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Agri-voltaic-triple land use: A review

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Abstract
Agriculture is backbone of Indian Economy. Sixty percent of the population is directly or indirectly dependent on Agriculture. Urban centres in India are facing an ironical situation with regard to water today. On one hand there is acute water scarcity and on the other, the streets are often flooded during the monsoons, requiring managerial efficiency of the Urban Local Bodies to use the surplus water of the rainy season to overcome the deficiency in other seasons. Harvesting and collection of Rainwater is a proper method that can be used to address the problem of water crises in various parts of the world. The future requirement of increasing energy and food production, Agri- voltaic systems (AVS) have been identified as a mixed system combining photovoltaic with agriculture at the same time on the same land. An innovative approach of agricultural mechanism- food production along with energy generation which benefits farmers economically and provides a new scope of development and revival in Indian Agriculture. Water Energy and Food (WEF) Nexus solutions such as agrovoltaics are increasingly being deployed to improve access to water for agricultural uses, improve yields and incomes, reduce drudgery especially for women, enhancing resilience and microclimate, and improve land use efficiency and food security. This innovative approach has opened new prospects to improve the quality of life for people as well as their environment as a whole.

Keywords: Agriculture, rainwater harvesting, triple land use, Photovoltaics, renewable energy

Introduction

Agriculture is the main source of food for human beings. However, agricultural farm needs a constant energy supply for operation of machineries, vehicles, irrigation pumps etc. which is conventionally, generated by fossil fuel. There is an increasing alarm that these fossil fuels will be exhausted soon due to increasing continuous demand for consumption. There are many possible sources of renewable energy but solar energy is the best form as it is possible to put up in almost all parts of the earth’s land surface, pollution free and cost efficient. Climate change is heightened by using machineries operated by fossil fuel energy in agricultural farms as it emits lots of greenhouse gases. The use of solar energy does not emit greenhouse gases unlike fossil fuel. As a result, now a day many developing countries are switching to renewable energy such as solar energy, which can be used for various purposes, including agriculture farm cultivation, greenhouse cultivation, water pump for irrigation, drying products, space heating, ventilation and so on in order to reduce the environmental problems.

Agro-voltaics refers to the innovative idea of developing the same area of land for solar energy generation as well as for agricultural production through photovoltaic methodology. It is also known as agrovoltaics.

In view of the future requirement of increasing energy and food production, Agri- voltaic systems have been identified as a mixed system combining photovoltaic with agriculture at the same time on the same land. Most of the areas receives ample amount of solar radiation though not properly utilized. To date, the ways by which solar efficiency can be maximized on the same land is not sufficiently addressed globally. Establishing PV panels at a location that is already in use, such as agricultural land, rooftops, parking garages, or other sites like wind farms, affords dual-use opportunities, taking advantage of the productivity of land use. Agricultural lands provide ideal opportunities for dual-use of lands as solar panels can intentionally be placed to provide energy while allowing continued productive agricultural use of the site. In other words, use the same unit of land for agriculture and electricity generation simultaneously. For some crops, solar radiation is frequently too intensive in high-irradiation temperate regions and especially during the summer. Accordingly, shade screens are used to reduce or moderate the light intensity which can be replaced by solar panels like semi-transparent PV panels. A potentially serious conflict of land-use between agricultural production and clean energy generation, on the other hand, is of great importance to find a way to combine these two. In order to fulfill the present as well as future requirements of these resources, the role of agrovoltaics has been discussed and proved through various research and experiments conducted worldwide. These experiments reflect the great potential of this the technique in enhancing farmer's income and in improving their livelihood.

Literature Review

Importance of renewal energy for agricultural farm

Several reviews of literatures have highlighted the importance of combining renewable energy and agricultural farming. The different types of solar energy technology applications for crop and grain drying, space and water heating, greenhouse heating, solar photovoltaic system and water pump for irrigation was discussed. (Chikaire *et al*., 2010; Mekhilef *et al*., 2013) [6, 15]. It was considered solar panel / photovoltaic (PV) system as the most suitable option in agricultural works especially in rural distance areas since the maintenance of solar panel system is cheap with no environmental impact and can be used for many purposes. This is further supported by Qoaider and Steinbrecht (2010) [18] investigated the economic feasibility of PV technology in providing the energy requirements for irrigation in remote farming communities in the rural arid regions with aims of helping the communities, thereby decreasing the high costs of generating electricity using diesel. This innovative energy technology system is a key for leading the region to sustainable development. It is technically designed, including calculation of the life cycle costs (LCC) of a PV system, which can supply the entire energy demand of the villages. Bardi *et al*. (2013) [3] examined the possibility of farmers switching from fossil fuels to renewable alternative energy, which may result to increase in the quality as well as quantity of food production in several types of agricultural farms. Along with this, it can supply power for operation of agricultural machineries including vehicles for transportation and for field work. Currently, only a few machine operators in the agricultural sectors are aware of the problems related to fossil fuel depletion and climate change. This is the root cause of the problem of climate change. Unless there is an attitude change among the farmers, the problem will worsen. So, it is advisable for agricultural farmers to use energy saving devices for growing crops and to maximize land by using PV system because it is economical, cost saving and can be used for multiple purposes (Dupraz *et al*., 2011) [8]. Similarly, Santra *et al*. (2017) [19] considered agri-voltaic system as the future energy source for food production as it has the different options for using the system even in hot arid weather condition.

