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Assessing Photovoltaic Trackers Effects on Open-Air Poultry Welfare

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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) trackers. The aim of this study is to evaluate (i) the microclimates generated under 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 a PV tracker and under a tree. Results showed that PV trackers, as trees, lowered summer soil and air temperatures and radiation, decreased the occurrences of stress situations for hens, and that more hens were counted under trackers than in a control area. Methodological improvements can be led to better apprehend differences of area uses by hens.

Keywords: Photovoltaic tracker, Poultry Welfare, Laying hens counting, agrivoltaïc 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, PV trackers could particularly fit: their highness generates large moving shadows, their punctual structure is easily arrangeable in the field and consistently with vegetation, and their electricity production profile is suitable with self-consumption, addressing aswell the issue of farms energetic autonomy. Depending on various factors such as climate, microclimate under panels, animal characteristics, farming practices, panels position [1], panels could effectively bring comfort to animals and poultry would effectively use the panels shadow area. 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 never for poultry systems. The aim of this study is to evaluate (i) the microclimates generated under PV trackers, (ii) the effect on laying hens comfort, (iii) the use of panels shadow area by hens.

2. Material and methods

For this purpose, three poultry farms located north-west of France (Fig.1), where laying hens are outside from the afternoon to sunset (table 1), were studied. 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. The control area was chosen more accessible for poultry than the tracker area in a conservative approach. In these areas, thermometers, hygrometers, pyranometers and cameras were mounted as described Fig. 3.

During roughly 3 months from July to October (table 1), every two minutes, microclimates were characterized with temperature and hygrometry measurements at 0 cm and 40 cm above ground (i.e. soil surface and air conditions) representing conditions for laying hens feet and heads, and radiation measurements at 1 m high (for hens damages prevention), and, every 15 minutes, pictures were taken and hens were counted. Microclimates were specifically observed during three different periods: (i) the whole period: all days and from 11am to 11pm, (ii) the afternoons: all days and only from 12 pm to 5 pm, (iii) the hot days: few days selected based on an afternoon mean T°C above 25°C, representing 24, 28, and 31 days for site A, B and C respectively.

Air temperature and hygrometry data were used to evaluate in each area and for the afternoons period the situations occurrences of (i) comfort, (ii) light stress, (iii) heavy stress or (iv) lethal stress, based on temperature-humidity stress index [6] for hens. 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 on 25m² fixed areas (Fig. 3) only for two periods similar to the so-called afternoons and hot days periods, except that counting started 30 minutes after gates are opened i.e. 2.30 p.m., 12 p.m., 3.30 p.m. in site A, B, C respectively.

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

3. Results

Soil and air mean temperatures under tracker were lower than in control area (by 2.0 and 1.2°C for the whole day period, 3.5 and 2.0°C for the afternoon and 5.7 and 3.5°C for hot days) where these differences were very slight between tracker and tree areas: in site A : soil and air mean temperatures were lower for tree by 0.6 and 0.4°C, 0.1 and 0.5°C, 0.1 and 0.4°C for the three periods, respectively, where in site B they were lower for tracker by 0.1 and 0.2°C, 0.1 and 0.0°C, 0.1 and -0.1°C (Fig. 4). Soil and air mean hygrometries under tracker were higher than in control area on average over the three sites by 3.9 and 3.6%, 7.3 and 5.2%, 11.1 and 7.1% for the three periods studied respectively. Under the tree, soil and air mean hygrometries were also higher than in the control area, but in a lower manner: lower than for tracker by 2.5 and 2.4%, 4.5 and 4.7%, 7.6 and 7.2% for the three periods respectively. Mean radiations were lower under tracker than in control area by 57%, 65% and 78% for the three periods studied respectively. They were lower under trees than under trackers, but these differences were lower than between tracker and control. Differences between areas were all significant except in hot days between tracker and tree areas in site A for soil temperature and soil hygrometry (table 2).

