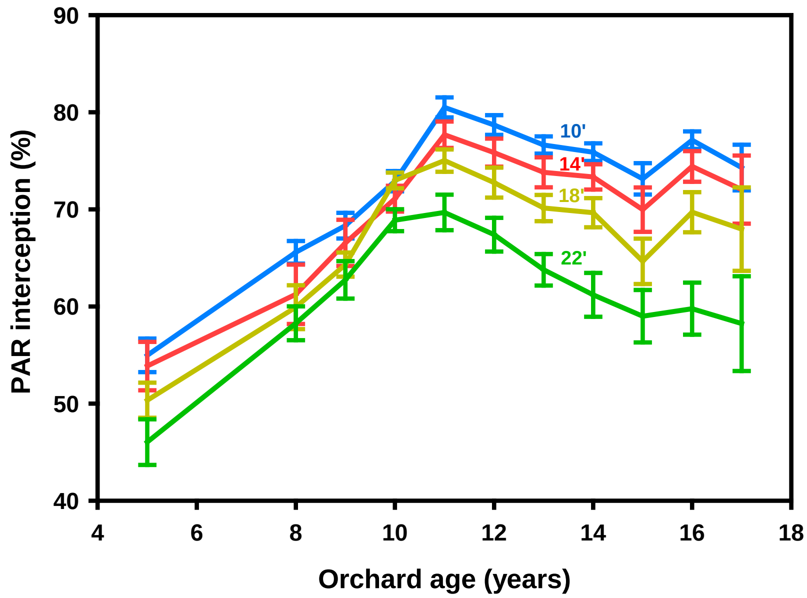

Fig. 3. Midday canopy PAR interception versus yield for a spacing trial conducted by Roger Duncan in Stanislaus County.

we see in almond orchards starting around year 11 to year 13 are not due to shading related effects from high density plantings since it occurs at all spacings. It is also not due to lack of pruning since pruned and unpruned treatments all show the same pattern (data not shown). We have also used the iPAR app to estimate interception over the course of a day (Fig. 4). PAR interception was relatively flat through the day in the medium density McFarland Variety Trial orchard while there was a substantial decrease in the high density Agromillora orchard (Fig. 4a). Part of this difference was made up by a somewhat higher integrated interception in the high density orchard resulting in about 76% of the daily integrated interception for the high versus medium density orchards. However, much of the canopy in the high density orchard has problems with cankers due to damage from mechanical hedging and the over the row harvester. In addition, the hedging results in lots of non-productive vegetative growth most likely leading to lower productivity per unti PAR intercepted (we were not able to measure yield in these orchards this year).

