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India, Sustainable Agriculture

An overarching repertoire of Indian Agriculture and Green Energy Conservation

India is a large country in Southeast Asia off the coast of the Indian Ocean, bordering the countries Nepal, Pakistan, Bangladesh, China, along with a few others. This massive country with a total area of 3,287,263 square kilometres is populated by 1.3 billion people ("India Population (LIVE)" 2020), making it the second most populated country in the world. As per the 2011 census, the urban population is around 34% ("Urban Population (% of Total Population).", 2020), while the rural population is 66% ("Rural Population (% of Total Population).", 2020). People in this nation primarily follow the religious practices of Hinduism, Sikhism, Islam, and Christianity. The government is structured as a 'Sovereign, Socialist, Secular, Democratic Republic' with a parliamentary system of government" ("National Portal of India.", 2020). India is a great agricultural producer. About 60.45% of the total geographical area is under agriculture ("India - Agricultural Land (% of Land Area)". 2020). There are an estimated 145 million individual farms in India, each owning an average space land of 1.05 hectares, which is almost two football fields ("India at a Glance", 2020). The agriculture and allied sectors of animal husbandry, forestry, and fishery compose about 17% of India's GDP (Gross Domestic Product) and engages 50% of the Indian workforce (Padmanabhan, 2018). The agricultural sector produces many important goods for human consumption, such as rice, wheat, milk, cotton, and sugar. Weather, climate, and geography, which differs throughout India, brings a distinctive peculiarity to the agriculture sector, found in no other country. India's climate can be classified through different geographical locations using Koppen-Geiger classification. The East India coast and the western margins are hot and tropical with high temperatures and a dry season throughout the winter. South India has a hot tropical rainforest climate with frequent monsoons and floods. Central and Northeast India have a dry Steppe climate with an average temperature of 18°C. Northern India is covered with the Himalayas and has a temperate climate ("India.", 2020). Because of all these different climates, agriculture is precise and different in every location. But, in many locations, agriculture and horticulture is declining (Mondal, 2014). Alluvial soil is found in the majority of areas, excepting the western part of India, where soil is sandy; but, the per capita availability of cultivable areas is low. This shortage in cultivable land is due to land degradation and desertification (Gaur and Squires, 2020), which is caused by excessive irrigation without proper drainage, overuse of fertilizers, salinization/alkalinization, mining, and other anthropogenic activities (Schwartzberg, Joseph E et al, 2020). Further, Indian agriculture is highly dependent upon the vagaries of monsoon. So, the insufficient or failure of rainfall directly causes crop failure and consequently famine. As a result, nutritious food is not available to a large population. In addition, with a growing population, competition for land for agricultural use is increasing; the fragmented lands may result in too much or too less irrigation, which may decrease crop yield. It is proposed that to increase the soil fertility and crop yield, the use of photo-voltaics in arable lands, or agri-voltaics, could be used to solve problems with irrigation, crop cultivation, as well as electricity generation. This would effectively also reduce the possible competition for agricultural land. In essence, agri-voltaics could be the solution to sustain agriculture in India and in parallel develop new forms of renewable energy, such as wind energy and solar energy, which is described by experts as the Food-Energy-Water Nexus.

According to the United Nations, an average household in India is composed of four to five people: two parents/adults and three children ("Household Size and Composition Around the World 2017."). According to Times of India, an editorial newspaper company in India, the average house size is too small to produce a good quality of life. “In fact, a majority of Indians have per capita space equivalent to or less than a 10 feet x 10 feet room for their living, sleeping, cooking, washing and toilet needs”(Thakur, 2008). In general, Indian housing is made up of low rise apartment buildings, high-terraced houses, and slums (Teoalida, 2020). The poor living conditions are due to the growing poverty rates and poor construction standards. A typical meal in a household consists of legumes, beans, lentils, grains, fruits, and vegetables (“How Healthy Is Indian Food? - Times of India.”, 2017). Most people eat a small meal for breakfast or skip it entirely and eat a heavy lunch, then later in the evening have a small dinner. Given the living conditions, this is actually a healthy diet and keeps most people somewhat well nourished. The vegetables, milk, and fruit are brought from street vendors or nearby markets, where other edibles such as rice and wheat flour are also found. Children living in more impoverished conditions may go to the local public school, where education is provided along with a meal, or may decide to go and work as laborers. Children belonging to the middle class most likely attend the public school nearby, but may choose to apply for an English-medium school (one may compare this to a private school in the United States). Upper class children mostly go to English-medium schools. Most children take tuition throughout their school years to further their education and get a chance to attend college. Popular degrees that students take in college include bachelors in computers, engineering, the medical track, and bachelors in commerce. The most common jobs taken after college include computer engineering, finance, and marketing. The typical gross salary in India is Rs. 885,361 (“India: 2019/20 Average Salary Survey.”, 2020). But, 5% of the Indian population, which is over 85 million and growing, does not have access to clean water. food, and overall sanitation. Electricity consumption is limited and roads and local markets are polluted and dirty. This results in an obstacle for the growth and health of people and their nourishment (Agarwal, 2016).

