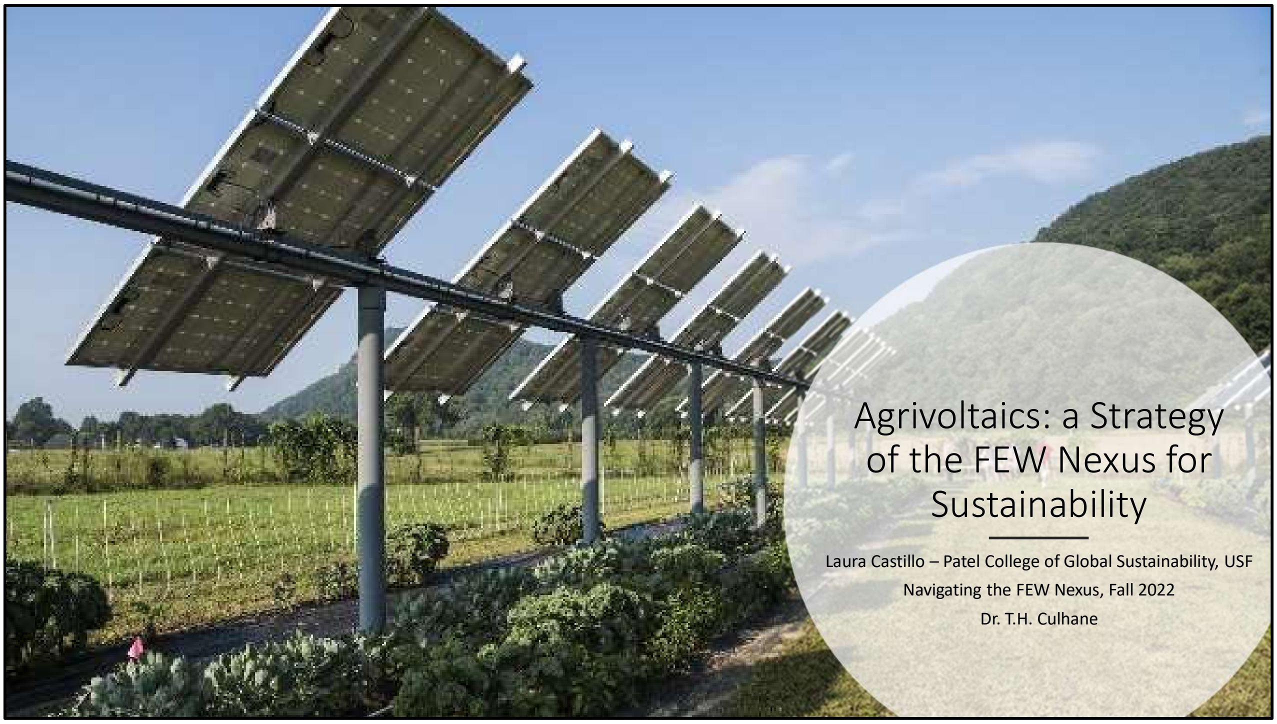
Agrivoltaics: a Strategy of the FEW Nexus for Sustainability
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Navigating the FEW Nexus, Fall 2022
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Presentation Outline

