Protecting Kent's Countryside

National Infrastructure Planning
Cleve Hill Solar Park
CPRE Kent (Reference 2002146)

Written representation:
HYDROLOGY AND SOIL MICROCLIMATE

Introduction

Photo-voltaic (PV) power generation, as proposed at Cleve Hill, is recognised as a practicable land-based renewable option, but its adoption has the potential to change the ground-level microclimate to an extent that can affect the fundamental plant-soil processes that govern the carbon-capture dynamics of the development site. This can lead to an overall reduction in carbon-sequestration capacity to set against the advantages gained by increased local power generation.

Soil constitutes the largest single store of terrestrial organic carbon: containing more than vegetation and the atmosphere combined. Biological plant-soil processes regulate much of the terrestrial cycle and thus govern soil carbon storage, and release of greenhouse gas emissions of CO_2, CH_4, and N_2O. There is a risk that large areas of productive arable farmland and grazing, with its natural capacity for carbon capture, will be lost in order to secure a disproportionately small gain in net power output.

There are few references to studies dedicated to the impact of solar technology on *wetland* hydrology. Those that are quoted (below) deal, for the most part, with site-preparation and installation works, and are therefore confined to the early years of the life of a scheme. These, however, also serve to highlight some issues of special concern, including soil compaction by heavy plant and, in the case of Cleve Hill, under-lain as it is by alluvium and clay, the panning and water-logging of the soil profile with its implications for long-term soil quality and biodiversity throughout the 480ha of productive farmland.

There will also be long-term implications, with building development in Kent already forecast to cover significant areas of land over the next 25 years. As the panels will be a long-term feature in the landscape, they will result in a loss of a valuable agricultural resource.

The following sections feature summaries of two studies relating to the impact of PV solar power development on wetland sites, and in particular, the implications for the UK commitment to the control of global warming.

Solar in Wetlands: Vermont Department of Environmental Conservation[1] –

This paper (referred below) addresses the impact of siting of solar panels on wetlands and wet meadows. It outlines a project led by the Vermont Department of Environmental Conservation,

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[1] Solar in Wetlands: Vermont Dept of Environmental Conservation – Mason et al, Spring 2016

focusing on the possible consequences of the loss of these natural assets in sustaining carbon sequestration.

In response to rising concerns about the seemingly rapid expansion of solar technology on greenfield sites, the Department was tasked with deciding whether, or not, the development of PV on wetlands or wet meadows should be promoted. The findings are relevant in the assessment of the Cleve Hill proposal, where the perceived benefit in the form of 'green' solar energy could be off-set, at least in part by a loss of carbon-control capacity.

There are studies in hand with regard to on the impact of solar fields, but many outstanding questions remain with regard to their installation and maintenance; as well as particular concern that solar projects will continue to have their impact on wetland eco-systems, long after de-commissioning.

Wind farm and solar park effects on plant-soil carbon cycling: uncertain impacts of changes in ground-level micro climate[2]

In this study the authors emphasise that while land-based solar generation is rapidly expanding, our understanding of the operational impact on bio-carbon cycling is limited. Photo-voltaic panels can significantly change local ground-level climates to a degree that can affect the fundamental plant-soil processes that govern carbon dynamics. It is therefore essential that the exact nature and extent of these changes in microclimate is understood, in order to evaluate the balance of costs and gains in renewable energy.

With the prospect of a substantial global increase in solar generation, there is as yet limited knowledge on the corresponding changes in micro-climates and their influence on the processes that govern plant-soil carbon cycling and storage.

These factors under-pin food and timber production, water purification and nutrient retention. Ground-mounted PV arrays also have the potential to affect albedo - cause shading, intercept precipitation and influence wind speed and turbulence at ground level – as explained at Appendix 1 to this representation (Direct Insolation Measures for Cleve Hill).

Soil moisture and water table depth also have a strong influence, with productivity and decomposition to CO_2 increasing with soil moisture, albeit with an upper threshold, above which, rates decrease – reflecting the response of different plant species to variations in soil moisture. Soil carbon sequestration may also increase or decrease, with decreases more likely in regions of relativity low solar radiation.

With regard to indirect effects on soil carbon cycling the conclusion is that over a period of 20-25 years we should expect changes in vegetation, and hence, a corresponding change in carbon cycling and sequestration. There is evidence that the influence of plant functional type on carbon cycling can be greater than climatic effects. Different albedos and transpiration rates are associated with different plant types and this may affect soil moisture, which is a strong carbon cycle control component.

