Agrivoltaics: Summary of research and recent UK projects

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Summary Research - location, types, general conclusions written in 2025 and updated in January 2026.

A number of literature reviews have been conducted to summarise research on agrivoltaics (Sirnik *et al.*, 2023; Chopdar *et al.*, 2024; Widmer *et al.*, 2024). From these reviews and from site specific studies, we can get a sense of the global span of agrivoltaics projects: predominantly Asia (especially Japan, China and Republic of Korea), Europe (especially France and Italy) and North America. Types of photovoltaic panels (PVPs) vary in terms of their mounting (for example stilt mounted, greenhouse mounted); their characteristics, e.g. orientation (tilted, vertical, dynamic, rotating, bifacial) or other design features that allow for more or less light to pass through (e.g. panels allowing for solar spectrum separation, or semi-transparent panels

Design Considerations

- A study on design considerations and performance indicators (Jain *et al.*, 2021)
- Technical, societal and environmental considerations and impact on design (Chopdar *et al.*, 2024)
- A simulated model for PVPs on greenhouses in the Mediterranean region, to identify ideal spacing for agrivoltaic greenhouse design (Torrente *et al.*, 2024)

Proof of concept in sunnier climates

Studies have been conducted in Turkey (Kallioğlu *et al.*, 2024), the Mediterranean region (Torrente *et al.*, 2024), Portugal (Ferreira *et al.*, 2024), Chile (Rodriguez *et al.*, 2024), Arizona (Barron Gafford *et al.*, 2019), and Brazil (Vidotto *et al.*, 2024). These contexts are generally characterised by high radiation levels and frequently by water stress. The increased shading and reduced evapotranspiration in the microclimate of the PVPs has been shown to be advantageous for some crops, particularly under hot and dry conditions.

Proof of concept in temperate climates

A study on rice, potato, sesame and soybean in the Republic of Korea showed potato has having the most potential for an agrivoltaic system (Lee *et al.*, 2022).
Another study looked at celeriac, winter wheat, potato and grass clover grown in an organic system in the Lake Constance region of Southern Germany. While all crops faced an overall reduction in yield under agrivoltaics, conditions became more favourable for potatoes and wheat under PVPs during a hot, dry year. (Weselek, Bauerle, Hartung, *et al.*, 2021) In temperate climates, the most suitable crops are those that are shade tolerant.

Photovoltaics and specific crops

One of the first studies was conducted on a prototype agrivoltaics site in Montpellier, France and looked at three cropping species and seasons- wheat, lettuce and cucumbers. The study explored the impact of PVPs on the microclimate at crop level (air temperature, air vapour pressure deficit and wind) as well as crop and soil temperature. Soil temperature was reduced under the shade of the PVPs, but growth rate and crop temperature was not significantly affected. The study recommends placing attention on the mitigation of light reduction and on selection of plants with a maximal radiation use efficiency in these conditions of fluctuating shade (Marrou *et al.*, 2013).
Since then, a variety of studies have looked at individual or multiple crops in particular locations grown under PVPs (both in greenhouses and in field agrivoltaics systems.
Here are a few initial results:

Vegetables

Lettuce shows mixed conclusions from a number of different studies (Widmer *et al.*, 2024)
Tomatoes show inconsistent results across various studies- partly explained by different crop varieties in studies and different climates (Widmer *et al.*, 2024).
Sweet peppers (in greenhouses) - two studies have looked at the cultivation of sweet peppers in greenhouses with PVPs mounted on the roof. Both show that growing conditions are favourable. In one study, the location is not revealed within the available content of the study (Kavga et al., 2019).

The other study (Zisis et al., 2019) takes place in the Mediterranean and mentions that the PVPs were semi transparent.
A study on ***peppers, tomatoes and lettuce*** grown outdoors in northern Colorado identifies no statistical yield reduction (Hickey, Uchanski and Bousselot, 2024)
Potatoes: results from two different studies on potatoes, conducted in Germany (Weselek, Bauerle, Hartung, *et al.*, 2021) and Korea respectively (Lee *et al.*, 2022) both showed that yields and quality were not seriously affected
Studies focussed on the following crops all showed no changes in yields when grown under PVPs: ***Soilless rocket*** in greenhouses (Buttaro *et al.*, 2024), ***celeriac*** (Weselek, Bauerle, Zikeli, *et al.*, 2021), ***cabbage*** (Moon and Ku, 2022), and ***broccoli*** (Chae *et al.*, 2022).

