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Forum

Toward Future Photovoltaic-Based Agriculture in Sea

Khaled Moustafa[1,*]

To meet the challenges of climate change and water shortages, combining solar energy-based seawater desalination technologies with floating agriculture stations in one innovative hybrid system would be worthy of investigation for dry and sunny regions for seawater desalination and crop production within the same platform. Here, I discuss the feasibility of such a 'floating farm' or 'bluehouse' in the sea, by comparing it with the use of terrestrial greenhouses. I also debate the potential advantages and shortcomings of such a system.

Introduction

Climate change and water shortages are important challenges for the future of agriculture, with substantial consequences for food security and environmental sustainability. Among the potential solutions to alleviate such challenges is to opt for vertical farming [1] and to breed new plant species that could be irrigable with seawater [2,3]. Investors and researchers should also address any other potential approaches that would help develop sustainable farming systems to minimize the burden on freshwater and to increase plant productivity, particularly in dry and arid lands where water shortage is at its most extreme.

Covering approximately 75% of the Earth, seawater is the most sustainable and inexhaustible source of water on the planet. However, in its natural state, seawater is unsuitable for productive agriculture and human consumption. To be usable, seawater needs to be desalinated (i.e., purified from its excess salts) to produce freshwater suitable for irrigation and human uses. Solar energy-based seawater desalination is one of the most promising desalination approaches that could be used in sunny regions, either directly to produce water distillate in solar collectors, or indirectly by combining other conventional desalination techniques, such as multistage flash desalination (MSF), vapor compression (VC), reverse osmosis (RO), membrane distillation (MD), or electrodialysis (ED) [4]. The availability of intensive solar energy in dry sunny regions over the year would make it possible to build large-scale solar-based desalination facilities [5]. Although the quality of desalinated water produced from seawater might not be optimal for plant irrigation and human consumption, different treatments are available to stabilize it and to ensure its quality via processes such as recarbonation, disinfection, and remineralization [6].

Photovoltaic Floating Farms as a Potential Agriculture and/or Aquaculture Solution

In the context discussed above, a new hybrid system combining in one structure a solar energy-based seawater desalination approach with a 'floating farm' station is worthy of investigation for use in dry, sunny coastal regions. Such a system could be implemented offshore as a 'floating marine field' or 'bluehouse' (in contrast to a terrestrial greenhouse). A conceptual design of such a system is given in Figure I (Box 1), and could comprise three main parts or units: (i) sunlight capture unit (or photovoltaic) that captures sunlight and converts it into electricity; (ii) thermal desalination unit to desalinate seawater using the energy produced in (i); and (iii) a 'floating farm' unit with a cultivable surface (e.g., sandy, hydroponic, or organic culture support) with walk-in growth rooms or corridors. The solar energy would first be collected by photovoltaic cells and then converted into electric power that could be used to desalinate seawater via a thermal approach (i.e., heating and condensation). The resulting freshwater would then be used to irrigate plants growing on board (Box 1). Coupling other desalination approaches and/or alternative energy methods (e.g., wind turbines) to the photovoltaic-based desalination approach could also increase the amount of freshwater and energy produced overall.

To provide the most effective expertise for building such a system, multidisciplinary investigations would be required, involving marine engineers, economists, mathematical modelers, system and mechanical engineers, biotechnologists, water purification and safety management specialists, and plant biologists. In an ideal approach, photovoltaic-based floating farms would be designed to be immobile, semi-mobile, or completely mobile (automatically adjustable). However, mobile or adjustable systems would be costly but with major advantages over other options in that they could be moved in response to natural disasters, such as any decrease or increase in seawater levels; in addition any salt accumulated during the desalination process should be diluted or discharged back into the sea as far from the site as possible.

Recently, prototypes of semi-transparent-bifacial photovoltaic modules for greenhouse roof applications were developed with potential for use in high-irradiation regions [7]. Moreover, the international BMT Design & Technology group (Melbourne, Australia) is currently working on a floating desalination system with the potential scalability to produce up to 150 million liters per day (http://www.bmtdesigntechnology.com.au/design-solutions/floating-desalination-plant).
Thus, combing similar, movable desalination stations with floating farm surfaces on board could be worthwhile investments for countries where freshwater is scarce and solar energy is plentiful over the year.

