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Agri-Pv: Harvesting Agriculture and Solar Energy for a Sustainable Future

Sustainability Research Paper

The Al-Attiyah Foundation

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Several challenges prevent the widespread uptake of Agrivoltaics (Agri-PV) including existing farming practices, high initial investment costs due to low market penetration and awareness, lack of government incentives and limited technical knowledge of best practices for adoption. How can Agri-PV benefit the MENA region by strengthening the energy transition while reducing GHG emissions? How can Agri-PV address multiple crises such as arable land scarcity and resulting food insecurity? These are some of the questions addressed in this research paper.

SUSTAINABILITY RESEARCH PAPER

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a current sustainability topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners, and universities, as well as made available on the Foundation's website.

03 EXECUTIVE SUMMARY

- Energising agricultural and food (agri-food) systems is a transformational feature of resilient agricultural development and is a prime factor in helping to achieve food security.
- Agri-PV is the practice of co-developing an area of land for agriculture and solar energy to maximise land utilisation and addresses the food, land scarcity and energy crisis that the MENA region faces.
- Agri-PV is particularly well-suited for arid regions, as solar panels provide shading for crops while reducing water evaporation.
- Several challenges prevent the widespread uptake of Agri-PV including existing farming practices, high initial investment costs due to low market penetration and awareness, lack of government incentives and limited technical knowledge of best practices for adoption.
- Cross-sectoral alignment and multistakeholder engagement is necessary to align economic priorities regarding energy, food production, water, land-use planning, and beneficiary end users (e.g., farmers).
- Creating awareness on the benefits of Agri-PV may increase adoption and uptake, while pilot projects can demonstrate its viability to policy makers, project developers and farmers.
- Policy instruments, subsidies and regulatory incentives may be necessary to attract investment and facilitate the development and deployment of Agri-PV.

Rising global temperatures and more extreme weather events as a result of the climate crisis are posing significant challenges for food security at the global, regional and local level. The combined impacts of the COVID-19 pandemic and military conflicts are amplifying global and regional food and energy insecurity. Agriculture is extremely vulnerable to climate impacts, in particular in arid regions. Higher temperatures and changes in precipitation patterns increase the likelihood of crop failures, increase water scarcity, and encourage the proliferation of pests and diseases that affect agricultural productivity, food quality and cost.

The MENA region is one of the most water-scarce regions in the world with an average water availability of 444 cubic meters per capita[01]. This is well below the recommendation set by the United Nations at 1,000 cubic metres per person, per year[02]. More than 60% of the population live in water stressed areas and have limited access to potable water[03]. Furthermore, almost all arable land in the MENA region is currently in use , with 86% of annual water consumption used for agricultural purposes[04]. Climate change models predict that the region will face a temperature increase of up to 4°C by 2050[05], decreased precipitation, and a rise in the rate of evaporation. Population growth and increasing water use for human consumption and irrigation purposes pose a significant threat to the region's food security, emphasising the need to alleviate this pressure in view of worsening climatic conditions.

Energy is essential for improving agricultural yields and reducing post-harvest losses e.g., by powering irrigation solutions and post-harvest storage, including cooling, thereby supporting the livelihoods of farmers. Global agri-food value chains account for 30% of global energy consumption, with a heavy reliance on fossil fuels that cause greenhouse gas (GHG) emissions[07]. The necessary shift from fossil fuels to renewable energy requires scaled-up deployment of renewable energy, which has led to a perception of land use conflicts between agricultural production and energy generation[08]. Agri-PV, however, offers a transformational solution to overcome these conflicts through dual use of land. This innovative technology solution is especially suitable for countries with abundant sunlight, such as the MENA region, and can provide additional benefits for farmers while simultaneously addressing multiple crises such as land scarcity, food insecurity and reducing GHG emissions.

WHAT IS AGRI-PV?

Agri-PV is the practice of co-developing an area of land for agriculture while simultaneously producing electricity from solar PV (see figure 1). The concept of Agri-PV was first conceptualised in Germany in 1981 and has more recently gained momentum due to growing interest in sustainable investments, demand for renewable energy and the fallen costs of PV technologies over the last decade. Installed capacity of Agri-PV worldwide has increased from 5 megawatts-peak (MWp) in 2012 to more than 14,000 MWp in 2020, with national funding programmes prevalent in China, France, Japan, South Korea and the US[09].

