Smart Farming with Renewable Energy: Integrating IoT and AI for Climate-Resilient Agriculture

Tarana Afrin Chandel[1], Shweta Dwivedi[2], Uma Prasad Pandey[3],

M Usama Kidwai[4]

[1,2,3,4]Integral University, Lucknow, Uttar Pradesh, India

Abstract

Harvesting of solar energy is nowadays an important issue, which unfortunately requires large area under the direct sun. On the other hand, agricultural lands utilise larger uncovered areas. Therefore if the solar panels are used to cover such agricultural lands, and the shade is systematically designed, the area can be doubly utilised. In order to avoid shading, a greenhouse Agrivoltaic system is designed and modelled to achieve 100% efficiency in harvesting crops and energy both at the same time. Solar panels can utilise direct sun rays and the light energy required by plants can be obtained from the light rays in between the panels, thus merging both the systems under the same sky with the same solar energy forming an Agrivoltaic system. The author Tarana A Chandel discusses this Agrivoltaic system as a Hybrid Agri-Energy-Harvesting System (HAEHs). Energy and agriculture are the basic requirements for sustainability of life. In the survey based study the author has highlighted innovations in Renewable Energy and tried to show the impact of various types' of HAEHs on crop yield. HAEHs can be modelled as development for life sustenance and as a technology for future.

Keywords

Introduction

Farming is the basic source of life sustenance along with energy. In 19th century energy required for cooking were wood, coal, kerosene oil etc. The source of energy was the fossil fuel only. The environment issues developed due to fossil fuel are global warming, air pollution, climatic change. All these issues were due to greenhouse gas emission. The first summit on Human Environment was held from 5 to 6 June 1972 at Stockholm, Sweden focussing on environmental issues within sustainability developments framework [1]. After 20 years, second UN conference on Environment and Developments was held at Rio de Janeiro, Brazil from 13- 14 June 1992, which was also referred as Earth Summit [2]. This conference was held to spotlight the effects of the social and financial activities on the surrounding environment. The solution for such issues is the transformation of fossil fuel towards green and clean energy, thus enhancing quality of lifestyle. This was the major development towards sustainability development. The developments; fulfilling the need of the current generation without compromising or harming the requirements of the next generation is sustainability developments (SD) [3]. For survival of human-life enhancement in agricultural products and energy are parallel and equal in priority. The 2030 agenda for sustainability developments involve 17 goals. 1st, and 2nd SD goals i.e. no poverty (SDG-1) and Zero Hunger (SDG-2) are very important. In order to eliminate poverty and hunger, enhancement of agriculture is very must. As we know that non-conventional energy sources such as wind and solar are tending now a day. Solar photovoltaic system is used for generating energy. This energy is a green energy and affordable. Harvesting of sun energy is nowadays an important issue, which unfortunately requires large area under the direct sun. On the other hand, agricultural lands utilise larger uncovered areas. Therefore if the solar panels are used to cover such agricultural lands, and the shade is systematically designed, the area can be doubly utilised. . Solar panels can utilise direct sun rays and the light energy required by plants can be obtained from the light rays in between the panels, thus merging both the systems under the same sky with the same solar energy form an Agrivoltaic system. This challenging technology has a new vision in the field of agriculture and energy on same platform. This study show light on Agrivoltaic system, Greenhouse Agrivoltaic system and IoT based Agrivoltaic system. Physical Constrains of shading effects on the agriculture land with PV module is taken into consideration, for enhancing the productivity of agriculture land. Looking from the prospective of PV system; production of energy is larger due to microclimatic effects developed by the agricultural crops maintaining the surface temperature