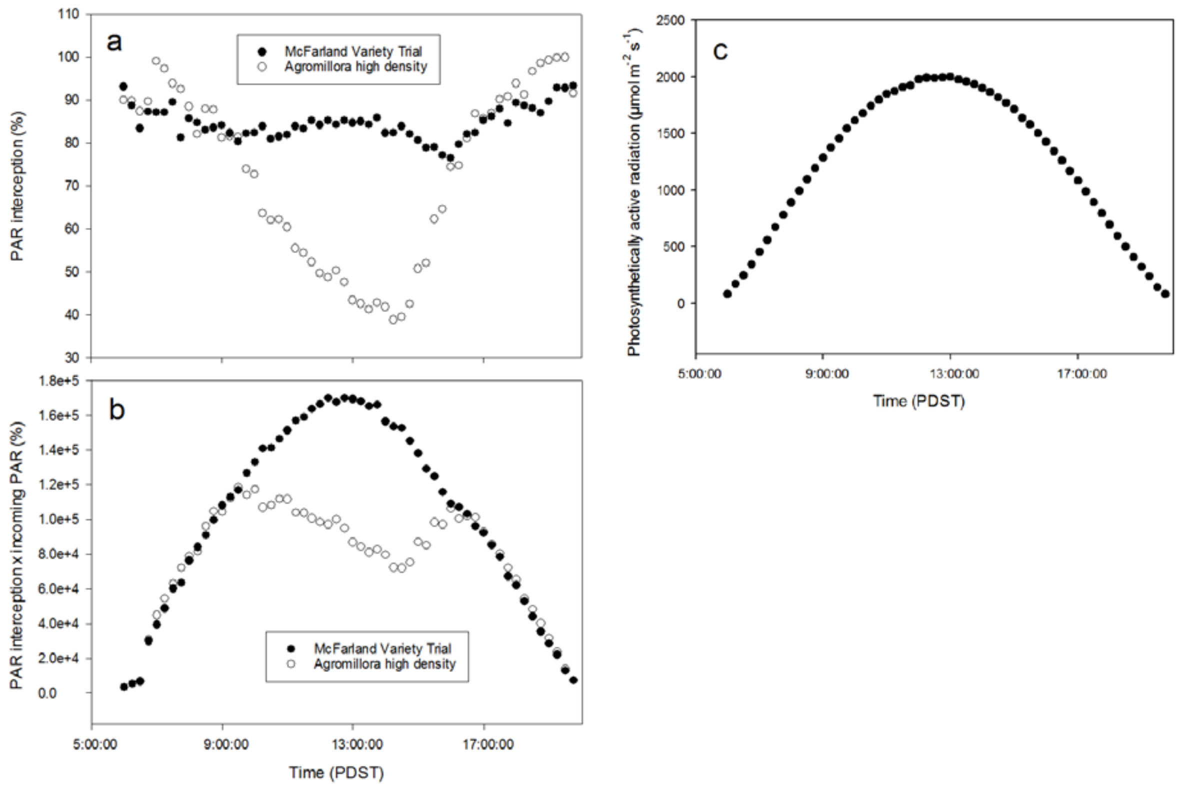

Fig. 4. Photosynthetically active radiation (PAR) interception data (a), PAR interception times incoming PAR (b) and incoming PAR incident on the orchard (c) from a high density (11' x 5' planting with 792 trees per acre) and a medium density orchard (20' x 18' or 121 trees per acre).

Objective 2. Rewrite the iPAR app to ensure it's future availability (this will include creating a PC based version for batch processing of images). The work on the PC based version was completed but the online version did not perform as well as the iPhone version of iPAR. The iPhone version of the app (iPAR) is still working and available in the Apple store.

Objective 3- Work to integrate the iPAR app with Brian Bailey's modelling work (several years). This work is ongoing with Brian's postdoc set to begin putting more emphasis on this in the near future. See Brian Bailey's Almond Board of California report on "Assessment of almond water status using inexpensive thermographic imagery" for details on this aspect of the work.

Objective 4- We have also been working with Ali Pourreza in Bio and Ag Engineering on comparing our light bar data with his drone imagery. We are still in the process of analyzing these data but so far results looks promising. We have run the light bar and flown the drone in our Stanislaus RAVT with Roger Duncan, the Kearney almond lysimeter trial with Ken Shackel and Mae Culumber and the almond precision irrigation trial with Mae Culumber and Khaled Bali. These comparisons will be presented at the Almond Conference and in the annual report next year.