There are two main design approaches of Agri-PV systems. Overhead-PV systems or high-elevation systems consist of elevated PV modules installed above crops, providing protection from extreme weather conditions. Interspace-PV or low-ground systems consist of vertical PV modules installed in parallel rows alongside growing crops to improve land use efficiency. Most land stays in use for farming and the crops receive protection from extreme weather conditions. Table 1 provides an overview of the differences between overhead and interspace PV systems.

Figure 1: © Happy Pictures/shutterstock
© Fraunhofer ISE: The dual use of agricultural land increases the land use efficiency by 60 percent[10].

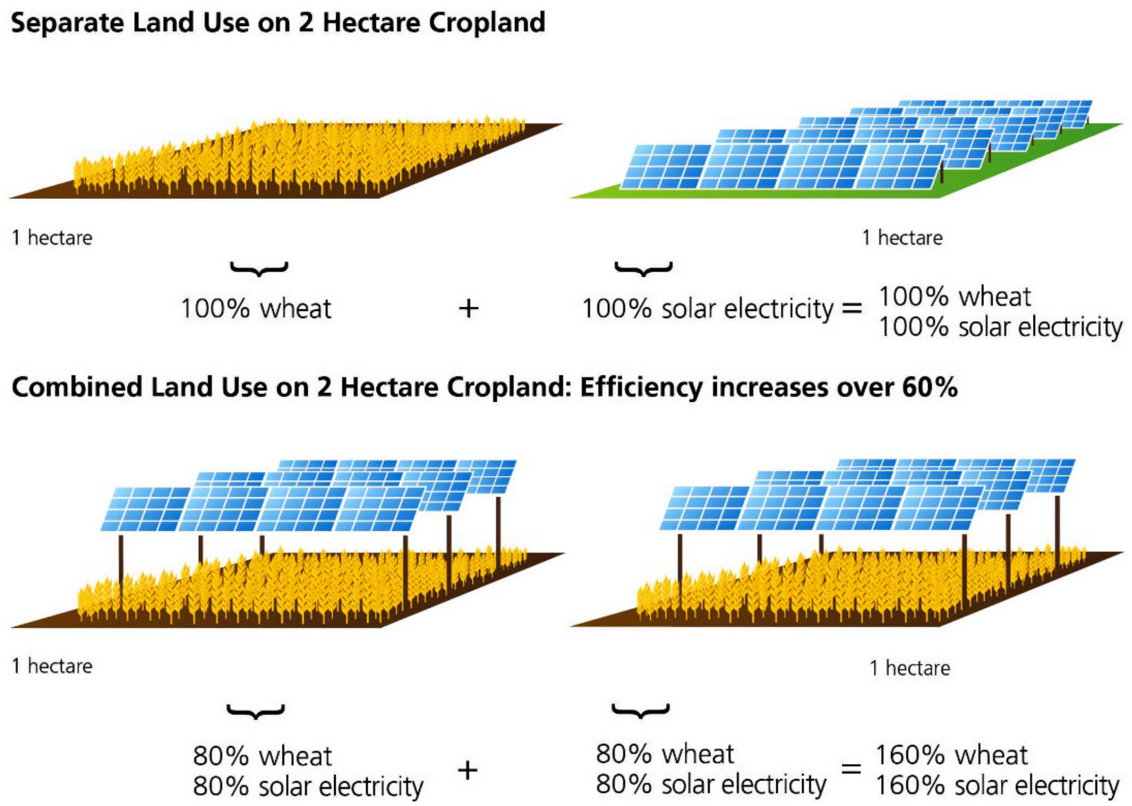

Table 1: Overhead-PV vs Interspace-PV: What's the difference?

Overhead-PV (High-elevation systems)	**Interspace-PV** (Low-ground systems)
Arranged at least 2.1 meters above ground, allowing farm animals and agricultural machinery to operate below. Less heat stress, improved water harvests, more consistent growing conditions, and long-term protection for crops resulting in improved crop yields. Protects farmland from wind and safeguards against soil erosion. For example, higher soil moisture protects against desertification and shade allows degraded land to be recharged with nutrients. Reduces the need for plastic to protect crops from pests and extreme weather. Less land use change required in spatial planning. Higher land use efficiency as agricultural land is not impacted. Estimated 10% loss of agricultural area.[11]	Agri-PV modules can be used for rainwater harvesting. Protects farmland from wind, safeguards against soil erosion and prevents land loss of up to 15%. Supports the protection and restoration of ecosystems and improved land efficiency. For example, higher soil moisture protects against desertification and shade allows degraded land to be recharged with nutrients. Agricultural land is practically divided for different uses e.g., artificial grazing fences for grazing livestock.