As with a tree, trackers allowed significant soil and air temperatures decreases, hygrometries increases, radiation decreases, whatever the period studied. Under trackers and trees, microclimates were relatively similar, regarding differences with control areas.

Based on the temperature-humidity stress index, comfort situations were more frequent under the tracker and the tree than in the control area (86% for tracker and 83% for tree compared to 65% for control in site A, 69% and 68% compared to 44% in site B, 91% for tracker and 82% for control in site C) as observable in Fig. 5. Respectively stress situations were less frequent under trackers or trees than control. If lethal stress situations were rare in control areas (0.2%, 0.4% and 0.1% in site A, B and C respectively) they did not exist in tracker and tree areas. Differences between the tree and tracker were very tight, whereas differences between tracker and control or tree and control were consequent.

Concerning animal counting, whatever the period and the site considered, cumulated hens counts were significantly greater in the tracker area than in the control area (except in hot days in site A where the advantage for tracker area was not significant). They were also consequently greater for tree areas than tracker areas, but these differences were not significant in site B.

4. Discussion

Temperatures, hygrometry and radiation observations clearly showed that trackers comparatively as trees create areas with more comfortable microclimates for laying hens, which were also related to higher frequentation by hens. These trends were observable on the three sites although comparisons between sites were not led as experimental protocol slightly varied from one site to another (period of measurement), the number of sites was limited, macroclimate conditions were rather similar... Further relationships between trackers areas and animal welfare could be led by studying animal behavior signs as studied for dairy cows [3] where a study including production indicators would mean two identical open-air poultry runs.

Despite significant differences in animal counts between areas, cumulative countings are very low. This could be explained by : (i) a small counting surface (25 m²) compared to the tracker shadow surface (a least 120 m²), (ii) counting area excluding the shadow borders where many hens were observable as in Fig. 7, (iii) limited duration of counting (between 1h30 to 5h depending on sites) and thus of number of pictures (between 7 to 21 per day in the counting periods), (iv) long distances between counting areas and building (between 40 and 65 meters) (v) with limited vegetation, stifling hens exploration, (vi) time for hens to be able to explore the open-air runs (i.e. causing small counts in the beginning of the measurement period) and (vii) hens genetics. These four last parameters might explain differences in animal countings between sites, that was not properly studied here.

Differences in animal countings could be better revealed by modifying the counting protocol (with larger counting area and/or moving counting area to follow the tracker shadow area) and by selecting experimental farms with farming conditions enhancing laying hens exploration in general (larger exploration duration for instance) or tracker area reaching (smaller distance between tracker and building, more centered tracker position, …).

5. Conclusion

Trackers showed true interest in terms of hens comfort by lowering summer temperatures and radiations in some area (under the trackers) in the open-air run, where higher frequentations were observed than in control areas. Such study should be led in other farms with different conditions and protocol methods as discussed to confirm such results. Trackers implantation in open-air runs probably enhance poultry exploration playing a shelter role comparable as tree, even more if smartly disposed in the open-air runs and consistently with vegetation.