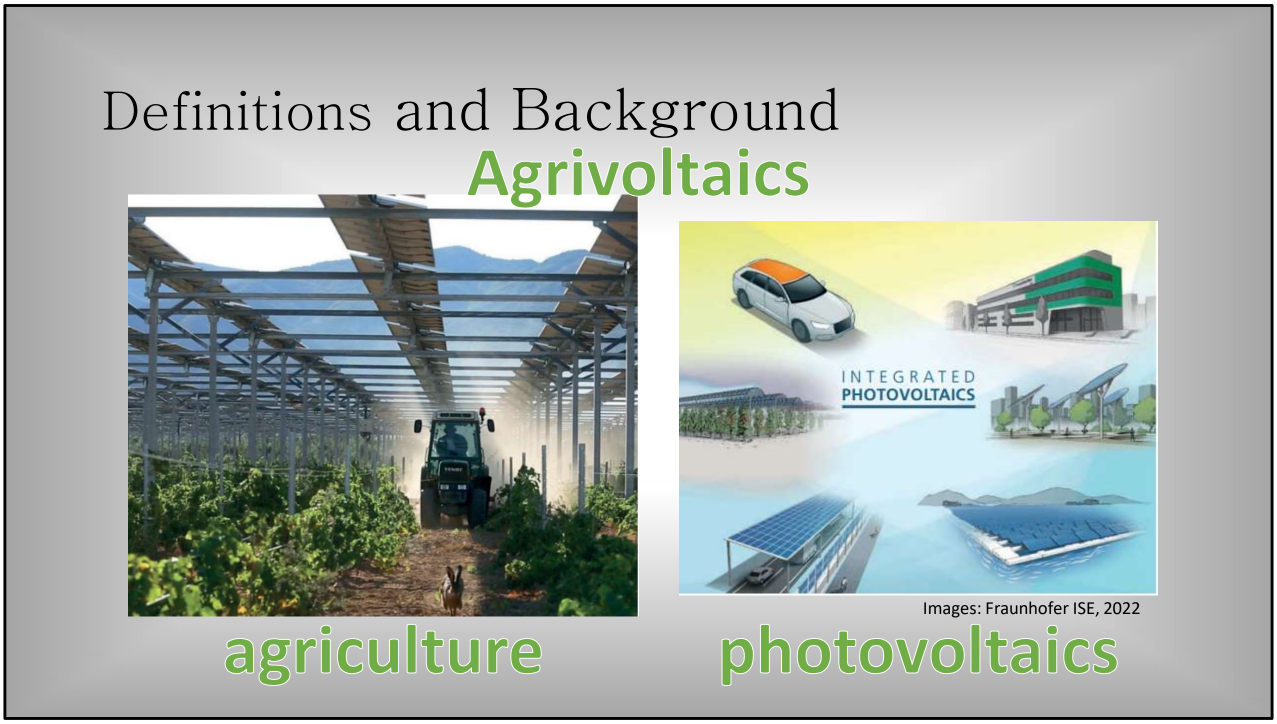
- Definitions and Background
- Applicability in:
  - Agriculture
  - Horticulture
  - Rooftops
- Virtual Model at Rosebud Continuum
- Sustainable Livelihoods and the F-E-W Nexus

Definitions and Background

ager colere

agriculture

The word agriculture is a connection of the Latin words *ager* and *colere. Ager* meaning field or land, and *colere* meaning to worship or tend to. The Meriam-Webster online dictionary defines agriculture as the “science, art, or practice of cultivating the soil, producing crops, and raising livestock…” With this definition, we can broadly understand agriculture as including sciences like agroecology, including art like horticulture, and including practice like mass crop production (Vries, 2012). Of course, each of those can have varying definitions and categories as well because the broad agriculture field is so diverse.



One of those categories or sub-fields is agrivoltaics, a practice that uses the same land unit for photovoltaic panels and crops (Dupraz et al., 2011). Not only is it a category of agriculture but it is also a category of integrated photovoltaics where PV energy is used for various applications like cars, parks, and buildings. Agrivoltaics combines agriculture and photovoltaics. Other names for the practice are hybrid agricultural-PV solar and agrophotovoltaics. Its purpose is to make the most efficient use of solar radiation by simultaneously converting it into food and energy. This practice makes sense because solar energy is earth's most abundant energy source. Of course, we know that simultaneous food and energy production is not a novel concept. The land-human integrated approach of sustainably producing food, energy, shelter, and other needs is known as permaculture (Mollison, 1988). Growing food crops for biomass is an example of simultaneous food-energy production that has long been practiced. The importance of focusing in on agrivoltaics specifically as a food-energy production strategy is that its implementation could play a significant role in combating issues like food and energy security, land-use conflicts, and livelihood prosperity (Barron-Gafford et al., 2021).