07 BENEFITS OF AGRI-PV

Agri-PV is a viable solution to the food and energy crises and delivers mitigation and adaptation benefits while offering farmers and landowners opportunities for new revenue streams. As a mitigation benefit, Agri-PV reduces the reliance on fossil fuels and may have soil carbon sequestration (SCS) potential. However, the SCS potential would further rely on the adoption of improved agricultural management practices that increase the amount of carbon stored as soil organic matter. In terms of adaptation benefits, in both cases of overhead- and interspace-PV, crops and animals are shaded from the harsh sunlight. Due to the protection PV modules can offer, the potential for water conservation may be up to 29%[12]. This safeguard also acts against desertification as there is less erosion due to higher soil moisture, which in turn improves food security. The shade also allows for degraded land to be recharged with nutrients, thereby giving underused land the opportunity to maintain or increase production in a changing climate. PV offers ways to save on electricity and even productively power other equipment, such as irrigation or cooling systems[13]. Agri-PV also increases overall resilience to extreme weather events such as crop failure, flooding, pests, and diseases. In addition to growing crops that yield well in direct sunlight, Agri-PV provides farmers with the opportunity to protect shade-tolerant crops and livestock, thereby improving and/or diversifying their income sources[14]. For certain crops e.g., peanuts and alfalfa, Agri-PV can even extend the growing seasons. A 2019 study found that cherry tomatoes doubled in yield and jalapeno peppers tripled in yield[15].

Sheep have also been found to be well suited to Agri-PV as they cannot climb or cause damage to PV modules and their grazing habits can help to control plant and vegetation growth[16].

Despite these benefits, several challenges exist with Agri-PV that have impeded its uptake globally. A main concern for farmers is the perceived compatibility of solar energy with their present farming practices and the impacts this may have on the productivity of land in the long-term. For example, in the case that farmers grow crops that are incompatible with shaded conditions e.g., butternut squash and melons. The possible loss of land depending on the choice of PV system may also prevent the uptake by farmers, particularly over concerns of reduced production.

High up-front investment to fund initial installation which include feasibility assessments are a further deterrent for adoption especially in the absence of financial support. Other barriers include a lack of technical knowledge which is required from merging multiple cross-cutting sectors (e.g., agriculture, energy, and water) for effective implementation and government incentives that would provide technical assistance and facilitate wider deployment. Depending on the installation type, PV panels may lead to a glare effect, which if erected in the vicinity of traffic routes, requires a cautionary approach to prevent negative impacts on health and safety.

Political feasibility

A key barrier to Agri-PV implementation is the lack of enabling legal and regulatory frameworks. While many countries in the MENA region have ratified the Paris Agreement and submitted their Nationally Determined Contributions (NDCs), most countries do not mention the (potential) use of Agri-PV as part of their NDC targets or sectoral adaptation or mitigation policies and measures.

Agri-PV requires a high degree of policy coordination for aligning different sectoral frameworks[17]. Wide adoption of Agri-PV will also depend on the willingness of policymakers and the public (including beneficiary end users) to change existing practices e.g., reduce reliance on fossil-fuel based energy, and/or adopt suitable farming practices.

To overcome these hurdles, policymakers should develop broad-based strategies that integrate the use of nexus approaches with linkages between (renewable) energy, food and water that are significant for long-term benefits for food and energy security.

The use of pilot or demonstration projects may catalyse early adoption of Agri-PV in the MENA region and increase understanding on the technology and its potential impact for the region. However, there is a high degree of awareness and political support for enhancing food security, efficient water use, and in many countries also for a significant expansion of renewable energy, which are all conducive pre-conditions for introducing and scaling up Agri-PV. As COP28 will be hosted by UAE, a spotlight on climate action in the MENA region may serve to catalyse the adoption of Agri-PV if the transformational potential of this opportunity will be recognised.