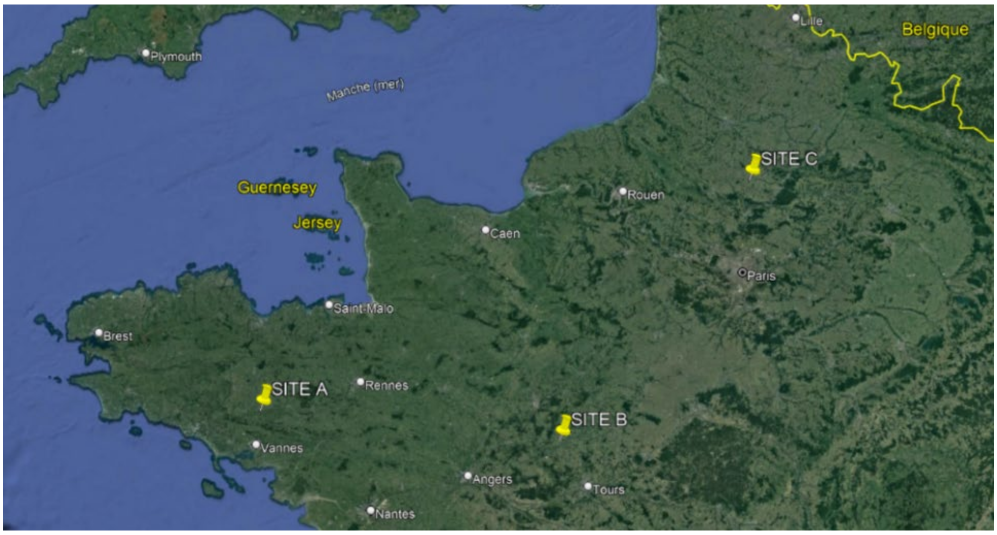

Figure 1. Localisation of the three experimental sites

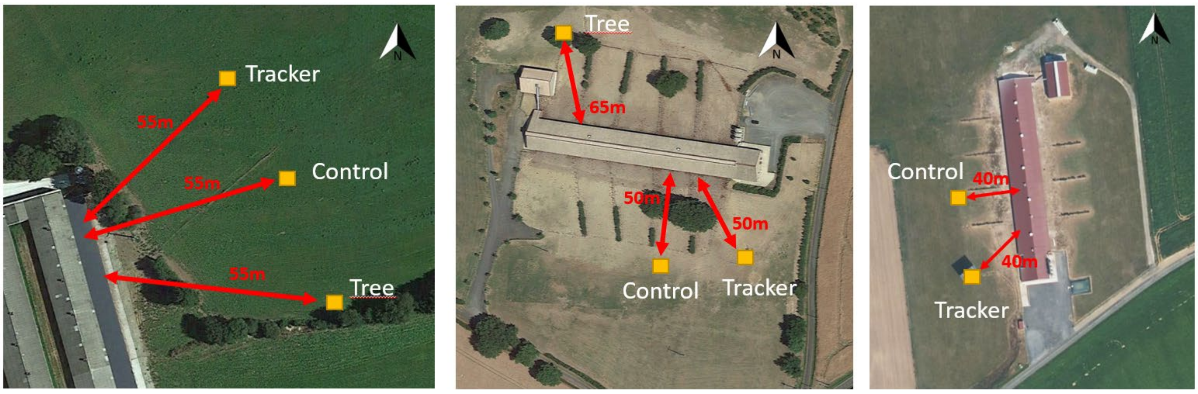

Figure 2. Observation and measurement areas in experimental sites A, B, C (from left to right)