Changes in the soil microbial community can also be significant as components of terrestrial carbon cycles in the uptake of atmospheric CO_2 and CH_4, and the release of these gases through respiration

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[2] Wind farm and solar park effects on plant-soil carbon cycling: uncertain impacts of changes in ground-level micro climate - A. Armstrong, S. Waldron, J. Whitaker, N. J. Ostler, 16 October 2013

and methane output. The soil microbial community is also influenced by changes in the plant community (and vice-versa). As a general case, increased CO_2 brings increased soil carbon. Numerous studies have examined the inter-action of temperature and soil moisture, which are the two variables governing productivity and decomposition. For example, warmer and drier conditions have been associated with increased respiration relative to production across a range of biomes. Other factors cited include:

- nutrient status of the soil (NKP)
- soil carbon sequestration under elevated CO_2
- trees more responsive than herbaceous species to increases in CO_2 concentration
- micro-climate influence on carbon sequestration may also be tempered by plant acclimatisation.

There is also a need to determine the long-term operational impact of solar power generation on plant and soil carbon. The authors' advocate investigation of solar panel options on the following lines:

- field assessment of the effects of solar park installations on the local climate (with potential for remote sensing);
- field experiments in carbon-relevant hosting ecosystems to examine the effects of solar power – influenced microclimates on plant-soil carbon cycling in-situ;
- controlled environmental studies examining the interactive effects of diurnal seasonal and annual microclimatic controls on plant-soil carbon cycling; and
- modelling that uses mechanistic understanding from field and laboratory studies to upscale and forecast effects of land-based solar power generation on carbon cycling and greenhouse gas emissions.

CPRE Kent notes that the authors' proposed further field study addresses the increasingly urgent need for a comprehensive assessment of the hydrological implications of the solar panel array at Cleve Hill. The programme should cover a period of at least three years in order to secure an approximation to the long-term average annual water balance for the site.

Summary and conclusions

There are concerns that the proposed solar PV panel array could change the vegetation and other natural characteristics of the Cleve Hill soil profile, to a degree that could significantly reduce its capacity for carbon-capture. This, coupled with the loss of 480ha of increasingly scarce grazing and productive arable land, would need to be set-against the relatively small gain in power generation that could, in any event, be secured from other, less environmentally vulnerable sources.
The proposed field study should set out how much natural capacity for carbon-capture will be lost at Cleve Hill. This will no doubt, attract comment from the Committee on Climate Change[3], who state: "The UK should set and vigorously pursue an ambitious target to reduce greenhouse gas emissions to 'net zero' … within 30 years", insofar as it could be seen to be at odds with the UK commitment to compliance with the provisions for control of global warming under the Paris Accord.

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[3] Net Zero: the UK's contribution to stopping global warming. Committee on Climate Change, - https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/ May 2019

Direct Insolation Measures for Cleve Farm

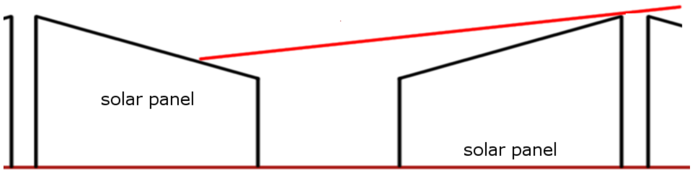
Peter Blandon B.Sc. M.Phil. Ph. D.

Introduction

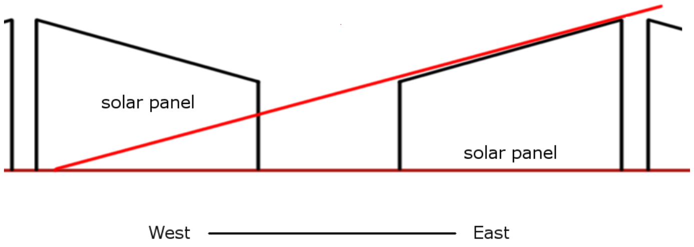
It is proposed to set aside some land within the Cleve Farm development for environmental purposes. However, it is still useful to look at what is likely to occur over most of the site where the ground will be predominantly covered by solar panels. This report looks at the levels of sunlight that will reach the areas between and under those panels.

Basics

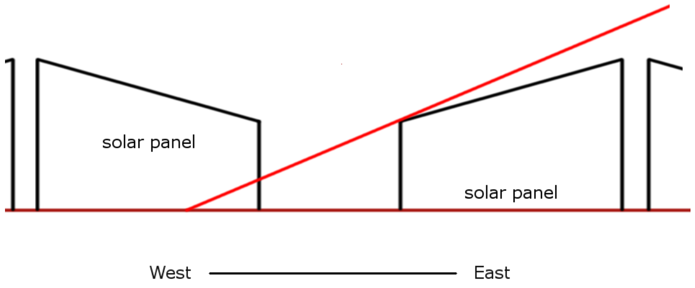
As the sun moves, so the shadows cast by the solar panels will move. There are four basic shadow patterns which are considered here.