Definitions and Background

Image: Permaculture Research Institute

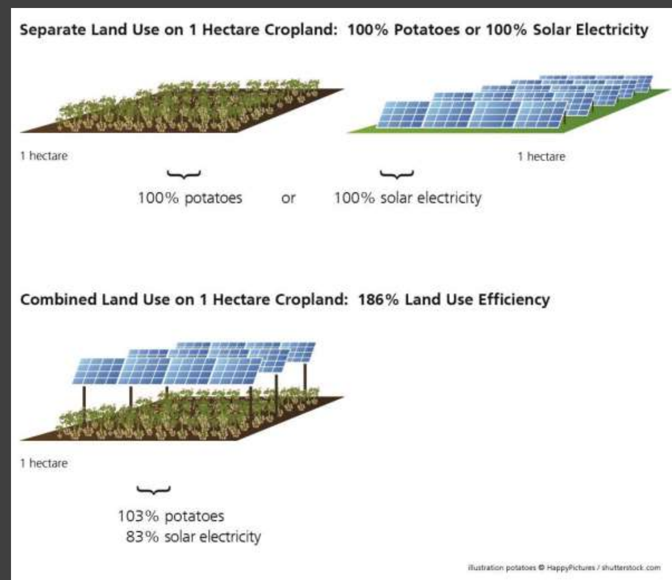


Image: Fraunhofer ISE, 2022

I mentioned land-use conflicts as a concern that agrivoltaics can potentially ameliorate. The food-versus-fuel debate is a prime example of a land-use conflict where the argument is that if land is diverted for energy production, then there will be less land available for food production. This dilemma has mainly applied to biomass crops, like corn and sugarcane, for ethanol production (Ketzer, 2020). Another food vs fuel land-use pattern is that of fields being retired out of agriculture (for various reasons including severe weather occurrences, financial burdens, and climate related risks) and shifting into energy production operations (Barron-Gafford, 2022).

I would argue that the food-versus-fuel debate is just as odd as conversation on water conflicts. Producing food or energy should not have to be an *either-or* debate, it should not have to be a competition, just like dwindling water supply should not have to be a cause for wars because there are solutions and strategies for both dilemmas- the biggest hurdle is getting everyone on board to implement sustainable strategies.

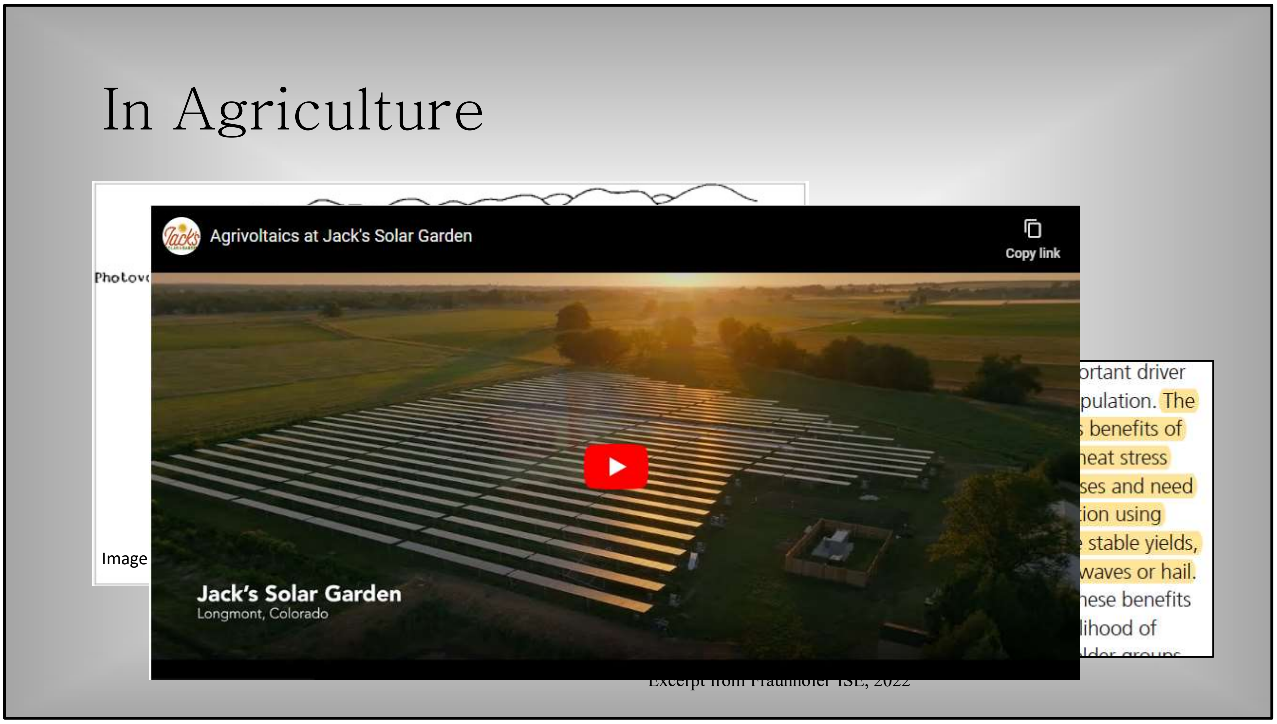
In Agriculture

This year, the garden produced more than 8,000 pounds of produce, while the panels above generate enough power for 300 local homes.