Technical feasibility

Regarding technical feasibility, Agri-PV provides many opportunities for farmers and landowners in the MENA region to implement this system. The region has high solar potential due to its favourable geographical location and long solar exposure over the year, with a daily sunlight average of 10 hours and more than 300 clear days per year[18]. However, the region is prone to frequent sandstorms, high humidity, and hail and airborne dust particles that serve as potential problems to PV structures[19].

Dinesh and Pearce (2016)[20] found that by increasing the tilt angle and height of the PV panels, less dust accumulation resulted. Additionally, the higher the PV module is built, the greater the chance for wind disruption and instability of the structure.

The Agri-PV structures are built mostly using steel, an expensive material, but recent research has shown the potential of using bamboo to replace steel in certain structures, as bamboo is fast growing, lightweight, very strong, readily available worldwide, and more affordable than steel[21].

Economic feasibility

While there are many benefits to implementing Agri-PV, there is a higher investment cost associated with these systems compared to conventional ground-mounted PV systems. There is a high upfront cost for the module installation due to design constraints, whether for interspace or overhead panels (overhead being more expensive the taller the set-up).

Agri-PV structures are usually built with bifacial panels or products that require a higher degree of transparency, thereby requiring special mounting systems[22]. The lack of experience with Agri-PV also raises initial feasibility study and project design costs.

Moreover, farmers may need to invest in new machinery that can operate under overhead panels. In the Al Attiyah Foundation January 2023 Sustainability Research Paper, the authors discussed the rising investment cost in renewable energy and sustainable projects. Investments into innovative technologies are often more capital intensive as they may require more advanced technologies and infrastructure, thereby making them more 'high risk' investments. However, Agri-PV as a renewable energy investment comes with additional revenue streams through energy generation and additional food security co-benefits that are even more compelling in arid regions where many crops cannot be cultivated without protection through shading.

Replacing diesel generators for irrigation and cooling systems through solar energy can also lead to additional savings, especially in countries with low capital costs. In countries with higher capital costs, farmers may be able to lease the Agri-PV modules to avoid high initial capex costs, or local regulatory bodies may be able to provide regulatory and monetary incentives for farmers to implement Agri-PV. Even if Agri-PV may not work for every farmer and every land type, there are still many benefits to installing solar on marginal or salt-degraded land[23].

Germany

Up until 1950, German farming was mostly conducted by hand. The introduction of technological advances forced agricultural farming to become more capital-intensive, shifting production from a needs-based approach to one that has been determined by growth. The majority of farmland in Germany is leased (about 59% in 2016), with the remaining farms and land run in the form of partnerships, cooperatives, and private limited companies[24]. Additionally, farmers continue to rely significantly on financial assistance provided by the Federal Government and the European Union through the Common Agricultural Policy (CAP). The CAP supports farmers based on their hectares of land while ensuring they are continually supported irrespective of output. It also aims to ensure farmers remain competitive and are not disadvantaged in the global market because of stricter standards and higher production costs compared to their global counterparts.

Despite having a high population density, almost half of the land in Germany is productive agricultural land. The agricultural sector is one of the four largest in the European Union, with around 50% of grassland and arable farming used specifically for food production, such as cereals, potatoes, oilseeds, fruits, and vegetables[25]. However, a growing population along with rising food and energy needs has presented itself as both a challenge and opportunity for farmers. As a means of diversifying their income, farmers have recently shifted their attention towards renewable energy, for example implementing wind turbines and solar energy, and utilising their land to produce biomass (such as rapeseed, maize, residual by-products like manure, straw, and timber). In 2019, around 15% of primary energy in Germany came from renewable energy sources, of which 58% stemmed from biomass[26].

Prices for solar PV fell by about 90% between 2009 and 2019 with the Levelized Cost of Electricity (LCOE) standing between 4–11 euro cents per kWh, making it the most affordable renewable energy technology today[27]. According to the Fraunhofer Institute for Solar Energy Systems (ISE), Germany had an installed PV capacity of around 59 GWp at the end of 2021. However, an additional 300 to 450 GWp is required by 2045[28]. ISE emphasises that the technical potential of elevated Agri-PV systems installed across Germany could provide up to 1.7 TWp[29], however, the necessary speed and scale of implementation is severely lacking.

