Farming sunshine

Solar energy integration with livestock farming

Why: To establish how solar arrays could be incorporated into livestock farms to provide environmental benefits, as well as shade and shelter for animals, while generating renewable energy for financial gain.

Where: Mid-Canterbury dairy farm and North Canterbury sheep and beef farm.

Who: Anna Vaughan and Megan Fitzgerald (Tambo), Alan Brent and Ellie Wright (Victoria University of Wellington), Jasper Kueppers (Infratec) and farmers.

What:

- Available agrivoltaic array designs with tilt and tracking systems (suitable for sheep and cattle and allowing for movement of farm equipment) were reviewed.
- Livestock benefit from the shade panels provide, but standard commercial design sets panels too low for livestock larger than sheep and may have a negative impact on pasture.
- There are good financial gains for sheep farming under agrivoltaic systems, but the costs to raise and strengthen structures for cattle may be prohibitive on dairy farms.
- Cost of installation is a barrier to farmers, along with lack of confidence.
- A closer relationship between farmers and solar developers may be needed to incorporate agrivoltaic systems on more sites.
- A guide giving farmers more information on solar arrays and agrivoltaics has been developed, along with an interactive tool to assess property suitability.

More:

ourlandandwater.nz/outputs/integrating-solar-livestock-report

ourlandandwater.nz/outputs/integrating-solar-livestock-booklet

ourlandandwater.nz/outputs/agrivoltaics-assessment-tool

As solar energy generation ramps up in this country, what should farmers consider when looking at integrating solar into their livestock farming operation – and does powering up a paddock stack up financially?

As the number of solar farms has increased globally, especially over the past decade, farmers and environmentalists have raised concerns that the sites had become ecological wastelands, with grass and weeds under the photovoltaic panels controlled by mowing or spraying.

Agrivoltaic systems respond to these concerns by allowing the dual use of land for producing food and electricity, with extra benefits for food security, biodiversity, and meeting future needs for more renewable energy production.

Overseas, some cropping is being done under solar panels, and some farmers have developed a ‘solar grazer’ business model, running sheep under the panels on pastoral farms. Sheep are popular, as the panel structures do not need to be reinforced or raised to allow them access.

Farmland is the focus for new solar developments in this country, with more than 14 large-scale sites in the pipeline already. Including smaller sites sees this number jump to more than 200, with more planned in the future.

Dual land use

Solar developers have been largely determining how the panels are set up. They aim to capture the maximum amount of energy, rather than designing for optimal dual land use, or for it to be incorporated into the surrounding farming systems (see **Figure 1**).

“They’re just running a few sheep underneath, not designing the layout of the panels to preserve pasture production,” says farm consultant Anna Vaughan of agricultural consultancy Tambo.

Vaughan approached Alan Brent, chair in sustainable energy systems at Victoria University of Wellington,

Sheep grazing among solar panels

to find out what dual-purpose designed arrays would look like and how would they stack up financially for Aotearoa New Zealand farming operations. Along with members of the Infratec team, they applied for funding through the Our Land and Water Rural Professionals Fund to find out.

The National Policy Statement for Highly Productive Land, introduced in 2022, requires local councils to map, manage and maintain highly-productive land to prevent it falling out of food and other primary production.

Even in areas that do not fall under the highly productive land classification, local councils may well be reluctant to allow rural land needed for solar developments to be used solely for electricity production, and many of the solar developers have indicated they intend to incorporate agrivoltaics in their resource consent applications. Dual land use is not currently a requirement but may be a possibility for the future.

Technical considerations

A desktop study undertaken by Vaughan's team combined what scant information there was available on agrivoltaics in an Aotearoa New Zealand context with overseas studies. This included previous research that had shown around 80% of our agricultural land was suitable for agrivoltaic systems, including much of Canterbury. The assessment took into account a location's solar resource, slope and orientation, and distance from transmission lines.

Mounting structures for the various agrivoltaic designs were investigated, as the cost of these can have a big impact on economic viability. In a pastoral setting, panels are typically set in rows with wider spacings to allow farm machinery to move between them. Panels set out in a row rather than a checkerboard pattern are the most efficient for energy gathering.

Fixed-tilt systems have panels running east to west and are permanently facing north. Single-axis tracker systems run north to south, and panels track the sun as it moves across the sky during the day. Tracker systems are more efficient, but are likely to need more maintenance and be affected by wind at height.

Raising panels significantly higher off the ground for large stock, as well as strengthening for wind shear at height, adds significantly to the cost and is likely to be a deal breaker for many developers.

