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A New Assessment of High Punctual Solar Trackers Effects on Poultry Welfare in Agrivoltaïc Open-Air Runs

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Abstract. Open-air poultry farming is currently developing with the increasing society demand for livestock farming better considering animal welfare. Outside animal comfort and open-air runs exploration could be enhanced by shelters such as trees or photovoltaic (PV) structure. The aim of this study is to confirm previous results to evaluate (i) the microclimates generated under high punctual PV trackers, (ii) the effect on laying hens comfort, (iii) the use of panels shadow area by hens. In three experimental sites, microclimates were studied and laying hens were counted in a control area, under such PV tracker and under a tree. Results showed that PV trackers, as big trees, lowered summer soil and air temperatures, radiation and lightness, decreased the occurrences of stress situations for hens, and that more hens were counted under trackers than in a control area. These results may help for optimizing such agrivoltaïc system and the hens welfare by improving the open-air run design with PV structures and vegetation.

Keywords: Photovoltaic Tracker, Poultry Welfare, Laying Hens Counting, Agrivoltaic System

1. Introduction

Open-air poultry farming is currently developing with the increasing society demand for livestock farming better considering animal welfare. Outside animal comfort and open-air runs exploration could be enhanced by shelters [1], especially during hot summer days which occurrences are increasing [2,3]. Enhancing exploration directly means limiting animal concentration, their droppings and their damages to grass, next to the livestock building. Such shelters, commonly bushes and trees once developed enough, could also be photovoltaic (PV) structures. For these combined activities, with PV bringing comfort to animals i.e. for such agrivoltaïc system, high punctual PV trackers could particularly fit: their height generates large moving shadows, their punctual structure is easily arrangeable in the field and consistently with vegetation, and their electricity production profile, related to solar tracking, is suitable with self-consumption, addressing as-well the issue of farms energetic autonomy. Depending on various factors such as climate, microclimate under panels, animal characteristics, farming practices, panels position [1], solar panels could effectively bring comfort to animals and poultry would effectively use the panels shadow area and likely explore the open-air runs. Agrivoltaïc systems with livestock farming were assessed in the light of grass growing for sheep farming [4] and of animal welfare and behaviors for dairy cows [5] but rarely for poultry systems. A similar study [6], led on laying hens, concluded in improvements on animal comfort with a consequent decrease in temperature during summer 2021 under PV trackers shadow and in higher hens frequentation compared to control areas. The frequentation differences were a priori underestimated due to method biases. The aim of this study is to confirm such results with new experimental sites and counting methodology.

2. Material and methods

For this purpose, three poultry farms where laying hens are outside from morning to sunset were studied, one located 40 km south of Le Mans and two 120 km east of Paris (fig.1). In each site, three areas were defined as described in Fig.2: (i) a control area, (ii) an area under the PV tracker, (iii) an area under a tree, except in site C where no tree is planted. The PV tracker and the tree areas were most of the measurements time in shade conditions where the control areas were always in sunny conditions. In these areas, thermometers, hygrometers, pyranometers, luxmeters and cameras were mounted as described Fig. 3.

Figure 1. Localization of the three experimental sites

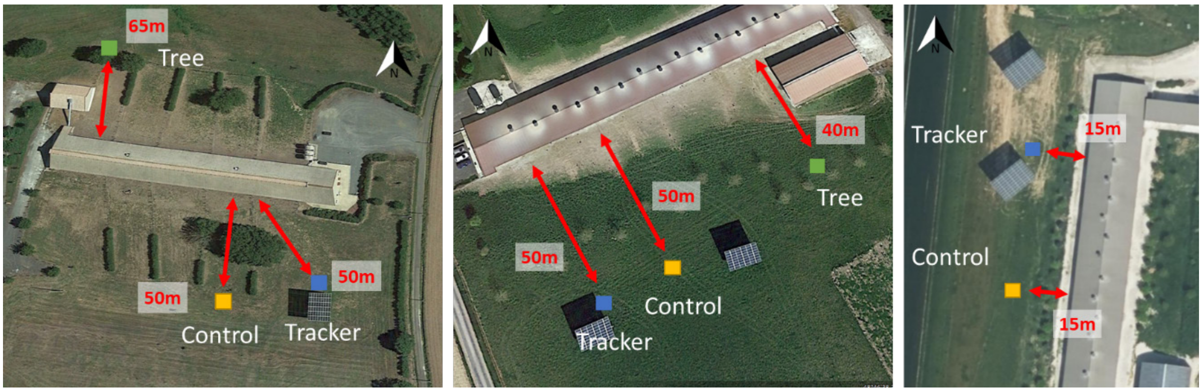

Figure 2. Observation and measurement areas in sites A, B, C (from left to right)

