Emerging Solar Energy Technologies for Sustainable Farming: A Review

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Abstract

This study extensively reviewed some literature on new solar energy technologies used in farming sector across the world in an attempt to sustainably protect the environment while producing food and/or harvesting food and energy together on the same farmland (dual farming). Emissions from agricultural activities across the globe and its contribution to the climate change were also reviewed. The study is divided into six parts; Introduction, Solar energy technologies and their benefits, solar energy technology tools used in farming, dual farming technology, emissions from agricultural activities and conclusion. The study drew conclusion from the literature that many developed and developing countries of the world such as U.S., U.K., Germany, China, India, Canada e.t.e have adopted the new farming technologies whereas many African farmers are yet to smell the benefits of these farming technologies despite the fact that African continent possesses 60% of the world agricultural land (RFI, 2019) and its solar energy potential is very high.

Key words: Emissions, Solar energy, Solar technology, Sustainable farming

1. INTRODUCTION

Agricultural production has much significant potential to build farmer’s recovery from food insecurity. Sustainable farming practices are highly known to increase productivity in agriculture, improve farmers’ incomes and contribute to climate change mitigation (reduction in emissions). Sustainable agriculture involves adoption and use of modern technologies which are harmless to the environment we live in [1]. Brown in 1987 highlighted on the concept of sustainable agriculture to comprise characteristics that include long-term maintenance of natural systems, adequate return per unit of farming, optimal production with minimum input, fulfillment of basic food needs, provision of the demands and necessities of rural families and communities [2]. In other words, sustainable farming is farming ecologically by promoting methods and practices that are economically viable, environmentally sound and protect public health. The United Nations’ SDG No. 2 is ‘‘Zero Hunger’’ and this can be achieved through the use of modern solar agricultural technologies which are sustainable in nature. Applying solar energy in agriculture is a good step forward in boosting productivity, farmers’ revenue, rural job creation, groundwater management and environmental protection. According to European Parliament, in its report of 2016, farmers in Europe had made concerted efforts in bringing down the level of emission by pushing up their consumption and production of clean and renewable energy resources [3]. The use of renewable energy such as solar energy in farming is the most important practice of sustainable agriculture because it is ecology friendly. Farmers can use solar panels to generate energy and use it for a number of agricultural purposes which include irrigation, heating, fencing among others.
and can also send their surplus energy generated to the grid and get paid by the government in countries such as U.S., Germany, China and India among others. According to a study conducted by Oregon State University in United States, 2019; the most productive places on earth for solar power are farmlands. The study further stated that if 1% of agricultural land were converted to solar panels, it would be sufficient to fulfill global electric energy demand [4]. The aim of this paper is to review across the world, the use of solar energy by farmers for sustainable farming practices and development.

**SOLAR ENERGY TECHNOLOGIES AND THEIR BENEFITS**

The Sun is a common feature in the sky. It is seen every day crossing the sky from one extreme end to the other pouring light and heat to the surface of the earth. The Sun is free and huge source of energy for mankind. Solar power also known as solar energy is the energy derived from the Sun’s light and heat. Solar energy is a form of renewable energy that is a prime choice among all the renewable energy sources in developing decentralized, feasible and affordable global power source which can be utilized in all climatic corners of the world. It is a free energy source only that, the equipment to tap and transform it into electricity can be a bit costly. According to Green, 2001, the average solar energy amount radiated from the Sun to the Earth is about 1360w/m², which depends on regional weather condition and latitude [5]. Solar energy is the conversion of sunlight into usable forms of energy. Solar photovoltaic (PV), solar thermal electricity and solar heating and cooling are well established solar technologies. These solar technologies are briefly discussed here below;

**Solar photovoltaic technology**

Solar photovoltaic (PV) system is a solar technology which directly converts solar energy into electricity. PV therefore, generates power from sunlight and that power output is limited to the timeframe when the sun shines. Solar photovoltaic has brought numerous job opportunities around the world through manufacturing, trade, installation and maintenance. It also provides off-grid electricity to areas far away from the grid such as rural areas. It does not produce any emissions during operation and therefore positively contributes to climate change mitigation. It also helps reduce the dependence on energy imports.