Inverters are needed on-site, so power produced can connect with the national electrical network. If producing more than 10 MW (a site around 20 ha), a developer or farmer would need to be registered as a generator provider. Approvals from Transpower or local lines companies are needed because not all substations can carry an increased load from solar and this will directly affect whether a site is suitable for development.

While Transpower is upgrading its systems, Brent says there are likely to be more issues in the short term with the local line companies.

Pros and cons of dual land use

Shade and (to a lesser extent) protection from inclement weather are the biggest gains for livestock on agrivoltaic farms.

There are significant advantages in providing shade to ward off heat stress in livestock, which affects animal wellbeing, as well as weight gain and increased milk production. Wooled sheep start to feel heat stress over 19°C. As the climate continues to warm this will take on even greater relevance.

Panels provide and retain more soil moisture, as well as keeping soils cooler during dry months, with wind also reduced under the panels.

Standard commercial heights for panels, however, create shading that leads to poorer ryegrass and clover pasture performance. Higher panel heights are recommended.

"The reflective surfaces of the panels can impact insect behaviour but not to a serious degree," says Brent, "and wouldn't interfere with honey production should a farmer look at diversifying by growing native plant biodiversity and flowering plants for bees instead of running livestock under the panels.

"When panels reach the end of their commercial life, at around 25 to 30 years, they will still be producing about 85% of what they were when new, and will likely last another 10 years or more. While there may be options for donating these panels for social development projects, there are currently no recycling plants in Aotearoa New Zealand, something that will need to be looked into seriously in the coming years," says Brent.

Sheep and beef farm case study

A sheep and beef farm and a dairy farm – both in the Canterbury region – were used as case studies to model agrivoltaic array design and potential impacts on farming systems. Both sites would use bi-facial panels able to capture light on both sides, with fixed-tilt and tracking systems modelled for each farm.

Removing the panels at the end of their life, waste management, and turning the land back into farmland were not part of the calculations, although replacing inverters once during the lifetime of the development was accounted for. All costs associated with the solar developments for the farmers were assumed to be covered by borrowing.

A 5.8 ha paddock on the 1,300 ha sheep and beef farm in the Hurunui area was modelled. With around 800 ha effective hill country and 300 ha of effective flats the farm winters 7,500 stock units.

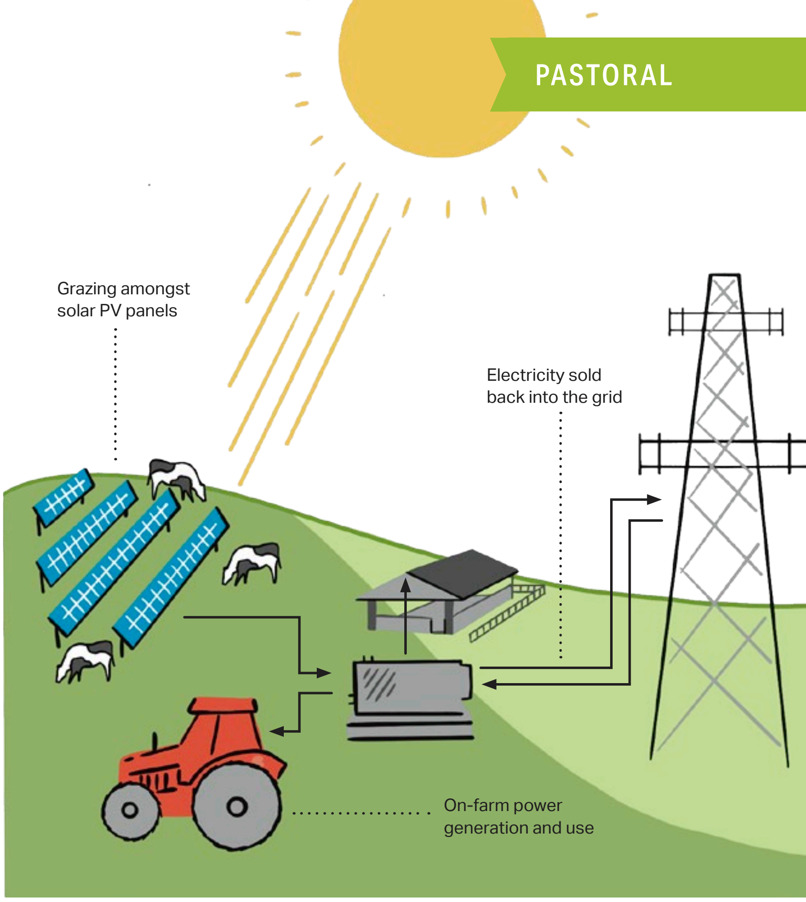

Figure 1: The scale of the solar system and the on-farm loads determine the required infrastructure configurations to enable the direct supply of electricity for on-farm usage

Heights of the solar panels were standard and suitable for sheep, although rows were wider apart than on a typical solar farm to allow farm equipment to move between the rows, and were placed further from the paddock boundary.