of PV module [4]. The dual utility approach concept of agriculture and energy generation by PV system was first introduced by Goetzberger and Zastrow at the Fraunhofer Institute (Germany) in 1981 [5]. The solar photovoltaic energy harvesting system on the same agriculture harvesting land is known as Hybrid Agri-Energy Harvesting System (HARHs). It was inspired primarily by the generation of electricity for the ground mounted PV system in agricultural land with constraints i.e. the farmers are benefitted from the selling of agricultural products along with the income of the electricity generated on same land. The sale of generated electricity from PV system was the additional income that helped the farmers to bear the losses in agricultural production [6]. The environmental is indirectly blessed by green gas emission which is utilized by plant during photosynthesis and releasing oxygen [7]. Numerous researches have analyzed the agrivoltaic system's effect on agricultural land. These researchers are from Japan [8], United States [9], Palestine [10], Spain [11], Germany [12], Turkey [13], Europe [14], India [15], Thailand [16], East Africa [17] and the Russian Federation [18]. All the above researchers have shown the importance of contemplation of land prior to installation of the hybrid agri-energy harvesting system [19]. The effects of hybrid agri-energy harvesting system were investigated by the scientists at global level. In the recent time many commercial agri-photovoltaic plants with research facilities are well-established all over the world [20].

Traditional farming was very common in 19th and beginning of 20th century. In traditional farming plough was an important tool of farmers for cultivation of soil for sowing seeds. The major drawback of manual ploughing was that it couldn't penetrate deep in the soil for the first time, taking extended time for ploughing the agriculture field. For significant ploughing it doubled the labour cost and time. Insufficient ploughing caused lack of air and water in the soil, taking longer time in harvesting and had low production. With the rapid increment in population, traditional farming increased its attention globally. Looking towards traditional farming, UN announced 2014 as International Year of Family Farming (IYFF, 2014) [21] to upgrade domestic farming, small scale farming with an aim to diminish hunger, enhance livelihood, maintain natural resources and well-being of the people

Objective of the research

Problems regarding increase in population with reduced land/man ratios, extensions of agricultural marts, challenges toward new technologies, and numerous outlooks for development cannot be ignored. The motive of this research is to achieve the following goals;

i.   Enhancing employment in energy and agriculture sectors, **achieving (SDG-1) i.e "No poverty"**

ii.   To gain maximum production in lesser space and time, **achieving (SDG-2) i.e. "No Hunger"**

iii. To minimize electricity cost and provide affordable green power to all citizen **achieving(SDG-7) i.e. "Affordable and Clean Energy" (SDG-7)**

iv.   To minimize green gas emission achieving (SDG-13) i.e. "Climate Action"

**Concept of Hybrid Agri-Energy Harvesting System**

This concept of Agri-photovoltaic System has speeded up after COVID-19 pandemic and approximate 0.7 billion people suffered from hunger by 2021[22]. The 2030 Agenda of sustainable goals toward no hunger, climatic change mitigation [22] joined together with clean and affordable Energy (SDG-7] [23] came into existence for human life sustenance and as a technology for future. Sustainability development is the primary step required to foster rationality. They focussed to contribute a social support for humanity with the insurance that human improvement takes place inside earth's biophysical horizon [23,24].

Design and Modeling of HAEHs

The hybrid agri-energy harvesting system is designed to serve same solar spectrum on the PV module and agricultural land at the same time. The design parametrs for APV system consist of location, land area, crop, direction of sun rise and set, sun peak time, maximum power point tracking for energy generation and finally installation of the PV system. The model of APV system is shown in figure 1.
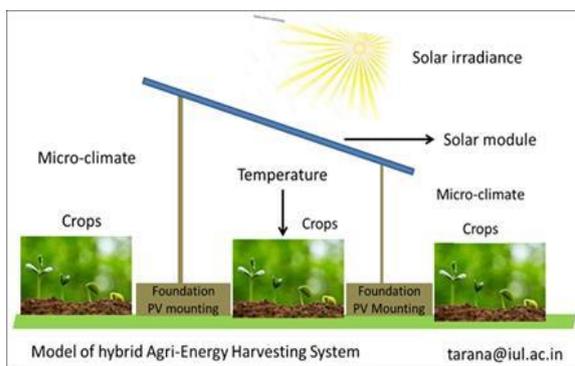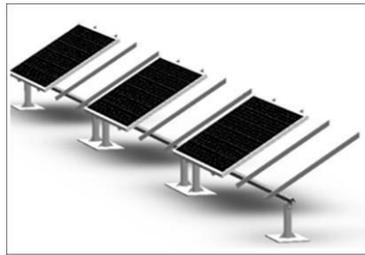