**Concentrating solar power technology**

Concentrating solar power, also known as concentrated solar thermal is a solar system that generates solar power through the use of devices (mirrors or lenses) to concentrate sun’s rays to heat a receiver to high temperatures. The heat is then transformed into electricity known as solar thermal electricity (STE). This thermal electricity derived from the Sun does not produce any greenhouse gas emissions; it is therefore among the leading technologies in reducing the effect of climate change.

**Solar heating and cooling technology**

Solar heating and cooling technology (solar thermal technology) collects the thermal energy from the sun which is then used to provide hot water, space heating and cooling for residential, commercial and industrial processes/applications. The amount of temperature required to provide the heat demand depends on the type and design of the collector.

In 2012, International Energy Agency (IEA) published a Roadmap for solar heating and cooling in which it set a target of solar energy to supply almost one-sixth (16.5 EJ) of the global total energy used for heating and cooling by 2050 [6]

**SOLAR TECHNOLOGY TOOLS USED IN FARMING**
Solar energy and farming are good combination for sustainable agricultural production. Solar energy can be harvested forever and will provide farmers with long-term source of revenue. Today, farmers in many countries of the world have adopted the use of solar energy on their farmlands. Most of the agricultural equipment conventionally used in farming have today been designed into solar energy base i.e. they operate using energy generated from the Sun instead of fuels such as diesel, oil and gas. It was found after research that solar energy can supply many energy requirements of the farm. The amount of energy that reaches the Earth on daily basis is very high. Energy from sunshine in 20 days is equal to all reserves of coal, oil and natural gas stored in Earth [7]. Bajpaye 2019 in an article stated that agriculture is a sector that strives to adopt the use of solar energy and hugely benefits from it by meeting the increasing demand of agricultural products of the rising population [8]. Solar energy, therefore, can be used on farms in many ways leading to reducing pollution, saving money and increasing self-reliance. Solar technology equipment used in farming across the world include; solar mower, solar tractor, solar water pump, solar greenhouse, solar heater, solar electric fencing and solar dryer among others. These solar farm equipment and the benefits farmers derive from them are given below;

- **Solar water pump**

Conventionally, farmers use water-pump machines that use diesel, oil or gas to pump out water from deep wells and open dams to irrigate the farms. Today, with the advent of solar water pump, farmers in many countries of the world including U.S.A., Canada, Germany, France, Finland, China, India, and European Union (EU) have shifted to the use of solar energy for irrigation and livestock watering system.

Figure 1: Solar water pumping system

Solar photovoltaic (SPV) pumping system consists of solar panels, motor pump, on-off switch and control and tracking mechanism. This system uses solar panels to convert solar energy into electric current which is then used to power the pumping machine. Solar pumping system requires less power and also cost-effective.

To encourage farmers on the use of solar energy for water pumping on farmlands, the government of Rajasthan state of India has recently proposed a scheme of purchasing excess power generated by solar pumps at ₹3.14/kwh through which 1 million grid-connected solar powered agriculture pumps will be put to use under KUSUM program. Also 1.75 million standalone solar powered agriculture pumps to be installed across the state. Some states in India and China offer about 40% and 80% subsidies to farmers as motivation to use solar energy in farming. International Solar Alliance (ISA) member countries including India, Brazil, Tanzania, the Dominican Republic and Ethiopia among others came up with a program in 2018 of implementing 500,000 solar water pumping systems in order to scale up solar application for agricultural and rural use. According to World Bank, solar water pumping has proven to be financially, operationally and environmentally sustainable but in some parts of the world the benefits of solar water pumps remain unknown to governments, communities and development institutions. For that, the World Bank developed a knowledge base program on solar water pumping in 2017 to create awareness about the technology [9] Muhammad, Mosleh and Hague khan
expressed in their research conducted on Bangladesh that, the result of the cost-benefit-analysis showed a great economic advantage for the use of solar irrigation system over the traditional grid-electricity-driven pump irrigation system or fuel-base irrigation. They further showed that solar irrigation in Bangladesh didn’t only shorten the gap between demand and production of electricity and increase farmers’ yield but would also help bring down agricultural production cost substantially for 20 years to come [10].