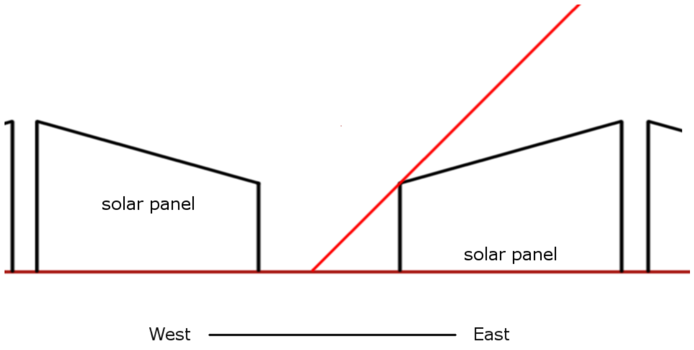
Shadow Pattern 1. Early in the day, or late in the evening, the sun will be so low in the sky that the upper ridge of the array effectively shades out not only the ground between the panels but also the ground beneath them.



Shadow Pattern 2. Later in the morning, or earlier in the evening, the upper ridge does not cast such a long shadow and the light is allowed to fall on the ground opposite. Where it falls depends on the panel dimensions but in the diagram here it illuminates part of the ground under the panels opposite.



Shadow Pattern 3. At higher angles, the upper ridge of the array does not obstruct the sun, and the shadows are formed by the lower edge. Here, the sun continues to illuminate only the ground under the panel opposite.



Shadow Pattern 4. Finally, the sun is sufficiently high in the sky to illuminate the ground in the gap between the panels.

The length of shadows and the angle of illumination both influence the light intensity across the site. An example at one of the equinoxes is presented below.

An example at the equinox

In the following section the assumption is made that the height at the ridge of the solar panel array is 3.9 metres, the lower end of the panels is 2.1 metres high, the gap between panels is 2.5 metres and runs north-south. The depth (east/west) of the panels is 12 metres from lower end to ridge.

Shadow patterns

At the equinox the sun rises at around 6am and sets 12 hours later (approximately). As it moves from east to west it will illuminate different parts of the ground in a given array. Figure 1 shows the shadow pattern for the longitude and latitude of Cleve Farm.

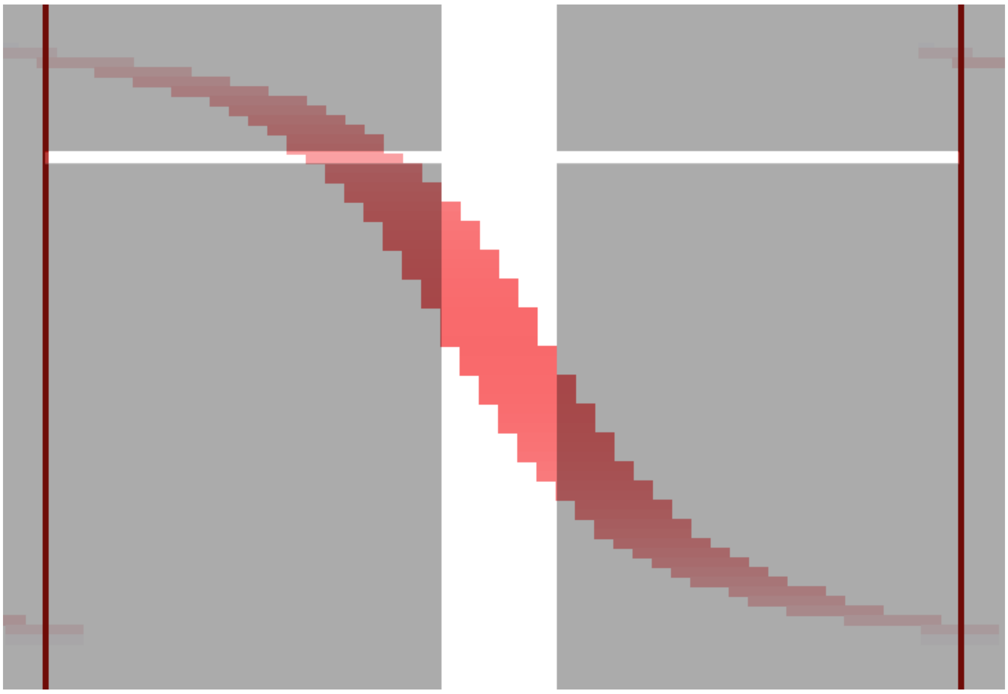


Figure 1 Shadows during the day at equinox

The diagram is based on a plan view of two neighbouring panels. The grey areas represent the solar panels and the vertical white strip is the gap between the lower ends of adjacent panels. The red, vertical lines are the pitch of the solar arrays. North is at the top of the figure.