Agriculture is very important to all the residents of India; many people use agriculture as a way to earn a living, while others rely on agriculture for impoverished subsidized rations. India populates 18% of the world’s population and 15% of the world’s livestock while only composing 2.4% of the world’s land area. Employing around 50% of the workforce, the sectors of agriculture, forestry, and fishery are an important part of Indian economy and culture. Unfortunately, the area under agriculture in India has been gradually decreasing. This has many repercussions: more than 8.5% of the population - the impoverished population - may starve because of under-nourishment and mal-nutrition due to famine. Many agricultural Indian exports, such as rice, wheat, and cotton may decrease in price, giving a blow to the Indian economy. But, most importantly, due to the falling prices and decreasing agricultural production, the 50% of the Indian workforce may be at risk of unemployment. This will further affect the overall standard of living and lower the Indian GDP. There are mainly two reasons that contribute to this detriment of agriculture: soil degradation and land fragmentation. If these two issues are resolved, this could fix many internal agricultural problems and decrease the poverty and mortality rates.

Soil degradation is a potent problem contributing to the rising issue of agricultural failure. Soil degradation is defined as “the decline in soil condition caused by its improper use or poor management, usually for agricultural, industrial or urban purposes”, as per the New South Wales Department of Environment. Mainly, there are many social and natural sources of the impending soil degradation. These include earthquakes, tsunamis, droughts, along with other natural disasters and anthropogenic activities. As there is no way to prevent these types of disasters, farmers can only take some preventive steps that may prove to be futile. But, there are mistakes made by the cultivators themselves that are contributing to the soil degradation. The poor irrigation and extraction of excess groundwater than their recharge capacity of the soil moisture may be responsible for exacerbation in soil erosion and decline in biological fertility. The use of canal irrigation, such as in the Indira Gandhi Nahar Project, has commonly been associated with salinity problems in the soil, creating an obstacle for soil production. In other regions that are arid or semi-arid, many arable lands are considered barren because of the rise of saline-sodic soils caused by the poor irrigation techniques. In the barren-considered lands, researchers find cracked soil, which may cause a bypass flow of water and nitrate leaching. These cracks grow and cause soil shrinkage. In essence, the irrigation is causing alkalinization and salinization: soils start to accumulate excess soluble salts and exchangeable sodium, as well as waterlogging (Bhattacharyya et al., 2015). Along with the poor irrigation techniques, lack of crop cover during heavy rainfalls also causes mass soil erosion. Many other variables add to this growing agricultural issue, but those are minute and can be controlled. To holistically assess soil degradation, of the total 179.9 M ha land under agriculture in India, 120.4 M ha is degraded or is still degrading. Most of these degraded lands are owned and inhabited by marginal and small farmers that tend to be poor and less aware. Unable to support -financially and through nutrition, their infrastructure and social structure of these cultivators would decline. These people would then migrate to other places in search of other arable lands such as forests or steep slopes, which would lead to further degradation of the new found soil. Food security thus decreases and worse agriculture occurs. On a macroeconomic level, the Indian economy would decrease, effectively increasing the poverty rates and decreasing the national productivity (Aulakh, 2015).

Although soil degradation may play a big role in the crop depletion, there is also an intertwined social aspect to this problem: land fragmentation. Land fragmentation produces an interesting problem. As the name may suggest, land fragmentation refers to the division of lands, specifically farm lands. Fragmentation occurs due to three main reasons: nepotism/inheritance, the lack of a progressive tax on farm lands, and an underdeveloped land market (Manjunatha, 2013). Because of these problems, farm sizes are decreasing and at the same time the number of holdings per owner is increasing. Farming households now possess many disconnected agricultural plots scattered across a wide area. This fragmentation and the possible irregular shaping of lands cause time wastage in going between and especially causes an obstacle to machinery use, as farmers must either rotate machinery or buy more machinery, which overall contributes to lower land productivity (Gaur, 2016). The machinery, if even affordable, will not be optimally used due to travel time and obstacles between farm plots. Farmholders would have to start bunding or hedging (heavily containing with broders) their plots to maintain the crops, which may decrease the area of productive land (Manjunatha, 2013). Finally, the lack of attention or focus on many lands instead of one land could lead to worse care and unstable facilities in all farmlands. This may mean that irrigation or care for all crops can deteriorate, also leading back to the soil degradation problem (Dhakal, 2018).