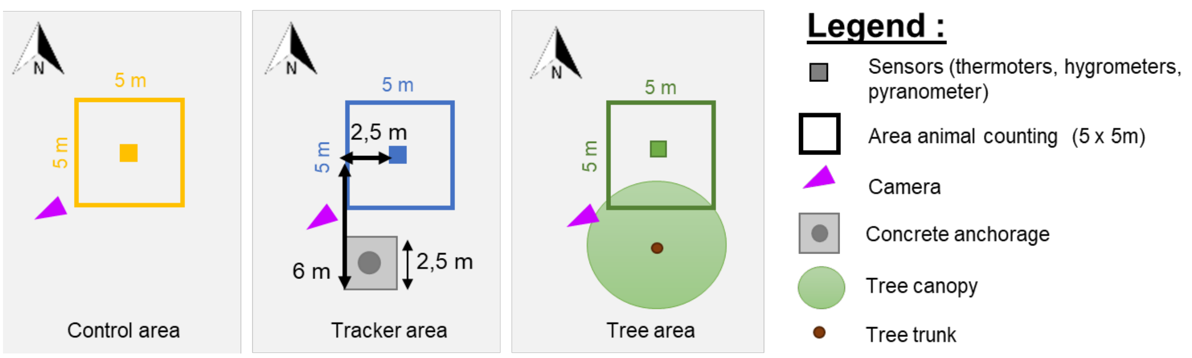

Figure 3. Experimental design

Table 1. Time experimental aspects

Time aspect	Type of data concerned	Site A	Site B	Site C
Whole experiment period	All data	7th July – 11th oct.	25th June – 28th sept.	13th July – 20th oct.
Daily period	Microclimate data	11 a.m. – 11 p.m.	11 a.m. – 11 p.m.	11 a.m. – 11 p.m.
Daily period	Pictures and counting	2.30 pm – 5 pm	12 pm – 5 pm	3.30 pm – 5 pm
Frequency	Microclimate data	2 min	2 min	2 min
Frequency	Pictures and counting	15 min	15 min	15 min

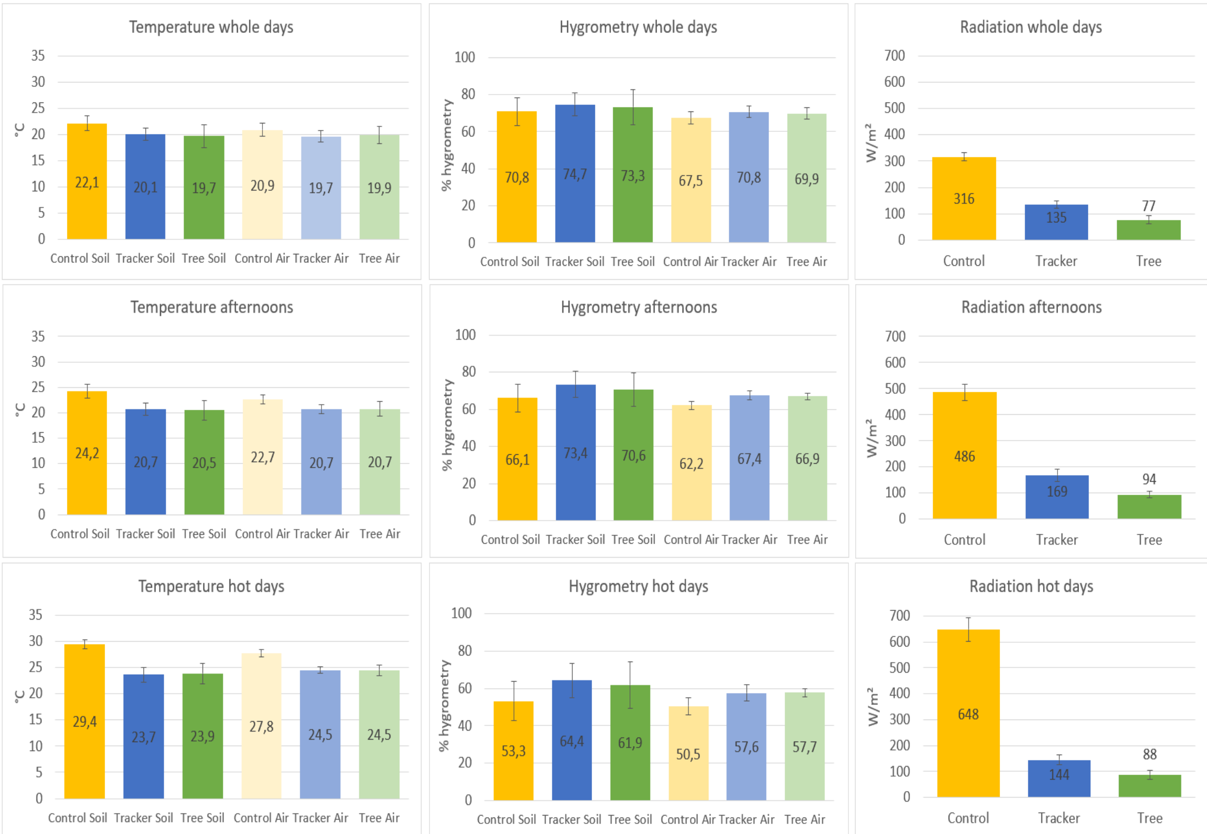

Figure 4. Microclimate comparison of control, tracker, tree areas (averages on three sites)