Image: Siegler, 2021

https://www.jackssolargarden.com/

An example of a farmer overcoming this very land-use hurdle is that of Byron Kominek whose 24-acre Colorado farm now produces a variety of vegetables and 1.2 megawatts of solar power using ground-mounted PV arrays (Siegler, 2021). His hurdle was that local regulations designated his farm as historic farmland and therefore disqualified the land for solar panel installation. He was told that the “land is for farming, so go farm it,” but after common sense discourse, the county regulators changed their land use code to allow the solar panel installation. Kominek’s farm, now called Jack’s Solar Garden, is a community solar garden that sells its power production back to the local grid and produces kale, beets, lettuces, squash, carrots, and much more https://www.jackssolargarden.com/



Farms that may only be interested in generating enough energy to supply their own operation instead of generating a surplus to sell can also take advantage of implementing agrivoltaics. For example, on-site PV arrays can power solar pumps for livestock watering and crop irrigation (Mohanty & Tyagi, 2015). This same concept of solar pumps can apply to other energy-dependent farm machinery, of course this would require an extensive transition for existing parts and infrastructure.

Regardless of whether farmers implement agrivoltaics for an additional source of income or to provide for their own energy needs, agrivoltaics can have desirable impacts on their crops. The most basic benefit of integrating solar arrays with crops is protection against excessive weather events such as solar radiation, wind erosion, heat, drought, rainfall, frost, and hail (Fraunhofer ISE, 2022). Other benefits should be tailored specifically to the farm's region and target crops. For example, shade tolerant plants, like some leafy greens and root vegetables, can thrive with the intermittent shade of an overhead solar panel. The added shade also prevents excess evaporation and therefore reduces irrigation demands. It is also believed that the supplementary shade may reduce nitrogen deficiency stress in some plants therefore reducing demands for added fertilizers (Dupraz et al., 2011). Overhead PV arrays can even serve as shelters for animals (Fraunhofer ISE, 2022).

Large-scale monoculture farms have contributed to environmental degradation, so although I am not an advocate for this type of agriculture, implementing agrivoltaics in these farms may be a step in helping farmers transition towards more sustainable practices. Again, Kominek’s Colorado farm story is an example of this. For 50 years, his family farm only produced alfalfa for hay and raised some cattle, but with the transition towards agrivoltaics also came the change of polyculture (Siegler, 2021).
Video: https://youtu.be/FGMNFPC-9fk

In Horticulture

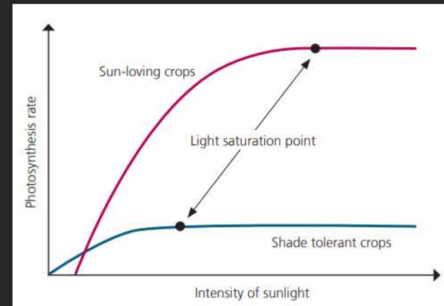


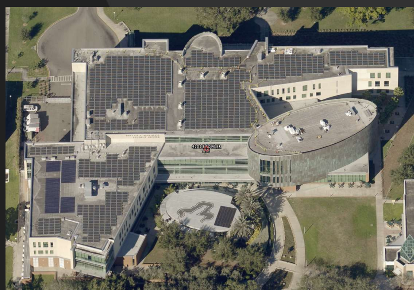
Fig. 30: Graph of the rate of photosynthesis against intensity of sunlight for sun-loving and shade tolerant crops[24].
© ASPS, modified by Fraunhofer ISE

Image: Fraunhofer ISE, 2022

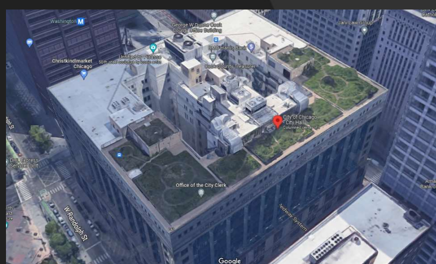
The main difference between agriculture and horticulture is that horticulture typically takes place on a smaller-scale and controlled settings, such as gardens. Just like in agriculture, crops grown in a horticulture setting are not limited to edible plants. However, horticulture can be a form of subsistence farming and is believed to be a crucial component of ensuring food security (Vries, 2012).