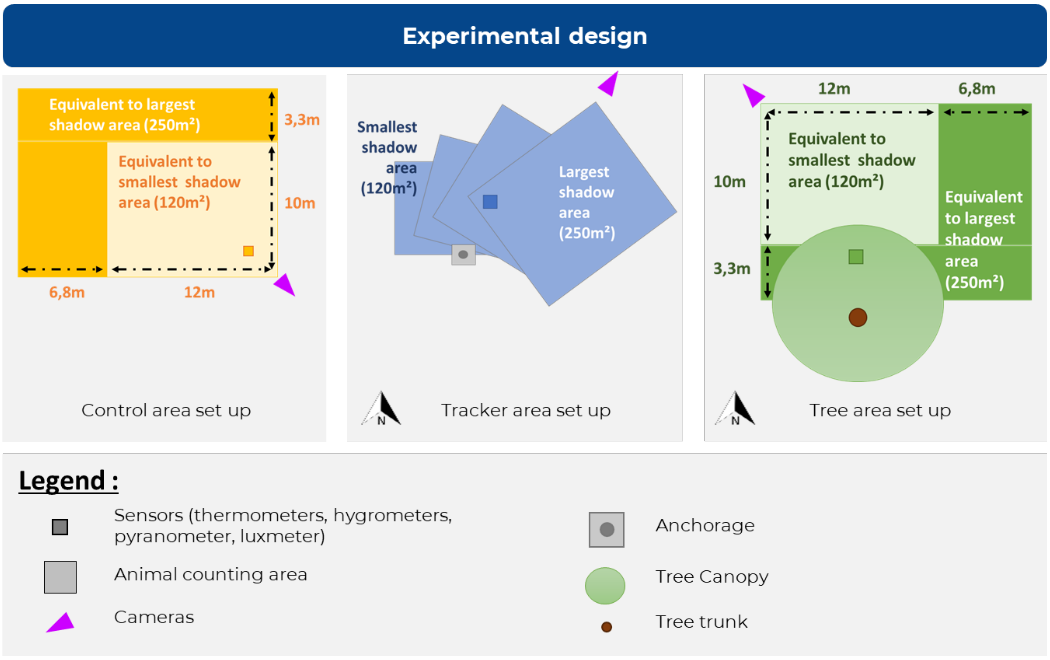

Figure 3. Experimental design

From July 21st to October 11th for site A, from July 11th to September 9th for site B, from July 12th to September 6th for site C, measurements and observations were led between 12 pm and 6pm. Every 12 minutes, temperature (T°) and hygrometry (H%) were measured at 0 cm and 40 cm above ground (i.e. soil surface and air conditions), radiation and light at 1 m high (for hens damages prevention). Six times per hour pictures were taken, and hens were counted.

Hens comfort was evaluated with a stress index [7] based on T° and H% data and also approached with light data. Air T° and H° measurements data were used to determine in each area the situations occurrences of (i) comfort, (ii) light stress, (iii) heavy stress or (iv) lethal stress, based on this index. These stress categories are related to signs of stress: (i) none, (ii) panting, activity decrease, wings deployments, (iii) ingestion reduction, water consumption increase, production decrease (quantity/quality), (iv) mortality.

Animals counting were led under the tracker in the area drawn by its shadow, and for both the control and the tree in (i) a small rectangle area (120m²) and (ii) a large rectangle area (250m²) corresponding roughly to the smallest and largest area taken by the tracker shadow during the studied period (Fig. 3). The control area was chosen more accessible for poultry than the tracker area in a conservative approach for hens frequentation evaluation (Fig. 2).

For statistics, non-normality data distribution was tested with Anderson-Darling tests. Kruskal-Wallis tests were used to evaluate differences between areas for animal counting and Dunn's test for differences between areas one-by-one.