Table 2. Microclimate measurements

Site A			Means	Means	Means	Grouping by dunn pairwise comparison		
			Whole period	Afternoons	Hot days	Whole period	After-noons	Hot days
Temperature (°C)	0cm	Control	20,5 ± 5,0	22,7 ± 4,5	28,4 ± 3,6	a	a	a
Temperature (°C)	0cm	Tracker	18,8 ± 3,9	19,3 ± 2,9	22,6 ± 2,4	b	b	b
Temperature (°C)	0cm	Tree	18,2 ± 3,3	19,2 ± 2,8	22,5 ± 2,5	c	c	b
Temperature (°C)	40cm	Control	20,4 ± 4,7	22,4 ± 4,0	27,6 ± 3,0	a	a	a
Temperature (°C)	40cm	Tracker	19,1 ± 3,8	20,2 ± 3,1	24,2 ± 2,5	b	b	b
Temperature (°C)	40cm	Tree	18,7 ± 3,6	19,7 ± 3,1	23,8 ± 2,6	c	c	c
Hygrometry (%)	0cm	Control	77,9 ± 12,7	73,8 ± 13,0	64,6 ± 11,6	a	a	a
Hygrometry (%)	0cm	Tracker	79,3 ± 12,1	79,4 ± 10,9	72,1 ± 10,1	b	b	b
Hygrometry (%)	0cm	Tree	79,9 ± 10,0	77,1 ± 9,5	70,7 ± 8,0	c	c	b
Hygrometry (%)	40cm	Control	69,5 ± 13,6	63,9 ± 12,1	54,2 ± 7,6	a	a	a
Hygrometry (%)	40cm	Tracker	73,4 ± 11,6	69,9 ± 10,0	62,0 ± 7,6	b	b	b
Hygrometry (%)	40cm	Tree	72,0 ± 11,8	68,2 ± 10,7	59,4 ± 8,3	c	c	c
Radiation ($W.m^{-2}$)	1m	Control	298 ± 257	450 ± 242	600 ± 251	a	a	a
Radiation ($W.m^{-2}$)	1m	Tracker	118 ± 116	142 ±	124 ± 73	b	b	b
Radiation ($W.m^{-2}$)	1m	Tree	66 ± 60	85 ± 47	76 ± 33	c	c	c

Site B			Means	Means	Means	Grouping by dunn pairwise comparison		
			Whole period	Afternoons	Hot days	Whole period	After-noons	Hot days
Temperature (°C)	0cm	Control	23,0 ± 4,9	24,7 ± 4,4	30,0 ± 2,9	a	a	a
Temperature (°C)	0cm	Tracker	21,1 ± 3,7	21,7 ± 3,1	25,2 ± 2,5	b	b	b
Temperature (°C)	0cm	Tree	21,2 ± 3,6	21,8 ± 3,3	25,3 ± 2,7	c	c	c
Temperature (°C)	40cm	Control	22,3 ± 4,4	23,7 ± 4,0	28,5 ± 2,7	a	a	a
Temperature (°C)	40cm	Tracker	20,9 ± 3,6	21,7 ± 3,2	25,3 ± 2,6	b	b	b
Temperature (°C)	40cm	Tree	21,1 ± 3,6	21,7 ± 3,3	25,2 ± 2,7	c	c	c
Hygrometry (%)	0cm	Control	63,2 ± 17,5	58,7 ± 16,8	43,7 ± 8,4	a	a	a
Hygrometry (%)	0cm	Tracker	67,7 ± 15,5	65,8 ± 14,3	54,2 ± 8,3	b	b	b
Hygrometry (%)	0cm	Tree	66,7 ± 14,9	64,1 ± 13,6	53,1 ± 8,6	c	c	c
Hygrometry (%)	40cm	Control	63,9 ± 16,7	59,7 ± 15,6	45,5 ± 8,5	a	a	a
Hygrometry (%)	40cm	Tracker	67,5 ± 15,0	65,0 ± 13,6	53,5 ± 8,8	b	b	b
Hygrometry (%)	40cm	Tree	67,8 ± 13,0	65,6 ± 11,9	56,1 ± 8,0	c	c	c
Radiation ($W.m^{-2}$)	1m	Control	323 ± 280	501 ± 263	655 ± 209	a	a	a
Radiation ($W.m^{-2}$)	1m	Tracker	142 ± 102	181 ± 83	146 ± 81	b	b	b
Radiation ($W.m^{-2}$)	1m	Tree	88 ± 65	103 ± 46	100 ± 56	c	c	c