Cereals and grasses

One study conducted on an experimental farm in Japan shows that maize, a typically shade intolerant crop, produced higher yields and greater biomass under PVPs (Sekiyama and Nagashima, 2019).
Another study looked at various cereal, legume and vegetable crops in South Korea (Jo *et al.*, 2022) Although the rice, legume and vegetable crop trials were inconclusive, the maize and rye crops showed no negative impact as a result of growth under PVPs.
A further study looks at winter wheat in an organic production system in Southern Germany (Weselek, Bauerle, Hartung, *et al.*, 2021). It concluded that yield reductions under AV are likely, but under hot and dry weather conditions, growing conditions can become favorable.
A study based in the Czech Republic looks at the potential for agrivoltaics in combination with energy crops (miscanthus x giganteus) as a way of maximising energy generation from a specific locality (Janota *et al.*, 2023).

Orchards and Groves

A study on golden delicious ***apple orchards*** under PVPs in the south of France showed that in the first two years, yields were affected negatively but when heavy frosts came in third year, the panels reduced the impact of the frost and led to higher yields (Juillion *et al.*, 2022)
Another study looks at the location of PVPs in super intensive ***olive groves*** in the Mediterranean region, (Fernández-Solas *et al.*, 2023), identifying a potential to contribute a 2.5% increase in the global PV energy output by covering only 1% of the total olive growing surface area in the Mediterranean. A second study simulates different spacings of PVPs to identify ideal spacing for maximising oil production, or electricity generation, respectively (Varo-Martínez *et al.*, 2024).

Berries

Berries show potential as they are more shade tolerant (Weselek, Bauerle, Hartung, *et al.*, 2021) Strawberries in solar greenhouses in China showed an increase in yield and maximum weight (Tang *et al.*, 2020).
Research in the Netherlands on blueberries (tolerant at up to 50% shade), blackberries and blackcurrant (tolerant up to 35% shade). Strawberries showed more yield reduction under shade (Hermelink, Maestrini and de Ruijter, 2024).

Gaps in photovoltaics and crop research

While there is a continual increase in agrivoltaics studies, it still remains difficult to compare the installations correctly because they are all different in terms of their design and the choice of solar panels used, as well as different soil and climatic conditions, and different species and cultivars. Furthermore, few studies have looked at separation of light spectrum, which results in reduction of shading, allowing wavelengths necessary for photosynthesis to pass through (Widmer *et al.*, 2024).

Photovoltaics and animal pasture

Sheep grazing under PVPs is already common. This study presents the efficiency gains on land use in North America (Handler and Pearce, 2022).
A study on lamb production in Oregon showed that although herbage mass was reduced under pv panels, pasture quality was improved- resulting in similar lamb production to open pastures (Andrew *et al.*, 2021).
A study in Minnesota explored the impact of PVPs on a dairy flock. No differences in fly prevalence, milk production, fat and protein production, or drinking bouts were observed between the treatment groups. Notably, the cows in the study only spent 22 days between June and September under cover of panels. Nevertheless, the microclimate of the PVPs offers a reduction in the cows' exposure to heat stress which is more relevant in warmer climates and in heat wave conditions (Sharpe *et al.*, 2024)
One study makes a case for pasture-raised rabbits under PVPs as opposed to cattle as a way of optimising yields from agrivoltaics whilst minimising environmental damage (Lytle *et al.*, 2021)

Co benefits and side effects of agrivoltaics projects

- Study promoting agrivoltatics as part of a design that focuses on ecosystem services, e.g. increasing pollination (Semeraro *et al.*, 2022)
- Study showing a negative impact from PVPs on global navigation satellite systems necessary for precision agriculture(Vélez *et al.*, 2024)
- Study exploring the effect on the landscape and regional economy (Sirnik *et al.*, 2023)
- Study looking at socio legal frameworks in mature agrivoltaic sectors in Japan and Massachusetts offer guidance on how to take into account who benefits from agrivoltaics; what legal processes and mechanisms should be considered; and how recognition of existing and future agricultural activities should occur (Taylor *et al.*, 2023)
- A review of more than 50 studies concludes that more than 50% shading significantly affects plant growth (Widmer *et al.*, 2024).