3. Results

Soil and air mean T° under tracker were lower than in control area on average over the measurement period by 4.1 and 3.3°C (Fig. 4) where these differences were slighter between tracker and tree areas and depended on sites: in site A soil and air mean T° were lower for tree by 0.7 and 0.2°C, where in site B they were lower for tracker by 0.6 and 2.8°C (table 1). Soil and air mean H° under tracker were higher than in control area on average over the three sites by 7.5 and 5.6%, where these differences were variable between tracker and tree areas depending on sites: in site A soil and air mean H° were higher for tree by 2.7 and 2.3% and in site B they were higher for tracker by 5.9 and 8.4%. These site-dependent effects might be related to the tree size which was large in site A (comparable to the tracker size) and quite small in site B.

Mean radiations were lower under tracker and tree than in control area by 53% and 60% respectively, as well as, lightness by 52 and 55%.

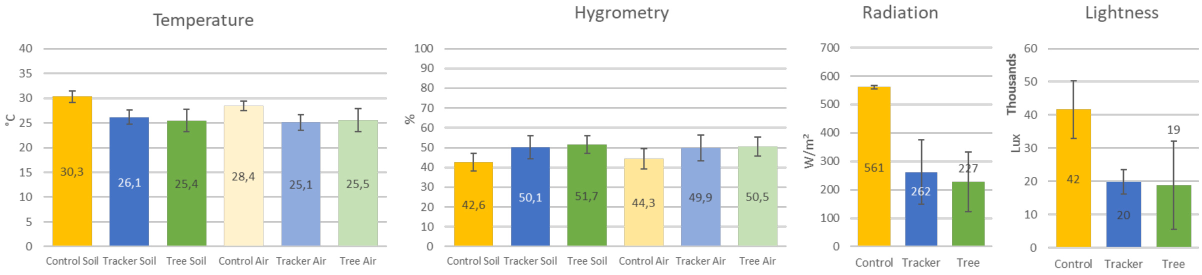

Figure 4. Microclimate comparison of control, tracker, tree areas (averages and standard errors on three sites and over the period studied)

Table 1. Microclimate measurements (averages and standard error over the period studied)

			Site A			Site B			Site C		
Temperature (°C)	0cm	Control	29,0	±	4,0	31,0	±	5,2	31,0	±	4,4
Temperature (°C)	0cm	Tracker	24,6	±	4,9	26,4	±	3,3	27,4	±	2,6
Temperature (°C)	0cm	Tree	23,9	±	3,7	27,0	±	3,7		±	
Temperature (°C)	40cm	Control	27,4	±	3,2	28,6	±	4,4	29,2	±	3,9
Temperature (°C)	40cm	Tracker	24,1	±	5,2	24,4	±	3,0	26,9	±	2,7
Temperature (°C)	40cm	Tree	23,9	±	3,7	27,2	±	3,6		±	
Hygrometry (%)	0cm	Control	47,4	±	14,0	41,4	±	16,5	39,0	±	14,4
Hygrometry (%)	0cm	Tracker	52,2	±	16,6	54,5	±	13,1	43,5	±	11,0
Hygrometry (%)	0cm	Tree	54,9	±	11,5	48,6	±	12,7		±	
Hygrometry (%)	40cm	Control	49,9	±	13,3	43,8	±	15,5	39,4	±	14,0
Hygrometry (%)	40cm	Tracker	51,7	±	16,4	55,4	±	11,3	42,7	±	11,5
Hygrometry (%)	40cm	Tree	54,0	±	11,9	47,0	±	14,1		±	
Radiation (W.m^{-2})	1m	Control	561	±	140	555	±	177	565	±	206
Radiation (W.m^{-2})	1m	Tracker	169	±	48	230	±	105	388	±	259
Radiation (W.m^{-2})	1m	Tree	153	±	78	301	±	97		±	
Lightness (Kilolux)	1m	Control	31,7	±	14,6	45,6	±	11,7	47,7	±	9,5
Lightness (Kilolux)	1m	Tracker	16,8	±	5,4	18,8	±	8,7	23,9	±	10,5
Lightness (Kilolux)	1m	Tree	9,4	±	3,8	28,2	±	7,7		±	

Based on the temperature-humidity stress index, comfort situations were more frequent under the tracker than in the control area (39% for tracker compared to 7% for control in site A, 69% versus 13% in site B, 8% versus 6% for site C) as observable in Fig. 5. Stressful situations were also less frequent under tracker than in the control area for all sites and all levels of stress, except for site C where more light stressful situations under tracker compared to control were (45% versus 73%) seemed related to less hard and lethal situations for tracker (19% versus 49%) also meaning a higher animal comfort under tracker than in control.

