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Interactive comment on "Rain concentration and sheltering effect of solar panels on cultivated plots" *by* Yassin Elamri et al.

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Authors: We thank the reviewer for his/her constructive remarks that will be considered in the revised version.

R2: I have some comments:

1. It will be interesting to see how the heterogeneities develop with random positioning of solar panels during rain events. I would imagine leaving the panels in random positions during rain storms should decrease the spatial heterogeneity of water distribution. If the panels stop moving when the rain starts, they will be at different positions during different rainfall events. This is something worth considering (and more energy efficient).

Authors: This is an interesting suggestion. This could indeed decrease the heterogeneity at the plot scale and on the long term, e.g. when considering an annual balance. In the case of agrivoltaism, the objective is to limit the impact of panels on crop growth, so it is preferred: 1- to minimize the heterogeneity for each event, using the avoidance strategy which is also energy efficient 2- if irrigation is necessary, to adapt the irrigation amount to the actual needs, considering that different depths would be necessary in different zones considering the effect of rain distribution. In the Mediterranean, it is frequent that rainfall events are spaced by several weeks, so random position may not guarantee global homogeneity during the cropping season. We will add a remark about this suggestion, which could be relevant in some contexts (more frequent rainfalls, no irrigation).

R2: 2. Is there energy expenditure/cost for the avoidance strategies described in the manuscript? It will be great if the authors could discuss about this. Are there any other cheaper water redistribution strategies? I feel like retrofitting the panels with some sort of water harvesting structures to redistribute rain might be a cheaper than installing tracking pv panels. Most of the existing solar installations are fixed ones.

Authors: The cost of operation is very low compared to the energy produced by panels. Trackers were installed initially to control radiation. This has become quite common for solar farms, considering that the cost of trackers is largely covered by the gain on electricity production. In the case of agrivoltaism, trackers allow controlling radiation received by crops. Therefore, trackers are not only justified by the rain strategy, but the presence of trackers allows implementing advanced control strategies at almost no cost. Rain harvesting is indeed an idea that could reveal to be interesting is some regions. It needs collecting and storing water, which appeared too costly in our climatic context. A remark will be added on this point.

R2: 3. How does the avoidance strategies affect the dust management /or cleaning of PV panels. The dust accumulation on solar panels is an key factor affecting power output and often the periodic rains are very effective in keeping the panels clean. This is something to consider along with managing the rain-water intercepted by panels.

Authors: This issue was not considered. We think that the avoidance strategy would favor the cleaning of panels: they are only moved after an amount of 0.2mm, then the panels have a maximum inclination of 50°. The threshold of 0.2mm appears quite low and could raised at a value selected by experience. A remark about this suggestion will be added in the final version.

R2: 4. Discuss other factors like shading by panels, that may be more important for crop production than spatial heterogeneity of water distribution in crop fields. Shading can- not be controlled as the panel need to face the sun, while water availability could be managed easily by providing additional irrigation. It would be great if the authors could discuss more on the relative role of these two factors. In arid and semi-arid regions, the redistribution of water could be an important factor compared to shading by panels. In fact, in extremely arid regions the crops might benefit from shading.

Authors: We fully agree with the reviewer. These factors are analyzed is a separate paper under review (so, not referenced here). Different strategies can be applied during rainfall events compared to the normal strategy (which are electricity- or crop-oriented strategies). We realized that hydrological heterogeneity was high in our Mediterranean context (with characteristics of semi-arid climate), so it was important to characterize this heterogeneity and its link to panel operation, and, in turn, to derive a model predicting rain distribution under movable panels. This led to design the avoidance strategy that applies only during the rain events. The other points developed by the reviewer need specific instrumentation to understand the effect of radiation variations on crop evapotranspiration, and specific developments to adapt classical water balance models to the conditions imposed by solar panels. AVrain model will be an input of the crop-water balance model, but other adaptations will be needed regarding crop development and water consumption. Obviously, this must be treated in a separate paper.

R2: 5. Do the avoidance strategies or controlling the panels to optimize water distribution impact evapotranspiration from the cropped area?

Authors: The avoidance strategy is followed only during rainfall events. The evaporation rates are low during these periods, since radiation reduces to diffuse radiation. Therefore, evapotranspiration will remain low whatever the control strategy. Once rainfalls have stopped, other strategies are applied (e.g., solar tracking).