Site C			Means	Means	Means	Grouping by dunn pairwise comparison		
			Whole period	Afternoons	Hot days	Whole period	After-noons	Hot days
Temperature (°C)	0cm	Control	22,9 ± 5,3	25,3 ± 4,9	29,8 ± 2,9	a	a	a
Temperature (°C)	0cm	Tracker	20,3 ± 3,3	21,1 ± 2,6	23,2 ± 1,8	b	b	b
Temperature (°C)	40cm	Control	20,0 ± 5,3	22,1 ± 4,6	27,2 ± 3,1	a	a	a
Temperature (°C)	40cm	Tracker	18,9 ± 4,5	20,1 ± 3,8	24,2 ± 2,5	b	b	b
Hygrometry (%)	0cm	Control	71,4 ± 17,6	65,7 ± 17,4	51,6 ± 6,8	a	a	a
Hygrometry (%)	0cm	Tracker	77,0 ± 13,5	75,1 ± 11,8	66,9 ± 6,3	b	b	b
Hygrometry (%)	40cm	Control	69,1 ± 15,5	63,0 ± 14,0	51,8 ± 9,7	a	a	a
Hygrometry (%)	40cm	Tracker	71,5 ± 15,1	67,3 ± 13,1	57,4 ± 9,5	b	b	b
Radiation ($W.m^{-2}$)	1m	Control	328 ± 288	507 ± 275	689 ± 207	a	a	a
Radiation ($W.m^{-2}$)	1m	Tracker	143 ± 103	183 ± 73	163 ± 71	b	b	b