- **Solar Dryer**

Solar dryers also called solar dehydrators are solar energy designed tool used by farmers to dry crops before packaging and sending them to markets or storage facilities. Components of a solar dryer include a shed, solar collector and drying tracks. They commonly use passive solar panels to generate energy and the crops get dried when hot air circulates through the shed by natural convection or forced fan. According to Schepens 1986, the size of the collector and rate airflow in solar dryer depends on the quantity of the material to be dried, the moisture content of the material, the average quantity of solar radiation available during the drying period and the humidity in the air [11]. A greater percentage of farm produce, especially perishable, get spoiled during the traditional open-air drying. But with solar dryers, crops dry faster with the additional advantage of protection from insects, birds and worms.

![Solar Dryer](image)

*Figure 2: Solar dryer*

- **Solar mower**

Solar mower or solar grass cutter is a solar powered machine that is used to cut grasses. Traditionally, it was powered by diesel or oil and gas which appear to be harmful to the environment. With the advent of solar energy technology, solar powered mowers have been developed to replace the one that runs on fossil fuels. Solar grass cutter has components which are; solar panel that charge the battery using charge controller, 3 wheels, DC motor, electric circuit and blades.

![Solar powered mower](image)

*Figure 3: Solar powered mower*

- **Solar Tractor**

Tractors are absolute essential on farms which facilitate various agricultural tasks. Farmers at all corners of the world use tractors on their farms and those types of tractors operate on fossil fuels and consume huge amount of money at completion of a task. But the combination of cheap solar panels and the evolution of lithium batteries and some other associated technologies are changing the world of farming. Solar tractors are powered either directly or indirectly by the Sun. They have rooftop solar power system which charges the batteries. Farmers in Australia, U.S., China, India and indeed many other countries in the world use solar powered electric tractors which cut the use of fossil fuels such as diesel, oil and gas. Mother earth news stated that several companies in U.S. sell solar powered tractors which are used for planting and harvesting on farms.
Solar energy is also used in agriculture to heat greenhouses. Solar greenhouses are designed to use solar energy for lighting and heating. EREC, 2002 stated that solar greenhouse has thermal mass to collect and store heat energy and has insulation to retain heat for use during the night and on cloudy days. Solar greenhouse relies on solar energy heaters to maintain the temperatures necessary to grow plants in the colder periods. Solar greenhouse enables farmers and gardeners to grow out-of-season fruits and vegetables since it retains heat. Solar greenhouse is oriented towards the South so as to maximize absorption of heat. This type of greenhouse is more economical and sustainable.

Solar space and water heaters

Solar heaters are used by farmers and ranchers heat water and space for livestock. They convert sunlight into heat for water and space heating. Operations of livestock and dairy have substantial air and water requirements. Present day poultry and pig farmers raise animals in a demarcated and enclosed buildings, in which air quality and temperature must be carefully controlled for maximization of health and growth of the animals. Solar space heaters need to regularly replace indoor air to remove toxic gases odors, moisture, and dust. Space heating requires large amount of energy and solar heaters have successfully fulfilled the task. Likewise, solar water heaters can provide hot water required for pen or equipment cleaning. According to Garg 1987, water heating accounts for as much as 25% of a family’s energy costs and also up to 40% of the energy used in a diary operation. All these costs can be cut by using solar heating system [12].
DUAL FARMING TECHNOLOGY