The "*y*-axis" in Figure 1 represents time, with the top of the diagram showing the situation at sunrise and the bottom of the graph sunset[4]. The white horizontal strip across the diagram is the situation at 9am. The diagram shows that, at this time, the sun being in the east will illuminate an area under the solar panel to the west, indicated by the red area. This is a case of "Shadow Pattern 3" with the lower end of the solar array creating a shadow

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[4] The jagged form of the red, illuminated area derives from the fact that the calculations for the shadow length were carried out over ten-minute intervals.

Interpreting the whole diagram in this way, it is clear that in the early and late part of the day (top and bottom of diagram) no area is in sunlight as the sun is too low in the sky – this is Shadow Pattern 1 above. Moving down the diagram, at seven o'clock some of the area to the rear of the panel on the west (left) is receiving light – Shadow Pattern 2 above. Note that in Figure 1 part of the illuminated area at this time (and in the late part of the day) is beyond the ridge line and, therefore, under the next panel. Thus, in the morning, part of the panel in the east receives sunlight coming from under the panel to the west– as indicated by the red area in the top right of the diagram.

As time progresses and the sun gets higher, the illuminated area moves closer to the open space and, fairly quickly in this case, the shadow pattern moves to Pattern 3 above. Finally, Shadow Pattern 4 is reached when the gap between the panel begins to receive light. Here this occurs at around 9:50am. At noon the sun is in the south and so is shining directly up the gap between the panels. This area is fully illuminated but no light penetrates below the panels.

After noon the sun moves to the west and the process repeats itself but with the shadow and sun orientation being reversed.

Sunshine hours

In Figure 1 the strip of land in the middle of the gap between the panels (the centre of the white strip), is potentially in sunlight for 2 hours and 20 minutes. This represents about 19% of the potential sunlight that it would receive with no shading (2.3 hours divided by 12).
This idea is developed in Figure 2. Here the horizontal axis shows the position between or under the solar panels, with zero being the point in the middle of the gap between the panels. As the length of the panels (in the east/west direction) is 12 metres from lower edge to ridge, the points on the axis of 12 and minus 12 are the ridge lines. The grey part of the graph represents, therefore, the area under the panels.

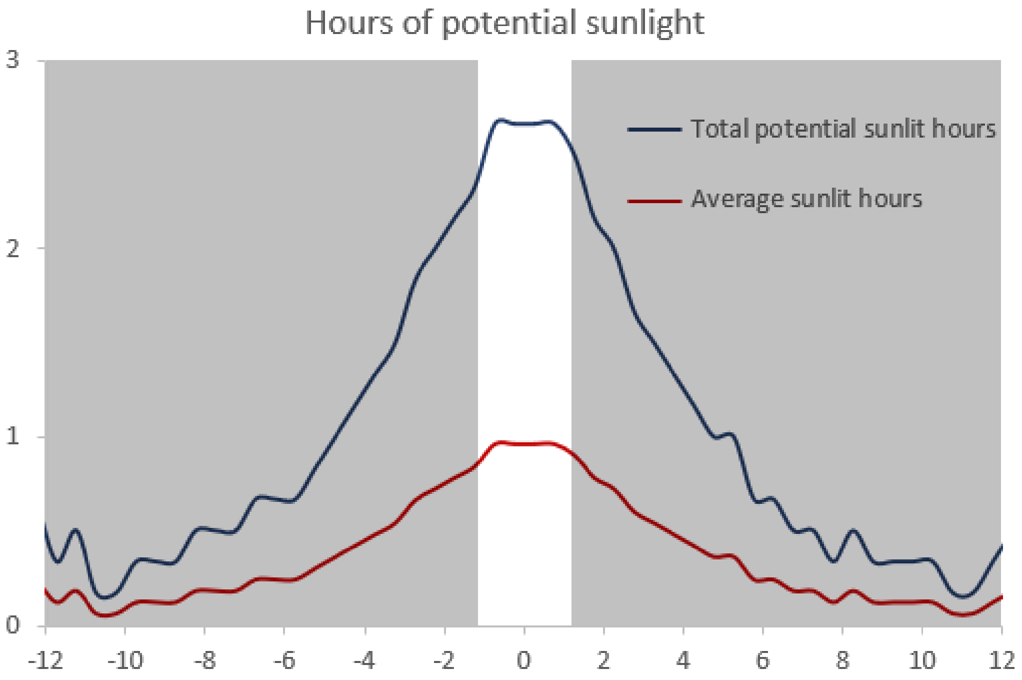

Figure 2 Sunlight between and under panels

As Figure 1 showed, the areas near the ridge receive light in the early morning and late evening and also light from under the neighbouring panels and this accounts for the upturn in the number of sunlit hours towards the edge of the panels at around 11 and minus 11 metres from the centre.