Despite this, several research and demonstration projects have been implemented in Germany: for example, the Agri-PV site at Heggelbach at lake Constance, producing 194 kWp, was implemented by BayWa r.e. and Fraunhofer ISE. Others include a small Agri-PV plant in Morschenich-Alt operated by Forschungszentrum Jülich and other partners as part of the BioökonomieREVIER initiative. These show the large-scale potential of Agri-PV[30], albeit dependent on the type of farming and livestock production that takes place. A larger demonstration project in Jackerath operated by RWE is investigating the growth potential of crops under different Agri-PV systems. It is expected that the demonstration facility will provide up to 3 MWp, however construction is not expected to begin until summer 2023[31].

Given the interconnectedness of energy, water and food systems, a nexus approach is necessary to achieve both development and climate related goals. In the next decades, food, water, and energy demand in the MENA region will increase as the population grows and climate vulnerability accelerates. This is likely to amplify the scarcity of land suitable for agriculture which creates an additional threat to the region's food security.

The benefits of Agri-PV are wide-ranging and could potentially make a strong contribution to address these challenges. Agri-PV in agri-food chains can contribute to food security and nutrition, enhance productivity and support income diversification. Furthermore, it can contribute to minimising GHG emissions and help the agri-food sector adapt to the effects of climate change. However, challenges and barriers still exist to support its widespread development and utilisation, in part due to a lack of awareness for this innovative dual-use approach. Based on the experiences that have accumulated from other regions.

Agri-PV systems require an enabling environment that fosters investment. Building on the considerable expansion of solar PV that is already taking place, there is a clear opportunity for countries in the MENA region to update energy, climate and agriculture plans by integrating Agri-PV into national agricultural and energy strategies. Pioneering countries have also demonstrated the need for investments in technological innovation, research, and development (R&D) to scale up Agri-PV.

Climate finance and appropriately designed financial instruments and mechanisms can support pioneering farmers to overcome higher initial costs at this early stage of market penetration. If demonstration projects can successfully deliver the projected additional benefits, economies of scale will lower costs and therefore enable upscaling without continued subsidies.

Hence the governments in the MENA region should consider investing in lighthouse projects to incentivise commercialisation of Agri-PV. COP28 may be a great opportunity to showcase such achievements to a global audience, which could accelerate the deployment of Agri-PV more quickly once commercial viability has been demonstrated. Collaborative research and pilot projects, as well policy dialogues between MENA countries and front-runners such as Germany and Japan could disseminate best practices and further enhance the efficacy of establishing Agri-PV.

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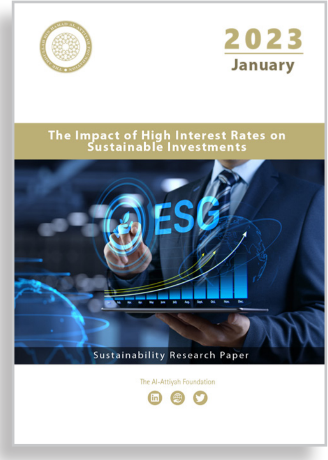

January – 2023

The impact of high interest rates on sustainable investments

How sensitive are sustainable investments to interest rate changes compared to non-sustainable investments?What role did low interest rates play in the growth of sustainable investments in the past decade? Do rising interest rates pose a threat to further growth of sustainable investments and the low-carbon transition? What policy measures can be implemented to cushion the effect of rising interest rates on sustainable investments?

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December – 2022

COP27: Taking Stock

Negotiations at COP27 revolved around the remaining prospects of avoiding a global temperature increase of 1.5°C; the provision of climate finance to assist developing countries to mitigate and adapt; and the establishment of new funding to compensate vulnerable countries for loss and damage.

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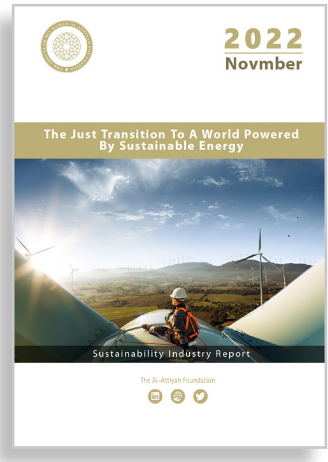

November – 2022

The Just Transition To A World Powered By Sustainable Energy

The energy transition will affect fossilfuel dependent countries, communities, and localities very differently. The financial flows from developed countries to developing countries have always been a thorny issue in climate change negotiations.

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OUR PARTNERS

Our partners collaborate with The Al-Attiyah Foundation on various projects and research within the themes of energy and sustainable development.

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