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Agrivoltaic Systems and Just Energy-Agriculture Transition in Southeast Asia

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To tackle climate change, Southeast Asian policymakers should look for ways to promote the use of renewable energy in agriculture. In this picture, a farmer operates a tractor to plough paddy fields in Pekan Bada, Aceh province, on 7 October 2020. Photo: CHAIDEER MAHYUDDIN/AFP.

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EXECUTIVE SUMMARY

- To tackle climate change and promote just energy transition, Southeast Asian policymakers should look for ways to promote the use of renewable energy in agriculture. This is because the sector consumes a significant amount of fossil fuels annually.

- Since the expansion of renewable energy increases land-use competition with agrifood production, policymakers should support measures to reduce renewable energy's land footprints, mitigate adverse effects on food security, and protect the livelihoods of vulnerable populations that might be affected by land-use changes.

- In Southeast Asia, there are now rural development projects that integrate renewable energy with agrifood systems. While they may have long-term environmental and economic benefits, renewable energy solutions in agriculture are more expensive compared to fossil fuel technologies. Therefore, governments should consider providing subsidies, grants, and low-interest loans to encourage agrifood actors to invest in such technologies. Alternatively, investments can be made through cooperatives, and farmers could be offered "pay-as-you-go" payment plans for renewable-powered services.

- Research from other regions suggests that agrivoltaic systems – where solar panels are integrated with farmlands – have the potential to increase land productivity in food-energy production, support rural electrification, generate employment opportunities, and diversify and increase the incomes of agrifood actors through the sale of electricity and ecotourism activities.

- To promote just transition, agrivoltaic projects can be organised as cooperatives where profits are shared among members. The energy and food produced can also be used to strengthen the energy and food security of low-income households. Research on agrivoltaic systems in Southeast Asia should also be strongly encouraged.

INTRODUCTION

The agricultural sector significantly contributes to climate change and should also be included in discussions about renewable energy transition. The current agrifood systems – the production, transportation and consumption of agrifood products – predominantly rely on fossil fuels and account for 30 per cent of the world's energy consumption (IRENA and FAO 2021, 9) as well as 21-37 per cent of total greenhouse gas emissions (Mbow et al. 2019, 439). Moreover, transition to renewable energy will increase competition for land and water usage (FAO 2021, 29; IRENA and FAO 2021, 32; Weis 2010, 325), which could undermine agrifood production and lead to social conflicts (Sovacool 2021). One study suggests that Nationally Determined Contributions (NDCs) of countries that are Parties to the United Nations Framework Convention on Climate Change (UNFCCC) will require 1.2 billion hectares (ha) of land – the equivalent of the global cropland area – by 2060 to meet these goals (Dooley et al. 2022, 8-9). Half of these (633 million ha) will entail changes in land use that could adversely affect biodiversity, agrifood production and the livelihoods of indigenous peoples and small-scale farmers (Dooley et al. 2022, 8-9). The development of solar parks in India, for example, has led to deforestation and undermined some people's access to common land that they rely on for energy resources and food production, such as biomass and cattle grazing land (Stock 2022, 171-172).

To tackle these issues, Southeast Asian policymakers should look for ways to promote the use of renewable energy in the agricultural sector, reduce land footprints in the production of renewable energy, mitigate adverse effects on biodiversity and food security, and protect the livelihoods of vulnerable populations that might be affected by land-use changes. Most of the energy used in Southeast Asia's agriculture comes from fossil fuels (IRENA 2022, 7) and although the agricultural sector consisted of only 10.5 per cent of Southeast Asia's gross domestic product (GDP) in 2020 (ASEAN 2021, 26), the sector is a major source of employment in countries such as Cambodia, Myanmar and Laos (33, 50 and 45 per cent of employment respectively) (ASEAN 2021, 39). With examples from Southeast Asia, the following sections discuss how renewable energy can be integrated into agrifood systems, explore the potential of agrivoltaic systems in the co-production of energy and food, and provide policy recommendations which take social justice into consideration.