The figures shown by the blue line and labelled “potential sunlit hours” would only be observed if there were no cloud throughout the day. The actual hours of sunlight will be less, depending on the degree of cloud cover. Figures for England suggest that the average daily sunshine for December, March/September and June are as follows.

- December – 1.77 hours – (about 26% of the total daylight hours)
- March/September – 4.34 hours – (about 36% of the total daylight hours)
- June – 6.4 hours – (about 39% of the total daylight hours)

When the figure for the equinox is included in the calculations, the average sunlit hours in Figure 2 shown by the red line are the result. The central gap will receive, on average, one hour of actual sunshine and the areas under the panels significantly less.

The effect of ridge height is shown in Figure 3. Lower ridge heights (and therefore lower heights at the other end of the panel as the drop is assumed constant at 1.2 metres) mean that more sunlight is received in the gap between the panels but under the panels the illumination drops off more quickly.

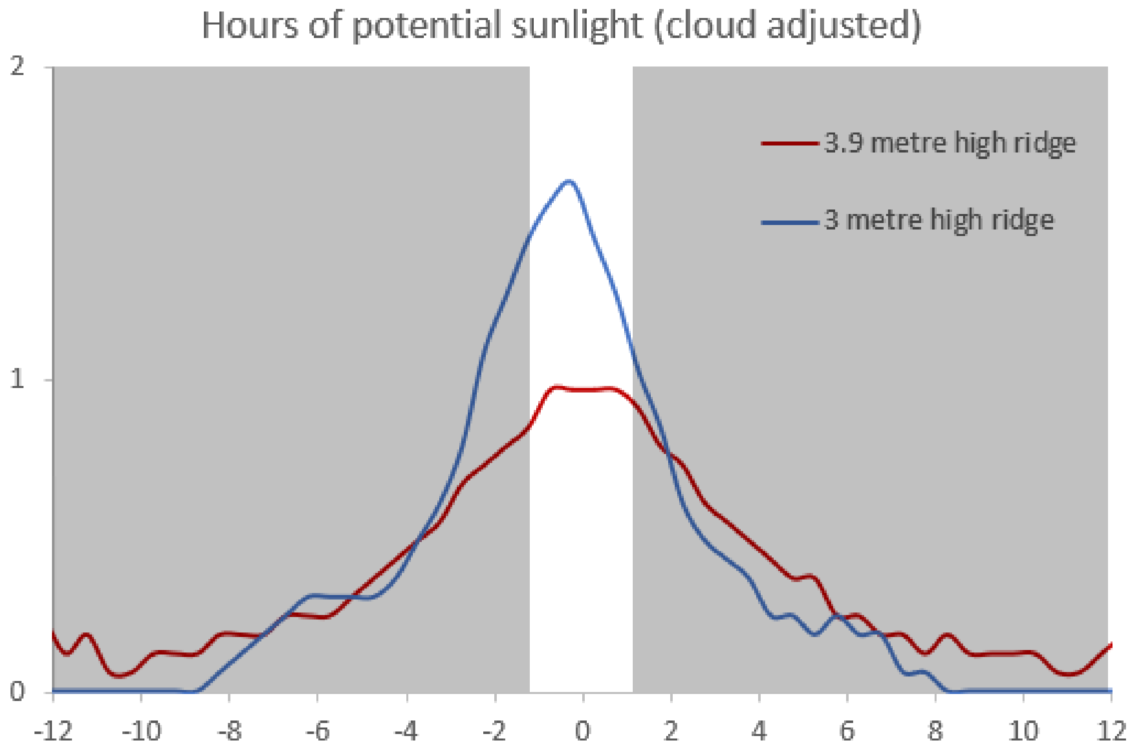

Figure 3 Effect of ridge height

The gap between the panels – *i.e.* the white space in the figures – was set at 2.5 metres in the calculations above. Obviously, if the panels are set further apart more sunlight will reach the ground but the number of panels that can be fitted into a given area will be reduced. Figure 4 shows the sunlight, adjusted for cloud, that falls on the ground for three different panel gaps. The assumption here is that the ridge height is 3 metres. As expected, the greatest amount of sunshine is associated with the widest gap.