The same benefits discussed in the agriculture section can apply to a horticulture setting. This hybrid design should be carefully tailored to the region, operation size, target crops, and overall intent. An example regarding target crops is knowing a target plant's light-saturation point. This is threshold at which a plant specie can no longer use light energy for photosynthesis and any additional light is either lost or can be harmful to the plant (Fraunhofer ISE, 2022). Knowing the light saturation point can assist with PV array design. Some other factors to consider include panel height and spacing, single or dual-axis construction, fixed or tilting construction for solar trackers, material, and cost benefit analysis (Dupraz et al., 2011; Fraunhofer ISE, 2022).

In addition to benefits for the crops, agrivoltaics has also been found to improve efficiency in energy generation. Having crop understories instead of concrete surfaces beneath solar arrays maintains cooler temperatures due to evapotranspiration from the plants. Cooler temperatures allow crystalline silicon PV arrays to perform more efficiently (Bousselot et al., 2017). This practice is also more efficient at producing energy in comparison to biofuel crops when considering that the same land unit is used for a dual purpose (Fraunhofer ISE, 2022).



USF Marshall Student Center, Google Maps



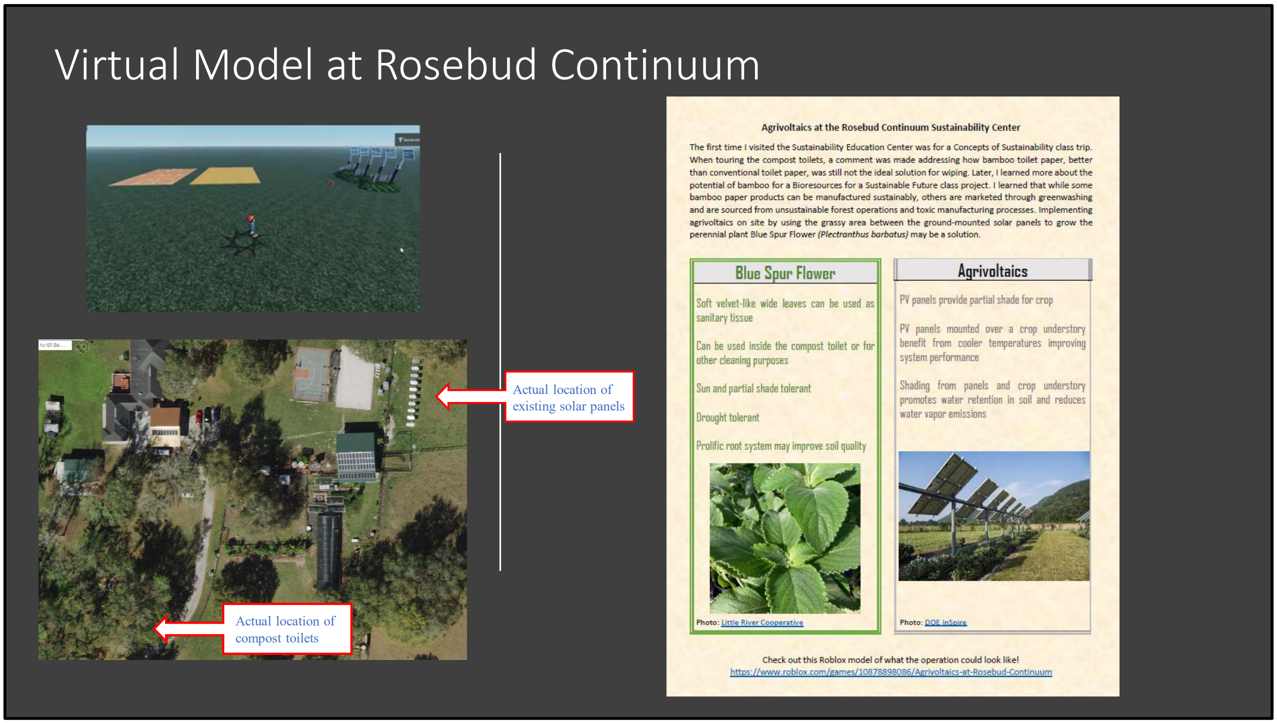
City of Chicago City Hall, Google Maps

On Rooftops

Image: Bousselot et al., 2017

Again, the same guidelines and benefits discussed in the agriculture and horticulture sections can be applied to agrivoltaic implementation on rooftops. Rooftop solar power systems are already popular and continue to expand for use on residential and commercial buildings, and other structures like parking garages. Green roofs are also increasing in popularity where their use serves many purposes including temperature reduction, stormwater runoff reduction, carbon sequestration, and other ecological benefits. Combining these two rooftop strategies is mutually beneficial for crop and energy production. A research team at Colorado State University (CSU) found that solar panels on conventional rooftops could reach 150 degrees or higher which reduces their efficiency (VandenEinde, 2022). Therefore, agrivoltaics can be especially valuable when implemented in semi-arid environments where the cooling effects of evapotranspiration promote water conservation and overall thermal reduction (Busselot et al., 2017).