Comfort situations under trees were similar to under the tracker in site A (35% under the tree versus 39% under the tracker) but rather similar to control in site B (12% versus 13% for control) and largely lower than under the tracker (69%). On this site B, the tree seemed to rather decrease occurrences of hard and lethal stressful situations for the benefit of light stressful situations, when comparing with the control. The tree size differences between site A and B might again explain these consequent differences in animal comfort under trees.

Figure 5. Comfort situations occurrences in each area and each experimental site

Concerning areas frequentation by laying hens (Fig. 6), counts were greater in the tracker shadow area even than in the large control counting area for site A and C, and rather similar to the large tree counting area in site A. In site B, counts under the tracker were similar to the small control counting area, despite higher comfort under the tracker, but they were also very small for both control and tracker compared to the other sites, suggesting other effects limiting the frequentation differences between tracker and control.

Figure 6. Laying hens cumulative counting in each area and each experimental site

4. Discussion

These results confirmed most results of Noirot-Cosson et al. (2021) [6]: (i) Under the tracker mean T°, radiations were lower and mean H% higher than in control, and quite comparable to under a tree, whatever the measurement height (ii) based on the stress index, comfortable situations were more frequent under the tracker and the tree than in the control area, (iii) hens mean counts were higher under the tracker and the tree than in the control areas (except for site B probably for other reasons than comfort conditions) and likely related to more comfortable situations with lower T°.

Here, the lightness was also measured, as this criterion is highly studied and monitored inside building for hens comfort and activities. The inside light is generally set to 15-120 lux [8]. Here, the outside light measured was on average (on the 3 sites and the period studied, focus on afternoons) of about 42 000 in the control and 20 000 lux in the tracker shadow. The decrease lightness under tracker or tree may also be related to improved comfort for hens despite the high levels.

Compared to the previous study, the new counting methodology with larger areas (from 4 to 10 times larger) and longer timelapse (one hour added for the only site in common) led to higher animal counts (from 24 to 45 times higher for the control, by 106 times for the tracker, and by 18 to 43 times for the tree). The higher increase for the tracker can be mainly explained by the integration of the shadow border in the counting area where laying hens seemed attracted [6] an effect not observed for tree areas.

In site B only, the tracker area frequentation by hens was not higher than in the control. The hens frequentation in the control and tracker areas were also very low. This might be explained by areas accessibility reasons, as they were far from the building and with little vegetation in between, in comparison to the other sites (see Fig. 2). Such effect was also observed in the previous study where the only site with no significant differences in hens frequentations between areas was the site with the lowest areas accessibility.

The trackers locally modified the microclimate and created more comfortable areas for hens. The exploration of the open-air runs supposedly enhanced thanks to hens attraction to these areas seemed to strongly depend on vegetation on the open-air runs and distance between sheltering elements. Further studies should be led specifically on the open-air runs arrangement and hens exploration. They could also focus on production indicators [5] which results would depend on many other factors to fix.

5. Conclusion

The high and punctual solar trackers studied showed true interest in terms of hens comfort by lowering summer temperatures, radiations and lightness in some area in the open-air runs (under the trackers), where higher frequentations were generally observed than in control areas. It confirmed previous results on the interest of such PV structures for laying hens comfort and open-air runs exploration. Further study should focus on open-air runs arrangement with PV structures in relation to hens exploration.

Author contributions

Table 2. Author contributions

Contributor role	Contributor name
Conceptualization	Paul-Emile Noirot-Cosson, Ophélia Sipan, Benoit Pineau
Formal analysis	Paul-Emile Noirot-Cosson, Ophélia Sipan
Investigation	Paul-Emile Noirot-Cosson, Ophélia Sipan
Methodology	Paul-Emile Noirot-Cosson, Ophélia Sipan, Benoit Pineau
Project administration	Ophélia Sipan, Benoit Pineau
Software	Tanguy Riou
Supervision	Paul-Emile Noirot-Cosson, Ophélia Sipan
Visualization	Paul-Emile Noirot-Cosson, Ophélia Sipan, Benoit Pineau, Tanguy Riou
Writing – Original draft preparation	Paul-Emile Noirot-Cosson, Ophélia Sipan, Benoit Pineau, Tanguy Riou
Writing – Review & Editing	Paul-Emile Noirot-Cosson

Competing interests

The authors declare the following competing interests: they are all employed by the corporation groupe OKWIND SAS.

Data availability statement

Data can be requested by contacting the authors.

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