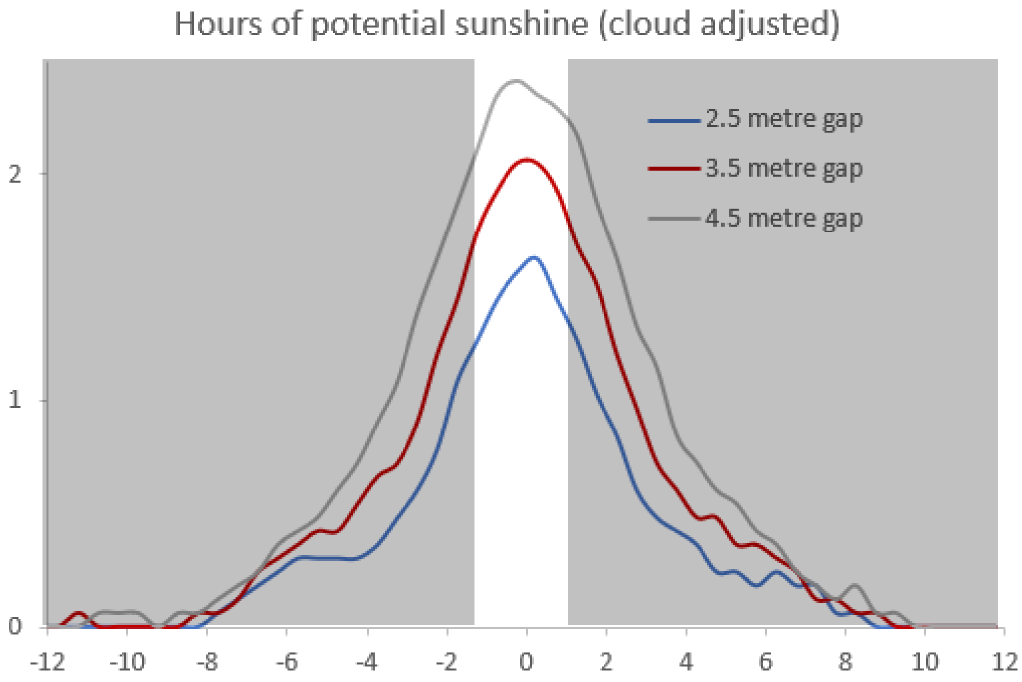

Figure 4 Effect of gap between panels

Relative potential insolation

Plant growth depends on the energy received from the light. Light early or late in the day impinges on the ground at a lower angle than that at noon and so the energy is dissipated over a wider area. Thus, the energy available for photosynthesis on a square metre of ground will be greater at noon than at other times of the day. Therefore, the energy received by the ground in the "centre" of Figure 1 at the middle of the day will be greater than that at the top and bottom of the diagram. This means that the energy received by the ground in the gap between the panels – the white strip in the middle of the foregoing figures – will be greater per hour of exposure than that received under the panels.

To take this effect into account, the "direct insolation" measure in Equation 1 was used. It shows direct insolation (I_D), measured in kilowatts per square metre, on horizontal ground when the altitude of the sun is α degrees and the sky is cloudless.

$$I_D = 1 \cdot 353 \times 0 \cdot 7^{\left(\frac{1}{\cos(90-\alpha)}\right)^{0 \cdot 678}} \qquad (1)$$

The equation does not directly reflect the energy available for plant growth as this depends on the wavelength of the light. But it is a useful indicator of the energy available for photosynthesis. The equation gives "potential" insolation. The energy delivered by the sun will be lower in cloudy conditions.

Here a measure of "relative potential insolation" was used. For example, the strip of land in the middle of the gap between the panels (the centre of the white strip in Figure 1) is in sunlight for 2 hours and 20 minutes. As this is in the middle of the day the insolation is higher than it would be otherwise. The total insolation is around 2.2 kWh/m^2 compared to the total possible insolation of 7.4 kWh/m^2 if the land had been totally unshaded. The relative potential insolation for this piece of land is, therefore, 28.9%.