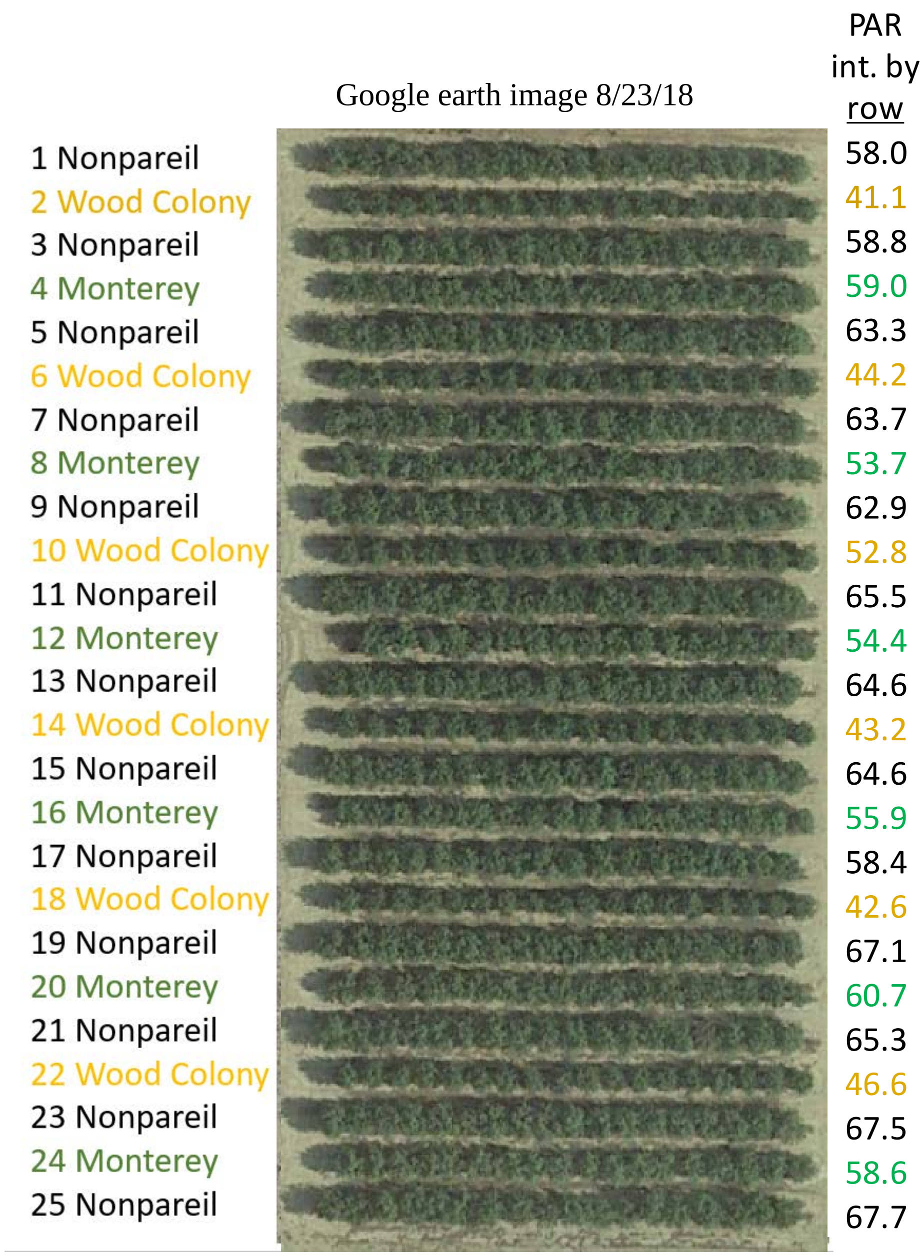

Fig. 5. Google Earth image and PAR interception for each row calculated using the mobile platform light bar data.

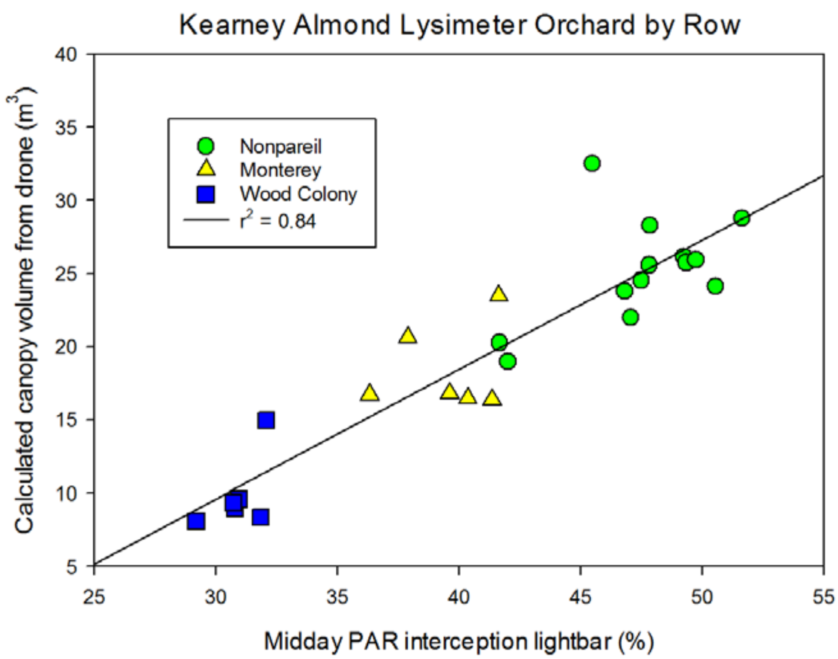

Fig. 6. Midday PAR as measured with the mule lightbar compared to canopy volume calculated from the drone imagery from Ali Pourreza.

D. Outreach Activities

Data from this project have been presented each year in oral presentations and poster sessions at the annual Almond Board Conference in Sacramento. In addition, it was presented at the Almond Short Course in Visalia in November 2019 and at the ISHS Almond and Pistachio meeting in Adelaide Australia in November 2017.