To counter this impending agricultural failure, many ideas of an agri-voltaic system have been formed, which further the idea of the Food-Water-Energy Nexus. Agri-voltaics connect energy production to food production. This idea deals with placing a solar panel over a region of crops. These crops may be grown through both partial and fluctuating shades of the solar panel. The solar PV panels must be placed at a certain inclination angle equal to the latitude of the location to maximize solar irradiation. Central Arid Zone Research Institute (CAZRI) Jodhpur (India), through its research and experimentation has prepared a design to install a PV panel in relation to the crops:

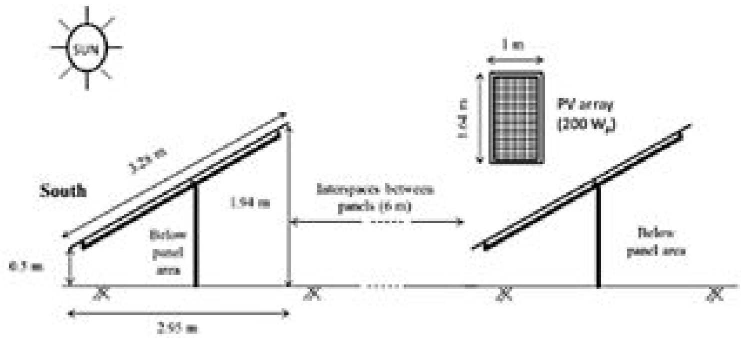

Fig. 1: Basic design of solar PV installation in an agri-voltaic system

(Santra, 2017)

Through this experiment, it is possible to calculate the amount of shade that may be provided by the solar PV panels on the ground surface. In essence, the very idea of the agri-voltaic system is a mixed system capable of both providing energy and crops on the same land area. Currently, there are allocated solar plants that solely produce energy and there are lands only producing crops. This dual purpose usage may solve the problem of land fragmentation. Since people are able to produce energy on the land, there will not be any delay in crop care or machinery disadvantage (Santra, 2017).

Poor irrigation techniques, as shown, is a fact of soil degradation. But, the solar PV panels may be installed with an attachment: solar PV pumps. These solar PV pumps would take the place of irrigation using pressure and discharge.The CAZRI has implemented solar PV pumps in its Jodhpur campus and compared the crop growth to a land in which 1 HP AC mini sprinklers and 1 HP DC mini sprinklers were used. Through the procedure, he concluded that the solar PV pumps produce the correct amount of water to the crops without causing salinization or alkalinization. Furthermore, rain falling on the solar panels of the system could be harvested. A harvesting system installed on the top of the panel gives the rainwater the capability of being reused for cleaning and drinking purposes once cleaned; but, this rainfall water may also be capable of being used for irrigation purposes. It is concluded that rainwater harvested from an agri-voltaic system that is 1 Ha in area can yield a potential 400,000 liters of water, used for reasons stated above. Overall, the solar PV pump and the rainfall harvesting system, when installed in the agri-voltaic system, enhances energy security and food security (Santra, 2018).

Mainly, this agri-voltaic system specifically combats desertification and land degradation. The moisture left from the plants, now under shade, is released into the soil, reducing the excess salinity and keeping the land fresh. This stops desertification as the soil stays fertile and moist, ready for reuse. In addition, these salinized agrivoltaic plants may be installed near the rural populations spoken of before. This would allow the harvesting of water done by the solar panels and pumps to be used not only for irrigation, but could be used for by the humans as fresh drinking water, thus solving various problems on water scarcity and water security to some extent.

It is also crucial to generally say that the agri-voltaic system increases crop production. Many different short-duration crops and vegetables may be grown underneath solar panels; in fact, since there is shade or partial shade from the sun, many crops are able to retain moisture, which keeps the soil fresh and reusable. Obviously, there are some drawbacks to what type of crops may be grown. Mainly, the issue is that the crop must not grow to be taller than the solar panel, as the physical form and taste may be impacted. So, in CAZRI's proposed diagram of the agri-voltaic set-up, the maximum height of the crops grown must not exceed 0.75 meters. Crops successfully grown using an agri-voltaic system include mung bean (*Vigna radiata*), moth bean (*Vigna aconitifolia*), and cluster bean (*Cyamopsis tetragonoloba*), along with greens such as spinach, aloe vera, and isabgol (*Psyllium husk*). It is to be noted that certain crops depend on the shade for proper production. For example, spinach must be grown under full shade, while aloe vera may be grown between two solar PV panels. This regular crop production within seasons is already benefiting the farmers, but in addition, the agri voltaic system helps during lean seasons. Lean seasons are the periods of time between different growing seasons; at this time, there is normally no planting or harvesting. Because of this, there is low farmers' income and a wide spread of hunger. Take the lean season between the winter season and the summer season for example; this includes the months of March to June. The Agri voltaic system allows cultivation/production to last for longer, thus effectively reducing the lean season. This increases farmers' income and also lowers overall hunger. Knowing that the agri-voltaic system solves problems for irrigation (water), electricity (energy), and crop yield/production (food), it is true to say that the agri-voltaic system complements the Food-Water-Energy Nexus and increases land productivity and effectively increases the poor farmers' income (Santra, 2018).

This project could be funded using government subsidies, along with technical support from research organizations such as the Indian Council of Agricultural Research (ICAR) or Department of Science and Technology. An agri-voltaic system, as described, would be very sustainable. With an initial investment of solar PV panels, farmers would be able to double the revenue and the Indian economy would holistically soar. Overall, the agri-voltaic system could be the solution to sustain Indian agriculture.

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