PV-based electricity generation from agri-voltaic system

The effective solar irradiation to generate electricity is available for an average of 4 to 5 hr in a day. Therefore, 1 kW PV system is expected to generate 4-5 kWh unit of electricity per day. The AVS has been connected to local electricity grid through net metering system. Therefore, the generated electricity is directly sold to state electricity board at a fixed tariff which varies across different states of India. The average tariff rate of Rs. 5/kWh may be

Considered to calculate the income from PV-generated electricity. Dupraz *et al*. (2011) [8] discussed the best strategies to convert solar radiation into both energy and food by designing the light transmission system at the cultivated crop by an array of solar panels and used a crop model that can predict its productivity. It is also called photovoltaic agriculture or

Agro-photovoltaic (APV) and is a natural response to supply the green and sustainable electricity for agriculture (Xue, 2017) [21]. This system was developed by raising the solar panels to 2 m above the ground in order to increase moderate shading of the crops (Weselek *et al*., 2019) [20].

Rain water harvesting

In Agrivoltaic system, PV panels water run-off from the panel surfaces. Water moves quickly due to no infiltration and panel angle. Rainwater can be harvested from the top surface of PV modules in Agrivoltaic system by fixing a suitable gutter at the bottom of the panel and thereby creating a possibility to use that harvested water for cleaning and irrigation, after storage. The potential capacity of rainwater harvesting from Agrivoltaic system depends on the mean annual rainfall received at a particular area, the area of PV array and the type of designing. Dust deposition on the PV panels with time is a common problem especially during dry seasons and in arid regions. Dust reduces the transparency of panels thereby reduces electricity generation. Therefore, regular cleaning of deposited dust is essential. A considerable amount of water is required and also that water can be again used to irrigate the plants. Periods in which the water is scarce, this stored harvested rain water can be very useful for irrigation as well as for cleaning purposes of PV panels. Dry cleaning of solar panels also becoming popular using specially produces brush and also could be automated. It has been reported that, in temperate regions, during the winter period, the formation of a sticky dust layer on the PV module after fixing with the dew at the night can be a problem. Same authors reported that, cleaning of PV modules is important for efficient and economical electricity generation.

Radiation availability for the crop under agrivoltaic systems

Bot *et al*. used the Dutch greenhouse for agriculture, without any fossil fuels. During the summer months, photovoltaic panels were set up to absorb light energy, store it and use the energy in winter when incident light is less and days are shorter. Then the overall energy savings realizable was over 60 percent. Dupraz *et al*. founded that agrivoltaic schemes to be competitive, environmentally sustainable and have high production rates. Cossu *et al*. evaluated climate conditions within a greenhouse with roof area replaced by photovoltaic modules of 50 percent. The reduction in solar radiation within the greenhouse was an average of 64 percent and up to 82 percent for the areas under the PV covers, and 46 percent under the transparent covers. Harinarayana and Venkata studied the use of fertile and cultivated land with about 5 m elevated structure with solar panels. 20% — 25% reduction in sunlight for 11.4 m separate panels, 25% — 30% reduction for 7.6 m and shades of chess pattern, 60% — 80% reduction for 3.8 m separate panels. Armstrong *et al*. Stated that seasonal and diurnal changes in air and soil microclimates were caused by the PV arrays. In particular, up to 5.2 °C during the summer cooling and up to 1.7 °C cooler during the winter period compared to under the PV arrays. PAR was 92 percent lower; rainfall was three times higher on average and wind speed was just 14 percent higher in control areas. Beck *et al*. observed in their simulation that directing the PV arrays towards southwest or southeast was most suitable to achieve uniform light conditions under the panels. This also resulted in a predicted reduction in electricity yield of 5% compared to conventional south-oriented arrays. The optimum module tilt angle depends on the geographical location; in Central Europe it is around 20–25°. It should be noted that a small inclination angle can lead to increased dust depositions as these are not washed off by the rain so easily. The same applies to snow covering in regions with regular snowfall. Dupraz *et al*. suggested modifying the panel tilt during certain periods of the year that correspond to light-sensitive stages of crop development.

Effects for the food-energy-water connection

While impacts varied by crops type, the agrivoltaic systems held promising implications for food production, water savings/water harvesting, and renewable energy production. The decrease in direct sunlight exposure benefits the SPV panels led to cooler air temperatures during the day and warmer temperatures at night, which allowed the plants under the solar arrays to retain more moisture than the open field crops that cultivated in open-sky planting areas.

Conclusion

The Agri-voltaic technology offers a number of benefits that differ depending on geographical and atmospheric condition. The AVS approach is advantageous in thickly populated developed and developing economies, where the renewable sources of energy development and gaining importance considerably. The LER value is used to determine AV system performance and if it exceeds one, the system is said to be optimal. Agrivoltaic system can be planned to optimize power production and anticipated crop yields. An agrivoltaic system may be a feasible option for the future in dry and arid regions of the nation. Additionally, the shade adapted crops and crop cultivated in hot, dry areas may be benefit from enhanced water savings as well as protection from the detrimental effects of high temperature and excessive radiation. Furthermore, by incorporating the additional system of rainwater harvesting, the stored water can be used for supplemental irrigation of crops during the dry seasons as well as clean the solar panels of dust to increase the efficiency of electricity generation. Also, aquaculture could be an additional option in stored water.

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