Hydraulic aspects (Flood mitigation etc)

Hydraulic Response of Solar Farms - (Cook & McCuen, 2013)

PV farms potentially having a beneficial impact on flooding. Flood prevention photovoltaics – Irrigation Nets https://irrigationnets.com/en/flood-prevention-photovoltaics-3/

Guidance on mitigating flood risk of solar farms:
https://www.centralbedfordshire.gov.uk/info/44/planning/1096/solar_farm_development_flood_guidance and pdf presentation http://irrigationnets.com/wp-content/uploads/2021/09/Flood-Prevention-Photovoltaics-1.pdf

Fish farming under PV Short article

https://www.pv-magazine.com/2024/11/21/dmegc-solar-energizes-940-mw-solar-fishery-project/ no included in bibliography

Different levels of transparency and crop growth

- Paper on different levels of transparency and crop growth

https://www.pv-magazine.com/2024/08/22/the-impact-of-semi-transparent-solar-modules-on-agrivoltaics-yield/

Rules and regulations

New rules in Spain about spacing and food production
https://www.pv-magazine.com/2024/04/30/catalonia-sets-guidelines-for-agrivoltaics/

https://www.pv-magazine.com/2024/04/18/agrivoltaics-for-berries/

French rules on PV fields
https://www.pv-magazine.com/2024/04/09/france-issues-new-rules-for-agrivoltaics/

Other useful work

In Cochin, India ... grew vegetables https://www.prakati.in/kochi-airport-grows-vegetables-under-solar-power-plant/

Dezeen trial https://www.dezeen.com/2022/09/30/agrivoltaic-solar-farms-feature/

Vertical PV and farms article https://spectrum.ieee.org/agrivoltaics

Optimum tilt angle article https://www.pv-magazine.com/2024/01/18/optimal-tilt-angle-for-agrivoltaic-projects-in-mediterranean-region/

German research on movable field panels https://youtu.be/tvt9tg9oDDc?si=6jCGA2QCtp_-BAhz

Vertical panels https://www.pv-magazine.com/2024/01/23/us-startup-offering-ul-certified-vertical-pv-systems/

Australian article on Agrivolt https://www.pv-magazine-australia.com/2023/11/01/agrivoltaics-and-the-art-of-farming-under-cover/

Current summary of what is happing re A PV.
https://cleantechnica.com/2024/03/25/the-agrivoltaic-juggernaut-the-agricultural-revolution-of-the-21st-century/

And really interestingly...Some high-value crops like broccoli, leafy greens, peppers, strawberries, and blueberries thrive in reduced light conditions. One study found that cherry tomato production doubled under solar panels and water efficiency was 65% greater," SEIA noted in a blog post last November.

This test case in Houston, Alaska, for combining food farms and solar farms, a practice called agri-voltaics, was designed as a model for other communities seeking energy and food security. Europe, which has ambitious climate goals and limited land, has been exploring high-latitude agrivoltaics in recent decades, but this is the first American project on an industrial-scale solar array.

https://www.nytimes.com/2025/10/21/climate/alaska-solar-farm-food.html?unlocked_article_code=1.vU8.G66T.YgN6c-LE_X1r&smid=url-share

UK projects and useful contacts

The University of Lincoln ran an AV research site at the Sutton Bridge Crop Storage Research Facility (now shut down but data is available)–
Departmental weblink: https://www.lincoln.ac.uk/liat/ (last accessed 23.01.25)
Contact person: Dr Simon Pearson spearson@lincoln.ac.uk

The University of Sheffield has run an agrivoltaic research project across East Africa (and may also be exploring appropriateness of agri-PV for UK conditions although no further information is available at the moment)
https://www.sheffield.ac.uk/news/harvesting-sun-twice-agrivoltaics-shows-promise-sustainable-food-energy-and-water-management-east (last accessed 23.01.25)
https://www.sheffield.ac.uk/research/harvesting-sun-twice (last accessed 23.01.25)
Contact person: Richard Randle-Boggis, r.randle-boggis@sheffield.ac.uk