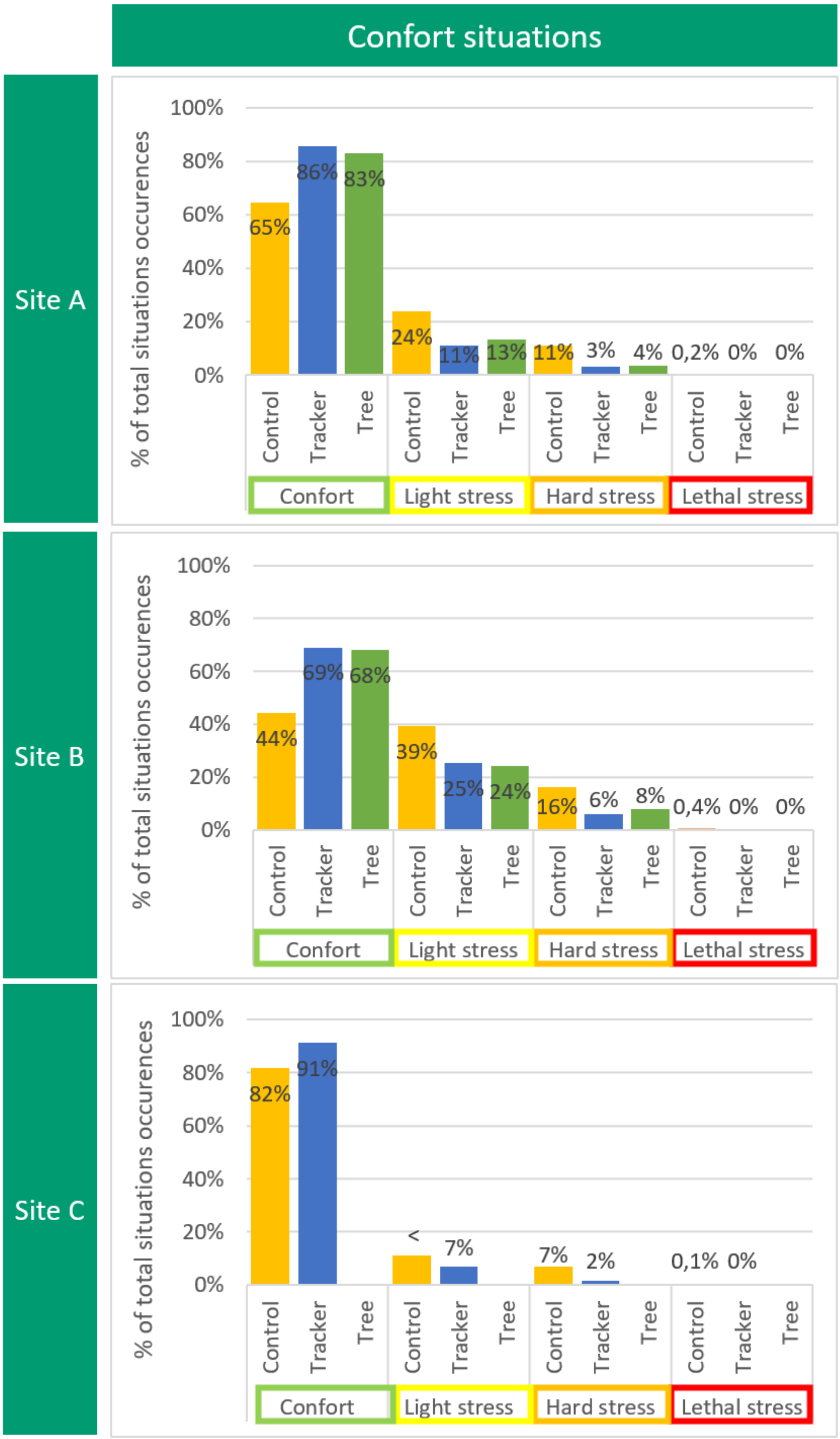

Figure 5. Comfort situations occurrences in each area and each experimental site

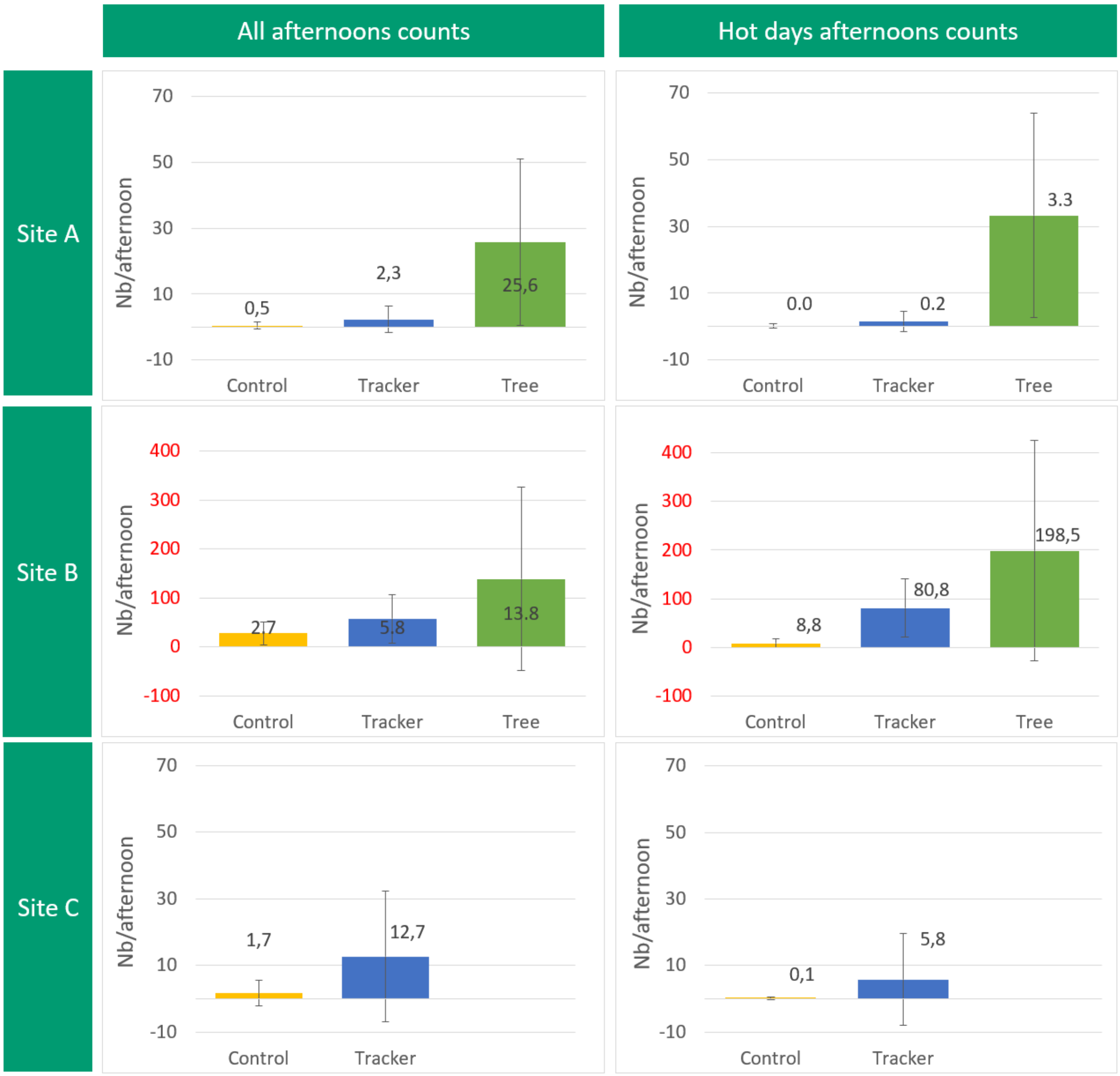

Figure 6. Laying hens cumulative counting in each area and each experimental site


Figure 7. Pictures illustrating the laying hens attraction for the shadow border

6. Author contributions

Author 1: Paul-Emile Noirot-Cosson

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☐ Data curation
☒ Formal Analysis
☐ Funding acquisition
☒ Investigation
☒ Methodology
☐ Project administration
☐ Resources
☐ Software
☒ Supervision
☐ Validation
☒ Visualization
☒ Writing – original draft
☒ Writing – review & editing

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☒ Methodology
☒ Project administration
☐ Resources
☐ Software
☒ Supervision
☐ Validation
☒ Visualization
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☐ Writing – review & editing

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First developer of the ideas and formulator of the research aims
☐ Data curation
☐ Formal Analysis
☐ Funding acquisition
☐ Investigation
☒ Methodology
First developer of the experimental design
☒ Project administration
☐ Resources
☐ Software
☐ Supervision
☐ Validation
☒ Visualization
☒ Writing – original draft
☐ Writing – review & editing

Author 4: Tanguy Riou

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☐ Funding acquisition
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☐ Methodology
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☐ Resources
☒ Software
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☐ Validation
☒ Visualization
☒ Writing – original draft
☐ Writing – review & editing

7. Competing interests

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

8. Data availability statement

Data can be requested by contacting the authors.

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