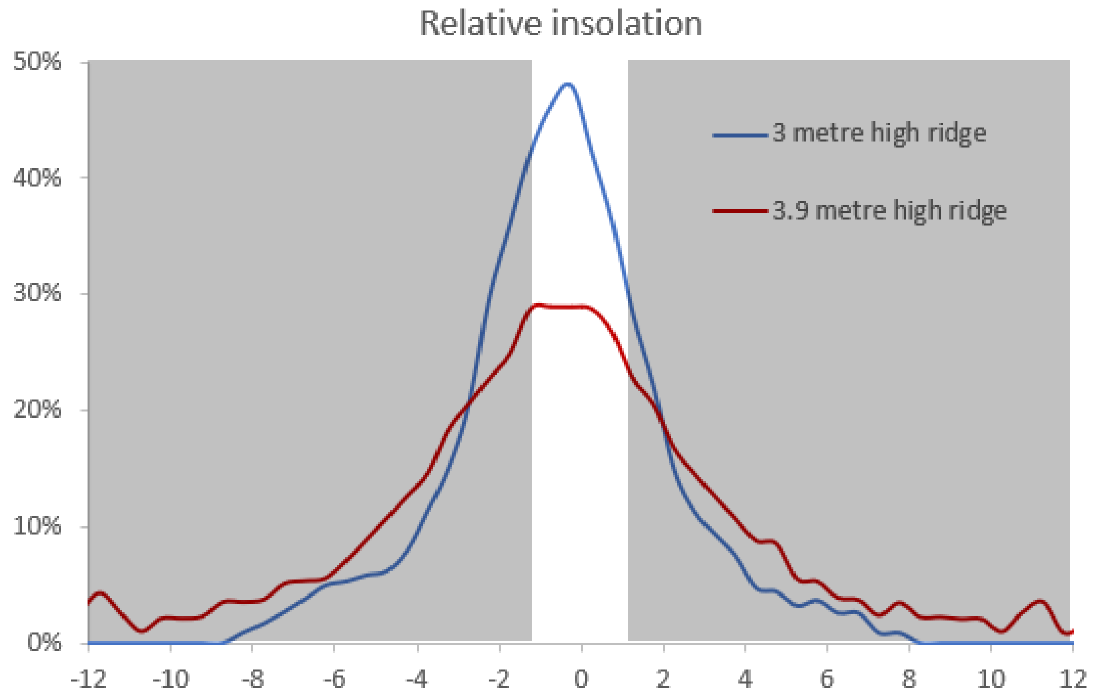

Figure 5 Relative potential insolation

The diagram above shows the percentage of total insolation falls on the ground across a solar array during the course of a day at the equinox. Looking at the case of a 3.9 metre high ridge, the centre of the gap between panels receives about 29% of total available radiation as it is sheltered for much of the day. The area under the panels receive considerably less. This is a combination of the fact that they receive less sunlight (see Figure 4) and that the sunlight that is received is less energetic as it impinges the ground at a lower angle.

As would be expected, a lower ridge height increases the energy received in the centre of the arrays but less is received, relatively speaking, under the arrays.

Equinox and solstices

The examples above all related to the equinox. It seems intuitive that more radiation and sunlight is received at the summer solstice and less at the winter solstice. This is supported by Figure 6 and Figure 7 – both of which are constructed on the assumption of a 3.9 metre ridge and a 2.5 metre gap.

Figure 6 shows the level of sunlight after cloud cover is considered. The red line in the diagram is the same as that in Figure 3. In winter the level of sunlight is very low, never exceeding 20 minutes. In summer, the central gap receives just over one-and-a-half hours of sun on average.

Relative insolation is less affected by season. The reason is that the measure is a relative one. The absolute level of insolation will be a lot less in winter but, relatively speaking, the gap between the panels receives between 23 and 33% of total available radiation through the year.