R2: 6. Is there a degree of error that is caused by the diameter of the tipping bucket? I feel that 30 cm width for one point of measurement might cause too big of a mesh when trying to characterize the rainfall distribution of a panel that is 1 to several meters wide at most.

Authors: The size of the buckets was selected to characterize the overall heterogeneity of the amount of rain received by the soil. Due to redistribution in the soil (see section 3.3) and to the sensitivity of the phenomenon to inherently dispersed factors (wind velocity and drop size), we considered that it was not meaningful to characterize the heterogeneity at a smaller scale. However, following the reviewer's suggestion, we checked that the conclusions about overall heterogeneity (and the relative importance of the 5 zones as defined in attached (Figure 1) were robust.

Obviously, the maximum rain amount depends on the size of the bucket, but the overall heterogeneity is weakly influenced by this size (here Cv around 2.3 for 30cm, 2.8 for 10cm).

R2: 7. For Table 3 and Figure 11, it might be helpful to include the porosity of the soil so that the volumetric water content can be viewed in context of relative saturation of the soil.

Authors: The porosity will be included in the figure and in the legend of Table 3

R2: 8. The word "weak" is used too often where the words "low" or "small" may be more appropriate.

Authors: We replaced “weak” as suggested by reviewer

R2: 9. It will be great if the authors could discuss the applicability of this study to other locations, in particular in dryland regions where most of the large solar installations are sited. Further, most of the existing solar installations are fixed ones.

Authors: The AVrain model is based on a mechanistic approach, so it is predictive, and fully applicable to any other context, especially in areas with high radiation (and large rain intensities). The model can be applied to fixed panels too. For such panels, a small width and an inclination of 20° will be recommended in order to avoid excessive intensities at the panel borders. Of course, the avoidance strategy may be adapted, as discussed above, although we think that, in the case of agrivoltaism (say, solar panels with an objective of crop production), avoidance strategy is the most appropriate in order to avoid undesired crop yield variability. Note that agrivoltaism is a quite new concept (Dupraz et al. 2011), justified by the search of areas to produce electricity without competing with food production. It raises new questions, but it also brings references that may be useful to more traditional solar farms.

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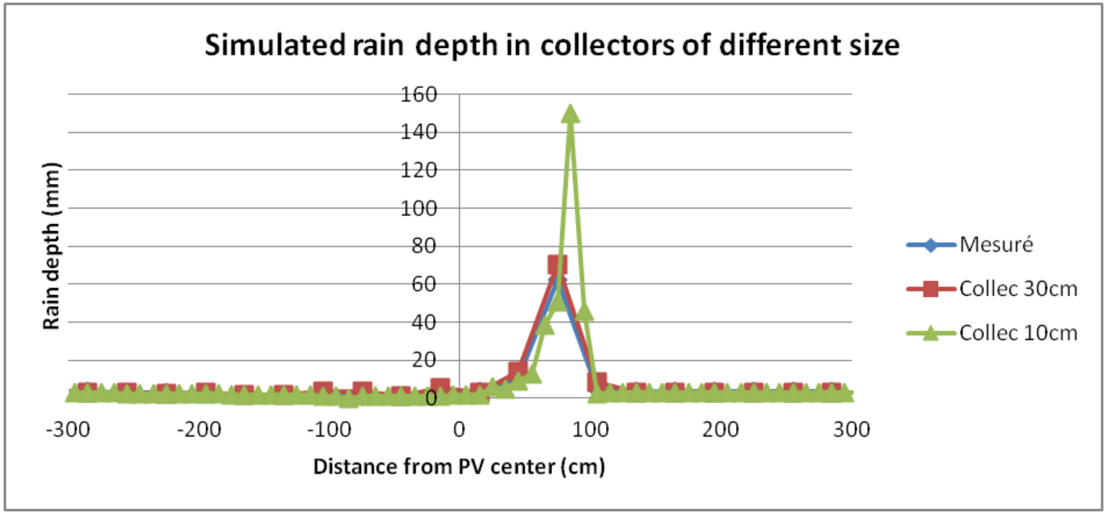

Fig. 1. Sensitivity of the model to the collector size (simulations with 10 and 30cm), measurement with 30cm

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Discussion paper