E. Materials and Methods *(500 word max.)*:

Objective 1- Refine light interception/yield relationship in almond. Twenty four almond orchard sites of varying ages and varieties from throughout the almond growing area of California were selected for measurements in 2019 (Table 1). An emphasis was placed on orchards with Nonpareil but other varieties were also included. Light bar measurements were done in 10-20 rows (depending on orchard size and variability) in representative areas of the orchard during June to August. In addition, measurements were done in various research plots around the state as described below. A portable weather station with temperature, relative humidity and photosynthetically active radiation sensors was set up outside of each orchard to provide reference data (on a one minute basis) during the period measurements with the light bar were being taken.

The photosynthetically active radiation data from this station was used to calibrate the sensors on the Mule lightbar throughout the measurement period. The data rows were then flagged and at harvest time, rough field weights were taken from the Nonpareil or other primary variety in the orchards. Subsamples from each variety were taken and dried and shelled to estimate kernel yield. In some cases, measurements were done in orchards that are being used for other almond trials including sites from the USDA-ARS Area Wide Methyl Bromide Alternatives trials, as well as projects funded under several federal grants. Other orchards were mapped from rootstock as well as pruning and

Site #	Trial	Location
1	Browne Avenalis almond	Fresno/ Kearney
2	On campus almond irrigation	Yolo/ Davis
3	Butte RAVT Chico	Butte/Chico
4	Madera RAVT Chowchilla	Madera/Chowchilla
5	Cynthia's Corning almond	Tehema/Corning
6	Duncan Almond Irrigation/Claribell Compost/ Del Don Rootstock/ Pruning/Fumigation	Stanislaus/Turlock
7	Kearney Browne 2016 almond drone	Fresno/ Kearney
8	Kearney Browne Fantasia almond drone	Fresno/ Kearney
9	Kearney Browne old almond drone	Fresno/ Kearney
10	Kearney Holtz almond grind and burn	Fresno/ Kearney
11	Kearney Shackel almond	Fresno/Kearney
12	Kelley's Corning almond	Tehema/Corning
13	Kelley's Nickels almond irrigation	Colusa/Arbuckle
14	Mae's Almond Lincoln site	Fresno
15	Mae's Almond precision irrigation trial	Fresno/Kearney
16	Mae's almond precision irrigation trial drone	Fresno/Kearney
17	Mae's almond precision irrigation trial post harvest 1	Fresno/Kearney
18	Mae's almond precision irrigation trial post harvest 2	Fresno/ Kearney
19	Nickels almond Franz	Colusa/ Arbuckle
20	Nickels almond Heather	Colusa/ Arbuckle
21	Nickels organic almond	Colusa/ Arbuckle
22	Nickels almond pruning	Colusa/ Arbuckle
23	Nickels almond rootstock	Colusa/Arbuckle
24	Nickels almond spacing	Colusa/ Arbuckle
25	Stanislaus RAVT Salida	Stanislaus/Salida
26	Scheuring almond rootstock	Yolo/ Esparto
27	Zuber almond	Stanislaus/ Turlock

Table 1. Almond orchard sites mapped with Mule lightbar during 2019 season.

Objective 2. Rewrite the iPAR app to ensure it's future availability (this will include creating a PC based version for batch processing of images). The work on the PC based version was completed but the online version did not perform as well as the iPhone version of iPAR. The iPhone version of the app (iPAR) is still working at the Apple store.

Objective 3- Work to integrate the iPAR app with Brian Bailey's modelling work (several years). This work is ongoing with Brian's postdoc set to begin putting more emphasis on this in the near future. See Brian Bailey's Almond Board of California report on "Assessment of almond water status using inexpensive thermographic imagery" for details on this aspect of the work.

Objective 4- Work to assess the possibility of using airborne (drone) based imagery as a quicker means of estimating PAR interception in collaboration with Alireza Pourreza (several years). This work is also ongoing. We ran the lightbar and flew Ali's drone in 3 orchards in 2019 and will continue this work in 2020.

F. Publications that emerged from this work

Browne, G.T., **B.D. Lampinen**, B. A. Holtz, D.A. Doll, S.K. Upadhyaya, L.S. Schmidt, , R.G. Bhat, V. Udompetaikul, R.W. Coates, B. D. Hanson, K. M. Klonsky, S. Gao, D. Wang, M. Gillis, and R.S. Johnson. 2013. Managing the almond and stone fruit replant disease complex with less soil fumigant. California Agriculture July-Sept. 2013: 127-137.