Jennifer Bousselot, an assistant professor at CSU and a member of that research team, claims that “it’s not urban versus rural…it’s really trying to grow plants near people,” (VandenEinde, 2022). I think her statement aligns with the thought that sustainability topics do not need to be competitions, they do not need to be *either-or* debates, just like there should not be a food OR energy disagreement. The focus should be on creating sustainable communities using a systems thinking approach to meet our needs.



The Rosebud Continuum Sustainability Education Center in Pasco County, Florida has ground-mounted solar panels with a grass understory. The intermittent shade produced by these panels could be utilized to grow a targeted crop. One idea for this site is to grow blue spur flower, a sun and partial shade tolerant plant that is drought tolerant. Its soft, velvet like, wide leaves can be used as tissue for general cleaning purposes and even as sanitary tissue inside the compost toilets. A virtual representation of what this operation might look like can be explored using the linked Roblox model:

https://www.roblox.com/games/10878898086/Agrivoltaics-at-Rosebud-Continuum

Sustainable Livelihoods and the F-E-W Nexus

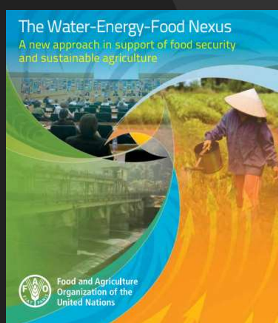


Image: FAO, 2014

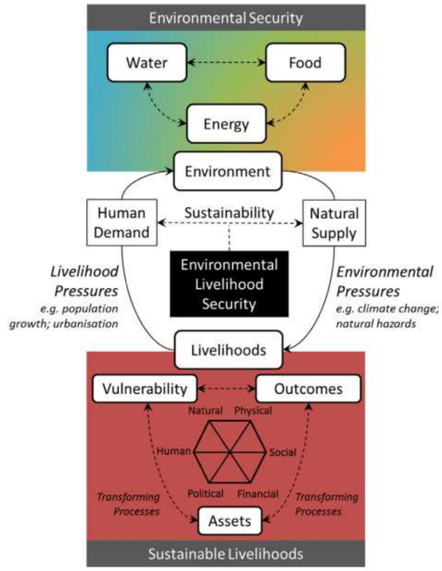


Image: Biggs et al., 2015

Integrated energy and food production is argued to be a key factor in avoiding local food shortages and in increasing incomes of the world's poorest (Ketzer, 2020). In this regard, hybrid agricultural-PV solar can be a strategy to improve quality of life through food security and energy independence. The F-E-W Nexus is the convergence point between food, energy, and water that highlights their inseparable links (FAO, 2014). The links between the F-E-W Nexus and Sustainable Livelihoods can be analyzed through the concept of Environmental Livelihood Security. ELS aims to find balances of human security to food, fresh water, energy, and equitable economic growth, while preserving environmental functionalities (Biggs et al., 2015). With regional and cultural differences across the globe, there really is not a *one size fits all* sustainable solution for each food, energy, or water problem. An advantage of agrivoltaics is that there is no one typical design requirement, and instead, its design is molded by the user's conditions and desired outcomes. Its design is beneficial and intentional, the basis of permaculture (Mollison, 1988). Its design and implementation flexibility can empower stakeholders, including in financial aspects, thus promoting overall sustainable livelihoods.

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