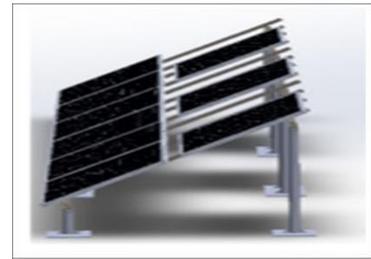**Figure1. Model of hybrid Agri-Energy harvesting system**
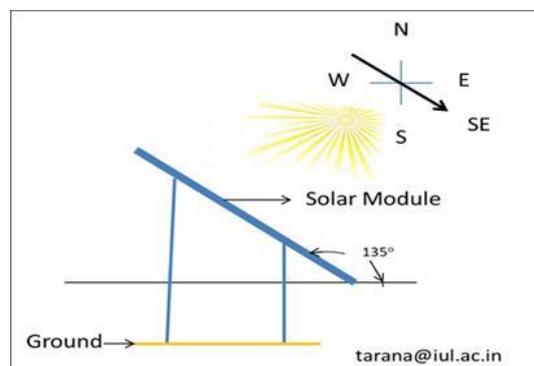
Figure 2. SPV module facing the solar radiation
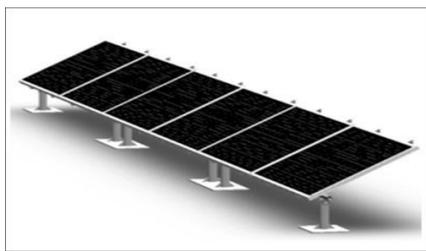
**Figure 3a. No gap in between PV modules in a pv array**

**Figure 3b. Gap in between PV modules in a pv array**

Figure 3c: Combination of PV module with and without gap in between, in a pv array

This system is perfectly suitable for locations having preferable sun radiation and cultivatable agricultural land. In such cases the tilt angle of the solar module should be maintained at convenient height above the land so that required sun light falls on the crop. The installation design parameters of hybrid Agri-energy harvesting system (HAEHS) are different from that of conventional PV system.

An innovative installation design of PV system is done above crop to gain maximum generation of power and agricultural products. The maximum gain is obtained when PV module is facing SE direction at 135º [25] from ground in our country as shown in figure 2. The PV installation can be done in three different ways; firstly; with no gap in between PV modules in an array, secondly; gap between the solar panels in an array and thirdly; combination of first and second design of PV module shown in figure 3. The solar irradiance distribution method can optimize food-energy production [25] as shown in figure 4.
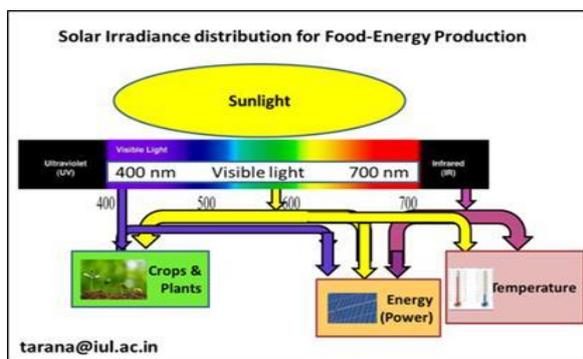
Figure 4. Solar Irradiance sharing for Food-Energy Production
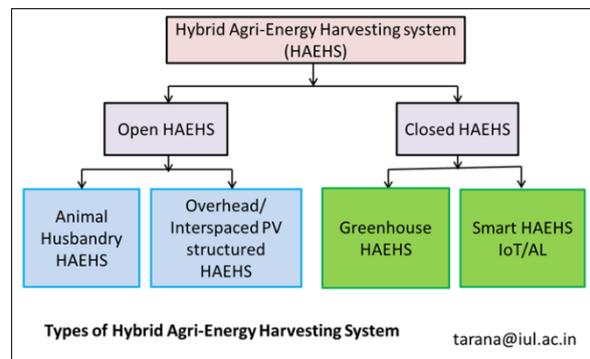
Figure 5. Different type of hybrid agri-energy harvesting system