R. Dhillon, V. Udompetaikul, F. Rojo, J. Roach, S. Upadhyaya, D. Slaughter, **B. Lampinen**, K. Shackel. 2014. Detections of plant water stress using leaf temperature and microclimatic measurements in almond, walnut and grape crops. Am. Soc. Agric. and Biol. Eng. 57(1): 297-304.

Dhillon, R., F. Rojo, J. Roach, S. Upadhyaya and M. Delwiche. 2014. A continuous leaf monitoring system for precision irrigation management in orchard crops. J. Agr. Machinery Sci. 10(4):267-272.

Lampinen, Bruce.D., Vasu Udompetiakul, Gregory T. Browne, Samuel G. Metcalf, William L. Stewart, Loreto Contador, Claudia Negron, and Shrini K. Upadhyaya. 2011. A mobile platform for measuring canopy photosynthetically active radiation interception in orchard systems. HortTechnology 22(2): 237-244.

Dhillon, R., V. Udomptetaikul, F. Rojo, J. Roach, S. Upadhyaya, D. Slaughter, **B. Lampinen** and K. Shackel. 2014. Detection of plant water stress using leaf temperature and microclimatic measurements in almond, walnut and grape crops. Trans. ASABE Vol. 57(1): 297-304.

Zarate-Valdez, Jose L., Michael L. Whiting, **Bruce D. Lampinen**, Samuel Metcalf, Susan L. Ustin, and Patrick H. Brown. 2012. Prediction of leaf area index in almonds by vegetation indexes. Computers and Electronics in Agriculture 85: 24-32.

Zarate-Valdez, Jose L., Saiful Muhammad, Sebastian Saa, **Bruce D. Lampinen** and Patrick H. Brown. 2015a. Light interception, leaf nitrogen and yield prediction in almonds: A case study. European Journal of Agronomy 66: 1-7.

Zarate-Valdez, Jose L., Samuel Metcalf, William Stewart, Susan L. Ustin, and **Bruce Lampinen**. 2015b. Estimating light interception in tree crops with digital images of canopy shadow. Precision Agriculture DOI 10.1007/s11119-015-9387-8 (published online 24 January 2015). 16 pages.

Couvreur, V., M.M. Kandelous, B.L. Sanden, **B.D. Lampinen**, and J.W. Hopmans. 2016. Downscaling transpiration rate from field to tree scale. Agricultural and Forest Meteorology. 221: 71-77.

Muhammad, Saiful, Blake L. Sanden, Sebastian Saa, Bruce D. Lampinen, David R. Smart, Kenneth A. Shackel, Theodore M. DeJong, and Patrick H. Brown. “Optimization of Nitrogen and Potassium Nutrition to Improve Yield and Yield Parameters of Irrigated Almond (Prunus Dulcis (Mill.) D. A. Webb).” *Scientia Horticulturae* 228 (January 26, 2018): 204–12. https://doi.org/10.1016/j.scienta.2017.10.024.

Browne, G., N. Ott, A. Poret-Peterson, H. Gouran, and B. Lampinen. “Efficacy of Anaerobic Soil Disinfestation for Control of Prunus Replant Disease.” *Plant Disease* 102, no. 1 (January 2018): 209–19. https://doi.org/10.1094/PDIS-09-16-1392-RE.

Holtz, B. G.T. Browne, D. Doll, M. Culumber, M.A. Yaghmour, E. Jahanzad, B. Lampinen, and A. Gaudin. 2019. Whole orchard recycling and the effect on second generation tree growth, yield, light interception, and soil fertility. Acta Hortic. 1219. ISHS 2018. Proc. VII International Symposium on Almonds and Pistachios pp. 265-271.

Abstracts

Roja, Francisco, Rajveer Dhillon, Shrinivasa Upadhyaya, Bryan Jenkins, **Bruce Lampinen**, Jedediah Roach, Kellen Crawford, and Samuel Metcalf. 2014. Modeling light interception for estimating yield in almond and walnut trees. 12th Int. Conf. on Prec. Ag., July 20-23, 2014, Sacramento, CA.

Zarate-Valdez, Jose.L., Margarita Huesca, Michael L. Whiting, **Bruce D. Lampinen**, Alicia Palocios-Orueta and Susan L. Ustin. 2014. Intensive ground sampling of canopy light-capture for modeling California nut yields for growers and regional satellite predictions. 12th Int. Conf. on Prec. Ag., July 20-23, 2014, Sacramento, CA.