RENEWABLE ENERGY IN AGRIFOOD SYSTEMS

Renewable technologies can be used in the production, processing and storage of agrifood products to reduce reliance on fossil fuels, improve energy access in rural areas, as well as increase productivity, reduce losses and add value to agrifood products (IRENA 2022, 16-17). Solar pumps for irrigation, for example, have helped to increase the incomes of small-scale farmers in South Asia and Africa (IRENA and FAO 2021, 34-36). Globally, many farming groups have started to use solar, micro-hydro and geothermal energy to process agrifood products (IRENA and FAO 2021, 49-50). Solar- and biogas-powered cold storage units have also helped to lengthen the shelf-lives of agrifood products, which increases farmers and fishermen's bargaining power vis-à-vis middlemen, and geographically extends their market reach (IRENA and FAO 2021, 42-46).

In Southeast Asia, there are now many rural development projects that integrate renewable energy with agrifood systems (IRENA 2022, 10-11). In Cambodia, Thailand, Vietnam and Indonesia, there are programmes that promote the use of bioenergy derived from agricultural residues and wastes – both for household uses, such as for cooking and electricity generation, and for small-scale processing plants, such as rice and sugar mills (IRENA 2022, 11, 20-29, 35). As part of Vietnam's biogas digester programme, more than 1,000 technicians and 1,700 masons have been trained and over 20,000 people have been employed since 2003 (IRENA 2022, 17, 28). Other examples include the Philippine's I-PURE project (Integration of Productive Uses of Renewable Energy) that promotes technologies such as solar-powered water pumps and coffee and seaweed dryers (IRENA 2022, 31-32), and the SWITCH to Solar project in Cambodia that supports the use of solar-powered dryers of organic herbs and spices to reduce losses during transport (SEADS-ADB 2021). Solar-powered cooling technologies have also helped many small-scale fishermen in Indonesia to preserve fresh catches and increase their incomes (IRENA 2022, 12; IRENA and FAO 2021, 47). The next section further investigates the dual production of food and energy in farmlands through agrivoltaic systems.

THE POTENTIAL OF AGRIVOLTAIC SYSTEMS

To generate the same amount of energy, solar photovoltaic and wind turbines have much higher land footprints compared to nuclear and fossil-fuel power plants (Lamhamedi and de Vries 2022, 9-10; Walker 1995, 4). To maximise land usage, one possible solution is that of "agrivoltaic systems", where solar photovoltaics are integrated with farmlands to produce both food and energy (IRENA and FAO 2021, 32). Ideas for agrivoltaic systems originated in Germany in 1982 and in Japan in 2003, and different names have been used such as agrophotovoltaics (Germany), photovoltaic agriculture (China), and solar sharing (Japan) (Brohm and Khanh 2018, 24). Large-scale agrivoltaic projects emerged in the 2010s, such as those in Germany, France, Japan, China and South Korea (Brohm and Khanh 2018, 6, 23-24, 31-38). France, for example, has integrated solar panels in vineyards, while the US and Australia have experimented with animal grazing in shaded areas under solar panels (Energy Watch 2021).

Aside from increasing land productivity, agrivoltaic systems can potentially increase the productivity of aquaculture and the yields of certain shade-loving crop species, such as leafy vegetables and herbaceous plants (Barron-Gafford et al. 2019, 848-851; Brohm and Khanh 2018, 29-30; Mamun et al. 2022, 9-10; Tajima and Iida 2021, 7). Agrivoltaic farming is also likely to be useful in water-scarce regions. A study of agrivoltaic in dryland areas in the US, for example, suggests "synergistic benefits" between energy and food production (Barron-Gafford et al. 2019). As solar panels reduce water evaporation from the soil and increase the productivity of chiltepin peppers and cherry tomatoes, growing crops underneath helps to lower the temperature of solar panels, which is good for their efficiency (Barron-Gafford et al. 2019, 848-851). Another project in Brazil called "Ecolume" has also found that, without the need for

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pesticides, agrivoltaic systems can help to increase agrifood production and restore degraded land in semi-arid areas that suffer from water shortages (Martinez 2022).