Overall, costs to establish either fixed or tracking panel systems were similar. Project development, consenting and grid connection cost around $625,000, and the design and build between $4.3 million and $6.3 million. This would generate, at peak, between 2.2–2.5 MW of electricity for the grid.

A comparison was made between the status quo (no solar) and the 5.8 ha area having a 30% reduction in stocking rate due to the installation of panels and subsequent shading. A total removal of stock from the area was also modelled.

The results showed that net profit (after debt servicing and depreciation) for the farm increased by $420,484, with a 30% decrease in stocking rate under that area. Return on asset increased significantly, as did return on equity (see **Table 1**).

The modelling showed a solar set-up would work well financially for the sheep and beef farm.

When viewed through a purely financial lens, the numbers for a standard commercial solar set-up stack up better than for an agrivoltaic one. However, there are still significant financial gains from the agrivoltaics system over the status quo.

Dairy farm case study

On a 235 ha farm milking 860 cows, a 2 ha dryland area used for supplementary feed production on the edge of an irrigated paddock was modelled.

The panels needed to be 2.5 m above ground level to enable adult cows to move underneath. For greater stability at that height, and given Canterbury wind speeds, a more expensive dual-pile system was recommended for the fixed-tilt panels. Again, rows were wider apart than on a typical solar farm to allow farm equipment to move between the rows, so they were placed further back from the paddock boundary.

Project development, consenting and grid connection costs came in at around $350,000 to $390,000, with design and build between $2.1 million and $2.9 million, for around 1 MW of power generation.

Comparison was made between the status quo (no solar), and the farm operating the array without stock underneath, due to this area being dryland and not typically included in the grazing feed budget for this farm.

Results showed that net profit dropped by $64,400 due to increased borrowing, as the interest rate was not covered by increased income. The return on asset and the return on equity also dropped slightly.

Financially, there was little benefit in installing a solar array on the higher income dairy farm, including the extra infrastructure costs and buying in supplementary feed. There could be some benefit from being able to use the electricity in the dairy shed and with irrigators if the agrivoltaic system is of appropriate size and properly embedded into the farm infrastructure.

Considerations for the future

A group of interested Canterbury farmers who attended a workshop on agrivoltaics, as part of this research, felt the arrays ticked boxes for animal welfare by offering shade to stock, along with contributing to their 'social licence' to farm.

While the workshop raised their interest in agrivoltaic systems, the high costs associated with installing the arrays was a barrier. The farmers didn't feel confident or informed enough to tackle agrivoltaic projects themselves, although some felt they would be up to the challenge with more clarity over costs. They also felt that without leasing or partnering with energy companies, fewer agrivoltaic projects would likely go ahead.

Solar energy companies setting up a standard system with no regard for optimising agrivoltaics, and then running sheep underneath while claiming dual land use, was one of the concerns Vaughan's team also had.

Should local councils take dual land use and preservation of productive land seriously, getting resource consent approval for a straight commercial solar set-up may become harder in the future.

"It would be a missed opportunity if in five years' time all the approved solar sites, which will be in operation for 30 or more years, have a standard commercial design," Vaughan says.

Research is also needed on how pasture and livestock perform under panels, along with cropping, re-seeding and other farm management systems and health outcomes for lambs and calves.

Delwyn Dickey for the Our Land and Water National Science Challenge

Table 1: Return on investment – sensitivity analysis (sheep and beef farm case study)

		Solar energy generation annual revenue per hectare ($/ha)						
		$81,000	$89,000	$97,000	$105,000	$113,000	$121,000	$127,000
Capital investment $/ha	$615,625	3.67%	4.04%	4.40%	4.76%	5.13%	5.49%	5.76%
	$678,000	3.34%	3.67%	3.99%	4.32%	4.65%	4.98%	5.23%
	$741,000	3.05%	3.35%	3.66%	3.96%	4.26%	4.56%	4.79%
	$804,000	2.81%	3.09%	3.37%	3.65%	3.92%	4.20%	4.41%
	$865,625	2.61%	2.87%	3.13%	3.39%	3.65%	3.90%	4.10%

Assumptions: Accumulated 30-year depreciating income (decreasing to 85% by year 30) over initial capital investment requirements. Does not account for cost of funds, cost to remove and remediate land at end of 30-year term, or any maintenance costs.