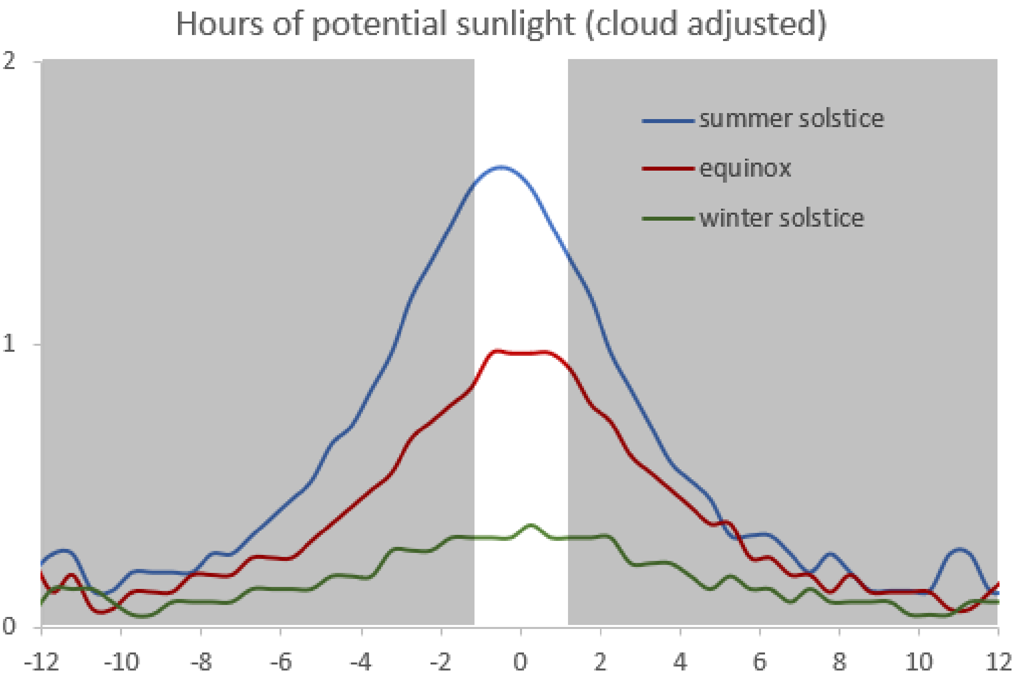

Figure 6 Effective sunlight through the year

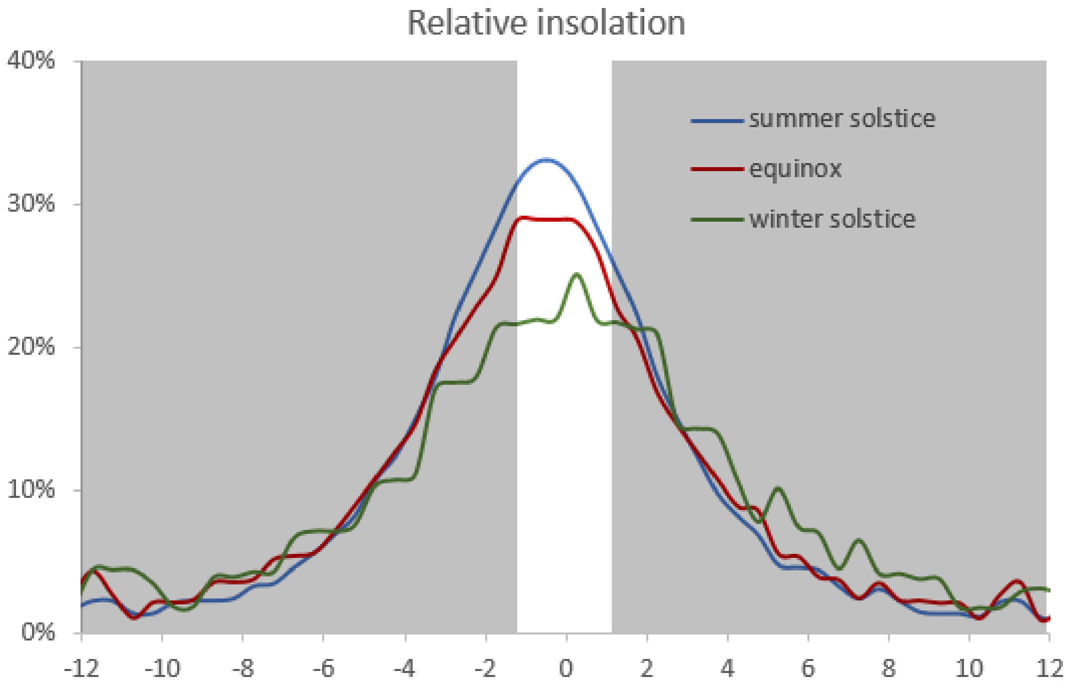

Figure 7 Relative insolation through the year

Related points

In interpreting the results above the following point must be borne in mind. Plant growth depends on photosynthesis which, in turn depends upon light. However, the relationship between photosynthesis and light is not a linear one. As a generalisation, photosynthesis increases with increasing light levels but then levels off when light levels reach a certain amount. This levelling off effect is also affected by temperature.

The reason for this is that photosynthesis requires a gas exchange between the atmosphere and the internal, porous structure of the leaves. Oxygen must exit and carbon dioxide must enter. This exchange is effected by the stomata which open to allow the gas exchange to occur. However, as the day progresses the stomata also allow water to be lost from the plant and, especially in high temperatures, this will cause the plant to be stressed. As a result, the stomata begin to close (although not fully in most grass species) and this has the collateral effect of reducing photosynthesis.

Thus, the light falling on the central gap, being of high intensity and at the warmest part of the day, will be less effective at promoting growth than the peaks in the graphs here suggest. Conversely, the light under the panels will be relative more effective.

Appendix

The basic data used were

Latitude of site	51 degrees 34 minutes North
Longitude of site	0 degrees 56 minutes East

Altitude and azimuth figures were taken from https://aa.usno.navy.mil/data/docs/AltAz.php

Dates used	Winter solstice (2019)
	Equinox (spring 2019)
	Summer solstice (2019)

Actual hours of sunshine were taken from the following web site.
https://www.metoffice.gov.uk/climate/uk/summaries/actualmonthly
The site gives monthly data and the figures chosen referred to December (for the winter solstice), the average of March and September (for the equinox) and June (for the summer solstice). The data series chosen was the "kernel smoothed figures."
Roughly tally with
https://www.pveducation.org/pvcdrom/properties-of-sunlight/calculation-of-solar-insolation