Dual farming also called agrivoltaics or photovoltaic agriculture is a type farming practice where a farmer harvests both crops and solar energy on the same farmland. It is a combination of photovoltaic power and agricultural practices. It enhances good management of agricultural land. A study published in Nature in which a research team in U.S. has found that combining solar power generation and agriculture gives not only a solution to land unavailability for photovoltaic projects in countries where soil consumption is an issue such as Japan and Netherlands but can also improve some kinds of agricultural activities at the same time giving better yield from solar power plants. According to the research the most efficient locations for harvesting both crops and solar energy on the same farmland include western America, southern Africa and the Middle East. The research team found grassland, cropland and wetlands to be the most suitable environment for dual farming practice by applying a model for solar panel efficiency that involved the influence of a panel’s microclimate. The model was applied to datasets of global microclimates. The research also drew on power production data from field tests carried out by U.S. car and PV manufacturer, Tesla across five fields of agrivoltaics in Oregon and found that crops such as tomatoes, aloe Vera, biogas maize, lettuce, and pasture grass were grown successfully [13]. Another study conducted by University of Massachusetts in U.S. where varieties of plants were grown below solar panels elevated 7.5 to 9 feet or more above ground level to allow for easier harvest. The crops which include beans, tomatoes, cilantro, Swiss chard and kale were successful under the solar panels. 3 to 4 feet gaps between cluster of panels led crop yields almost the same as what they would have been under the full Sunlight according to study [14]. Another study also conducted in U.S. titled “Food Crops Do Better in the Shed of Solar panels” highlighted the advantages of combining solar energy generation and agricultural production. According to the study, growing jalapeno, chiltepin pepper and cherry tomato on dryland areas of U.S. under the shade of photovoltaic modules is not only possible but can lead to a better harvest [15]. Germany’s Institute of Solar Energy Systems demonstrated combining solar generation and agricultural activity was not only viable at lower costs but might be suitable for arid regions. The Institute stated that combination of solar generation and agriculture was significantly raising efficiency of land use- land use efficiency at its 194kw agrivoltaic pilot installation rose 186% per hectar in 2018 compared to 160 rise in 2017 [16]. Also a study was conducted in India on a grape farm to investigate and quantify solar power generation without harming agriculture. Techno-economic analysis was run for the installation of PV on the grape farm. The results of the study were found to be eco-development of both PV and agriculture. The results showed that the economic value of grape farms using agrivoltaic could go up 15 times more than the conventional farming system. According to the research, when this dual use of land is implemented across India, it could make a significant impact by generating over 16000Gwh of electricity which has the potential of meeting electricity demand of 15 million people [17]. In Dornbirn, Australia, tomatoes were also grown under solar panels. The practice of using same land for both energy generation and agriculture was conducted in Japan in 2004 and the idea was expanded to some countries in Europe [18].

EMISSIONS FROM AGRICULTURAL SECTOR

The concentration of greenhouse gases in the atmosphere has increased mainly as a result of human activities which include burning of fossil fuels (coal, oil and natural gas) due to economic growth and development. Greenhouse gases trap heat
from escaping into space and radiate it back towards the surface of the earth. This phenomenon is known as ‘Greenhouse Effect’ which subsequently causes global warming as a result of raising temperature.

Agricultural sector, like most economic sectors, produces greenhouses. These emissions from agricultural sector are linked to various activities on farmland such as management of livestock, soil, crop production, burning of biomass and use of diesel, oil and gas in fueling agricultural machinery. Word Resource Institute (WRI) in 2014 published that the share of emissions from agricultural sector in 2011 was 6 billion tonnes of GHGs, about 13% of the total global emissions and that makes the agricultural sector second largest emitter of GHGs after energy sector (includes emissions from power generation and transport). According to an article published in 2015 by European Union termed as ‘eurostat’, contribution of agriculture to total greenhouse gases emissions in percentage stood at 9.58% as at 2015 for EU-28 [19]. In a study published in 2018 on emissions from agriculture in Africa, it was found that they were among the fastest growing emissions in the world. The study said between 1994 and 2014, emissions from agriculture in Africa increased at average annual rate of 2.9% and 3.1%. In the whole continent, East Africa and South Africa appeared to be the largest producers of emissions from agriculture with 34% and 27% while the lowest producers were Central and North Africa with 10% of the total emissions from agriculture in the continent. Half of the emission from the continental agricultural sector is from fermentation [20]. United States Environmental Protection Agency in its 2017 annual report stated that U.S. emission from agricultural sector stood at 9% of the total emissions from all sectors of the economy of U.S. [21].

CONCLUSION

In conclusion, it can be drawn from the above literature that solar energy can offer lasting solutions to many problems facing the world today which include climate change (the leading problem of the 21st century), energy poverty, environmental protection, and drought among others. As highlighted in the literature, farmers in U.S., EU and Asian countries are forefront in adopting solar technologies but most of the farmers in African continent have less adopted the solar technologies for agriculture despite the fact that these technologies have immense benefits as shown in this paper. Also, African continent is blessed with high sunlight radiation and possesses 60% of the global agricultural land (RFI, 2019).

Further research guide: Application of solar technologies in farming is of great advantage in cutting the cost of agricultural production, mitigating climate change and rural job creation. There is, therefore the need for a research to be carried out in African rural areas to investigate why African rural farmers have not much adopted the use of solar technologies in farming. Do not they have awareness of these technologies? Are the solar tools expensive for them? Are there encouraging policies and schemes by governments?

Reference


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