Agrivoltaic systems can also reduce greenhouse gas emissions, support rural electrification, generate employment opportunities, as well as diversify and increase the incomes of agrifood actors through the sales of electricity and ecotourism activities (Brohm and Khanh 2018, 29-30; Gonocruz et al. 2021, 14; Mamun et al. 2022, 10). In Japan, agrivoltaic is seen as a solution to rural economic decline and over 120 crops, including rice, can now be grown in agrivoltaic systems (Tajima and Iida 2021, 3). One study estimates that, if agrivoltaic systems were to be applied to rice paddies in Japan, the electricity generated would meet 29 per cent of total electricity demand in the country in 2018 (Gonocruz et al. 2021). Another good example is in Jiangshan, China, where a 200 Megawatt (MW) agrivoltaic project, situated on degraded land, has been generating incomes from energy and biodiverse food production and ecotourism since 2015 (Xiao et al. 2022, 2-6). It is expected to meet the annual electricity demand of 400,000 people in Jiangshan city for 25 years, and has so far employed over 1,000 farmers and over 200 locals and agricultural specialists (Xiao et al. 2022, 7).

Pilot agrivoltaic projects can also be found in Southeast Asia, but much more research and development are needed to evaluate and fully realise the potential of agrivoltaic systems. One report funded by Rosa-Luxemburg Foundation and GreenID (Vietnam) suggests that, based on a comparative study of international experiences, Can Tho city in the South of Vietnam has a high potential to develop agrivoltaic farming of rice, maize, soybean, sesame, vegetables, cassava, livestock, fish and shrimp, and that the electricity generated could exceed the city's electricity demand (Brohm and Khanh 2018, 6-7). There is also now a pilot project in Vietnam – PV SHRIMPS – that applies solar photovoltaic to shrimp farming in Southern Bac Lieu province. Funded by the German GIZ Energy Support Programme, the project aims to study technical and economic viability of agrivoltaic systems in small-to-medium size aqua-farming units, with subsequent plans to promote knowledge diffusion in the Mekong Delta (Brohm and Khanh 2018, 39).

Pilot agrivoltaic projects in other Southeast Asian countries are also in nascent development stages. Examples include an eggplant-growing agrivoltaic project in Baron Technopark, South Java Island, Indonesia (Ahmad et al. 2022), an agrivoltaic project in Malaysia jointly operated by Universiti Putrajaya and PEKAT solar (Energy Watch 2021), and Citicore Power's Agro-Solar initiative where the company works with local farmers and cooperatives to promote dual energy-food production (Manila Standard 2022). In Thailand, an academic study found that the yield of bok choy vegetable in a pilot agrivoltaic project in Chiang Mai is very low (Kumpanalaisatit et al. 2022). However, given the potential of agrivoltaic systems, the same study recommends further research on other shade-tolerant crops (Kumpanalaisatit et al. 2022).

POLICY RECOMMENDATIONS

Policies to support just energy transitions usually focus on compensating and retraining workers in the fossil fuel industries, and on the creation of decent jobs in the green sectors – with wider goals to promote inclusive, sustainable and gender-sensitive development that takes

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into account difficulties facing vulnerable groups (Elliott and Rahman 2021). However, given that renewable energy requires large land footprints, policies to promote just energy transitions should also consider the potential effects of renewable energy expansion on land use, food security and other adverse consequences on the local populations. As this paper has discussed, agrivoltaic systems can potentially increase land efficiency, promote both energy and food security, and increase farm incomes. However, the design and implementation of agrivoltaic projects ought to consider social justice and distribution of economic benefits as well as technical aspects of energy-food production. Policy recommendations to promote renewable energy solutions in agriculture and agrivoltaic systems in Southeast Asia are further discussed below.

- Renewable energy solutions in agriculture are still more expensive compared to fossil fuel technologies (IRENA and FAO 2021, 37-38) so agricultural actors might be hesitant to take on such large investments, even though there are long-term environmental and economic benefits. Governments should incentivise large and financially secure agribusinesses to invest in renewable energy solutions. Additionally, governments and donors should provide subsidies and grants, coupled with low-interest loans, to help small-scale farmers (or their cooperatives) to invest in renewable energy equipment such as solar pumps and cold-storages. Alternatively, farmers may be offered "pay-as-you-go" payment plans for renewable-powered services (IRENA 2022, 16; IRENA and FAO 2021, 37-38, 48; Johnstone et al. 2022). For biogas projects in Vietnam and Indonesia, subsidies accounted for only 10 and 20 per cent of total investment costs (IRENA 2022, 26, 35). Since farmers bear most of the costs and the risks involved, there should be further studies into the long-term cost effectiveness of these projects and potential effects on rural debts. Projects can also be designed for women empowerment. The I-PURE project in the Philippines, for example, sets a target to specifically involve women's groups in post-harvest agri-fishery activities (IRENA 2022, 32).