The James Hutton Institute conducted a trial agriPV project in Dundee.
Departmental weblink: https://www.hutton.ac.uk/scientific-services/research-collaborations/ (last accessed 23.01.25, no longer mentions agrivoltaics)
No current contact person

The University of Greenwich ran a Farming Innovation Programme study (launched in 2021) exploring agrivoltaics and berry growing in polytunnels, in collaboration with a Kent fruit farmer and solar company Polysolar Ltd https://www.gre.ac.uk/articles/public-relations/solar-panels-to-grow-food-thanks-to-250k-university-of-greenwich-project (last accessed 23.01.25)
Contact person: Dr Ellinor Thompson, e.thompson@gre.ac.uk

Westmill Solar Park (Oxfordshire) operates sheep grazing under PV panels. Solar farm is community owned and runs as a co-operative.
Weblink: https://westmillsolar.coop/ (last accessed 23.01.25)

Elements Green (public liaison provider for the 1GW Great North Road solar project in the East Midlands) have announced a deal that has been signed with local farmers for a flock of 4000 sheep to be grazed under panels that form part of the scheme https://www.solarpowerportal.co.uk/agrivoltaics-deal-to-bring-9000-sheep-to-1gw-solar-park/ (last accessed 23.01.25)

ADAS has run a variety of agrivoltaics research projects across the UK
Weblink: https://adas.co.uk/services/renewable-energy-and-low-carbon-development/ (last accessed 23.01.25)
Contact person: Dale Greetham, dale.greetham@adas.co.uk

Agri-EPI centre and Innovate UK have conducted field trials in multiple locations
General weblink (no specific mention of agrivoltaics) https://www.agritech-uk.org/agri-epi-centre/ (last accessed 23.01.25)

The National Farmers' Union has included agrivoltaics in their strategy
Weblink for citation: https://www.agrisolarclearinghouse.org/the-international-landscape-of-solar-farms-and-agrivoltaics/

Nottingham Trent University NTU
PhD studentship. It is about carbon capture and biodiversity: Quantifying Carbon Sequestration Dynamics in Solar Farm Landscapes: A Predictive Tool for Sustainable Land Use and Biodiversity Co-Benefits | Nottingham Trent University

Lancaster University

Professor Alona Armstrong, Our vision is to revolutionize food and power supply, through research, innovation and demonstrators that accelerate the exploitation, commercialisation and marketisation of agrivoltaics https://www.lancaster.ac.uk/energy-lancaster/research/agrivoltaics/

Projects and contacts elsewhere in Europe

Baywa-re (German renewable company) offers support through the entire agrivoltaic installment process including planning, purchasing, financing and installation. They offer different models from leasing, licensing, or a full handover for use of power by the landowner
https://www.baywa-re.com/en/solar-projects/agri-pv

Baywa-re and its Dutch subsidiary **Groenleven** have built agrivoltaic fruit pilot sites in the Netherlands
Weblink: https://www.baywa-re.com/en/news/details/baywa-re-grows-agripv-across-the-netherlands (last accessed 23.01.25)
https://www.baywa-re.com/en/solar-projects/agri-pv (last accessed 23.01.25)

Fraunhofer Institute for Solar Energy Systems is the largest solar research institute in Europe, at the forefront of agrivoltaic technology. They have led a number of projects including on organic farms.
Weblink: https://www.ise.fraunhofer.de/en.html (last accessed 23.01.25)

Next2Sun is a German company offering a variety of vertical and bifacial PV deployment models catered to the needs of individual landowners
Weblink: https://next2sun.com/en/agripv/ (last accessed 23.01.25)

Sun Agri (French agrivoltaic specialist) is the leading AgriPV provider in France, and was awarded a French government tender in 2020 to establish 7 agrivoltaics projects combining viticulture, market gardening and arboriculture. The panels are tiltable.
Weblinks: https://sunagri.fr/en/, https://sunagri.fr/en/key-findings-vine-growing/ and https://www.pv-magazine.com/2020/05/28/france-embraces-solar-with-viticulture-arboriculture-and-market-gardening/

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