Depending on the crops that would be cultivated in such systems (e.g., cherry

Box 1. Photovoltaic-Based Agriculture in Sea

A conceptual design for a prospective hybrid photovoltaic-based agriculture system combines a seawater desalination station and a floating agriculture system (floating farms or floating fields) for sunny costal regions (Figure I). In contrast to terrestrial greenhouses, comparable solar energy-based structures ('bluehouses') could be built offshore comprising three main units: (i) a photovoltaic unit to capture sunlight and convert it into electric power that would be used to automate the system and meet all its power needs; (ii) a desalination unit to desalinate seawater thermally (or through a hybrid approach based, for example, on thermal and membrane desalination approaches); and (iii) a confined floating farm in which plants grow and are irrigated with the freshwater produced in (ii).

To set up the appropriate materials and proportional surfaces and volumes of all the inputs and outputs of such a system, precise calculations and multidisciplinary investigations would be required involving marine engineers, mechanical engineers, economists, plant biologists, and water purification and safety management specialists. The prospective system could be fixed or, preferably, would mobile or adjustable to respond to fluctuating environmental conditions or disasters (e.g., changes in seawater level or hurricanes).

The plants could be grown on organic matter, sand, or using a hydroponic system with one or more layers (or flats); this could be circular, square, or rectangular, and designed with walk-in growth rooms or corridors, and so on. To maximize the energy produced, wind turbines or tidal and wave power-generated energy could be combined with the photovoltaic panels so that additional energy is generated to allow full automation of the entire system, including automatic level adjustment and adjustment of growth conditions to meet any specific needs of the crop grown on board. High-value plants, vegetables, medicinal plants, or even rice in an adapted planting system, could be tested to grow in such a set-up.

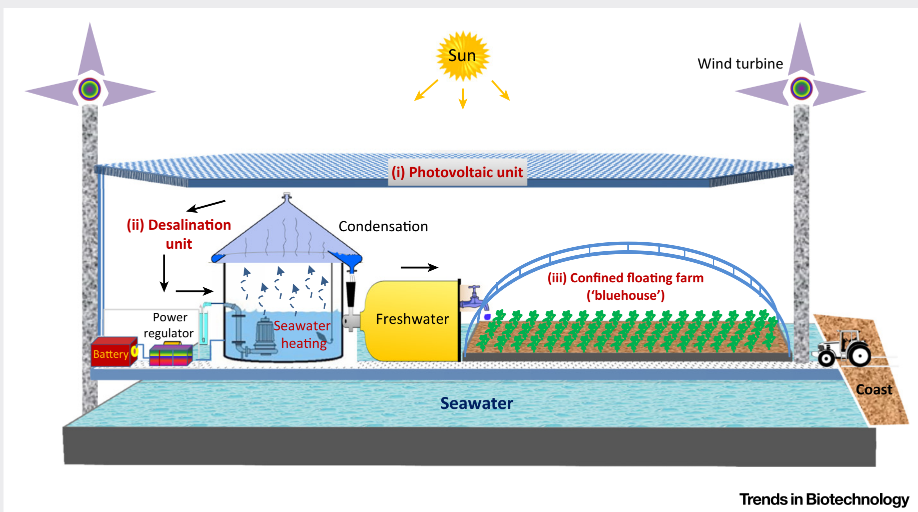

Figure I. The Proposed Photovoltaic Agriculture System.

tomato, strawberry, spinach, lettuce, or even rice using appropriate apparatus), precise calculations would be needed to establish optimal and proportional surfaces, volumes, farming support surfaces, thickness and appropriate physical and chemical characteristics of all the materials and components used. For example, what are the conditions needed to set up a photovoltaic surface that would produce sufficient energy to fulfill all the energy requirements for X m^2/m^3 of culture surface not only over the whole life cycle of the growing plants, but also before and after harvest, when energy and freshwater are also needed. Farming operations onboard and system maintenance could also be fully automated. To do so, energy and freshwater should be produced in excess and stored to be used as required (beyond the requirements of the system, any excess energy and/or freshwater could be transferred to land for human use or industrial applications).

Expected Advantages

Floating photovoltaic-based farms should offer many advantages over traditional soil-based farming systems, including, for example, the possibility to avoid the effects of high temperature and sand storms, which can damage desalination stations built on land [8]. Given that it should be possible to have full control of all the environmental aspects of a floating farm, they should offer optimal conditions for plant growth and maturation, maximizing the yield of crops. In addition, well-designed and isolated floating farms would reduce the impact of plant disease and resulting yield losses, also avoiding the need for pesticide use, in contrast to terrestrial farms, which are exposed to a variety of biotic and abiotic stressors. This could be achieved by using appropriate wall or barrier designs; such systems are currently used in hospitals to protect vulnerable patients, and are already suggested for use in indoor farming [1]. To meet the quality criteria required for plant irrigation, salts resulting from the desalination process could be reused in controlled and optimal proportions as mineral fertilizers for the floating farms after qualitative