- To support agrivoltaic projects, expected financial returns from selling renewable power should incentivise investments. Due to high initial costs, external finance is likely needed to support farmers who want to invest in agrivoltaic systems (Brohm and Khanh 2018, 70). With regards to regulatory frameworks to balance food and energy production, Southeast Asia can learn a lot from Japan's experience. After the Fukushima nuclear disaster in 2011, the Japanese government encouraged renewable energy investments by introducing a very generous electricity feed-in-tariff (FIT) rate and by allowing new entrants into the power sector (Spivey 2020, 1691, 1699). To an extent, food security is protected as farmlands are not allowed to be turned into mega solar parks, and the Japanese Ministry of Agriculture, Forestry and Fisheries also requires that agrivoltaic systems in rice paddies still produce at least 80 per cent of the yield of conventionally-grown rice (Gonocruz et al. 2021, 14; Spivey 2020, 1702). Due to the protection of farmlands, large-scale investors have developed mega solar projects on forested and underutilised land in rural areas, causing local conflicts (Spivey 2020, 1702). On the brighter side, such regulatory change has encouraged rapid expansions of community-based renewable energy companies and agrivoltaic farms (Spivey 2020, 1702; Tajima and Iida 2021, 6). There are now over 1,992 agrivoltaic farms (560 ha in total) across Japan, and most of them are small-scale operations (less than 0.1 ha)

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(Tajima and Iida 2021, 2). Agrivoltaic farms generated only 0.8 per cent of total power of solar photovoltaics in Japan in 2019 (Tajima and Iida 2021, 2). However, if all of the abandoned farmlands (423,064 ha) were to be converted into agrivoltaic farms, these could produce another 280 gigawatt (GW) of electricity (Tajima and Iida 2021, 7).

- Publicly funded research on renewable energy solutions in agriculture and on agrivoltaic systems should consider the needs of smaller actors as well as larger ones. It has been noted, for example, that research is very much needed on renewable-powered agricultural equipment that are suitable for use in small-to-medium size farms (IRENA and FAO 2021, 51-52). As for agrivoltaic systems, more studies are needed on suitable crops, safe integrations with livestock grazing, the applicability of next-generation solar panels, long-term environmental effects of agrivoltaic systems (such as the effects on biodiversity), and the consequences of e-wastes from solar panels (Barron-Gafford et al. 2019, 852; Gonocruz et al. 2021, 15; Mamun et al. 2022). More research is also needed on the economic viability and socio-environmental effects of agrivoltaic systems on urban rooftops (Jing et al. 2022), and of "floatovoltaics" – where solar panels are used to cover water reservoir (Almeida et al. 2022).

- To promote just transition, the design and implementation of agrivoltaic projects should go beyond technical issues to include socio-economic considerations. Southeast Asia can learn from socially conscious agrivoltaic projects in other countries, such as Jack's Solar Garden in Boulder County, Colorado in the US. This research and learning centre donates two per cent of its energy production to low-income households, and its agrifood products are distributed to food insecure people through farmers' markets and the government's Supplemental Nutritional Assistance Programme (SNAP) (Solar Power World 2021). Agrivoltaic projects can also be organised as cooperatives that share profits among members. Examples of such organisational models can already be found in well-established energy cooperatives in various parts of the worlds, such as in the UK (Rapid Transition Alliance 2021).

Given the potential of renewable energy solutions in agriculture and of agrivoltaic systems, further research on these topics should be supported by Southeast Asian governments. Although research on technical feasibility is important, there should also be research and pilot projects that investigate how these green technologies can be used to promote development goals such as women empowerment, universal energy access, food security and the reduction of economic inequality.

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