Hybrid Agri-Energy Harvesting System

Different ways of hybrid agri-energy harvesting system exist in the word depending upon the use and activities carried out for specific purpose [25] as shown in figure 5. Open HAEH system include animal husbandry [26] and interspaced/ overhead PV structured HAEHs. Closed HAEHs involve greenhouse HAEHs and smart IoT/AI based HAEHs

Greenhouse Agri-Energy Harvesting System

In the last decades, greenhouse farming has risen globally. Greenhouse farming increases the production of vegetable and crops due to modified environmental factors, providing suitable climate for plants to grow. In fact greenhouse farming protects the crops from unacceptable environmental hazards, pests and neighbouring plants disease. The structure of greenhouse is a plastic enclosed with a bamboo or steel frame, with suitable window or ventilation [27,28] as shown in figure 6 and 7 respectively. The costs of the bamboo or the wooden framed greenhouse are low and are affordable by marginal or small farmers. Such types of greenhouse are specially found within hilly areas [28]. The life of bamboo or wood is enhanced with chemical therapy, stopping from rotting and termites attack. The chemical therapy enhances the life of wood/ bamboo up to 50 years [28].

Figure 6. Greenhouse with bamboo framing   **Figure 7. Greenhouse with steel framing**

The window or ventilation maintains the inside temperature for production of vegetable, crops fruits and also flowers. The maintained temperature is as per the requirements of vegetable and crops, helps to grow and survive in a controlled environment. Fertilizers, climatic controlled environment system, equipment for irrigation, covering frame materials are the component affecting the efficiency of crop production. Greenhouse structure vary, depending upon the covering materiel used such as high density polythene (HDPE) and polyvinyl chloride (PVC, plastic film, fiberglass). The covering materials are usually

transparent or translucent. Material used for framing is steel, coated with zinc or iron to protect it from environment hazards, rusting and extending its durability. Temperature plays a significant role in greenhouse farming. The motive of green house was to cultivate high temperature stringent species in cold climate in temperate regions. During cold climate, a moderate temperature is maintained inside the greenhouse, protecting the crops, vegetable, and fruits from wind strokes. During hot climate, in the Mediterranean areas temperature reaches to its peak. Greenhouse has hazardous impact on the production of crops. The polyvinyl shading protects the crop from heat strokes and regulates the temperature through proper ventilation in the greenhouse. With proper designing and equipment greenhouse technology has made very easy to cultivate horticulture species in any region of the world. The solar insolation and ambient temperature are two important parameters for sustainable crop in the greenhouse. Other parameter involves soil temperature, wind, rainfall, humidity and carbon dioxide. Vegetables requiring medium temperature such as tomato, pepper, cucumber, melon, water melon, marrow and green beans are commonly grown in greenhouse [29]. Artificial climatic control system is also used to maintain the temperature in the areas not having suitable climate for crop production [29]. The solar radiation required for the above mentioned crops is 2.34 kWh/m2/day during the three months having shorted of the year i.e. from November to January in the Northern Hemisphere and May to July in the southern hemisphere [30]. This shows that 6 hour of sunlight per day is must for crop production in greenhouse.

Smart Hybrid Agri-Energy Harvesting System

Smart HAEHs is a creative technology which enhances land utility efficiency and sustainability by combining power and agriculture together. This innovative technology focuses on smart farming which includes IoTs, large data analysis, cloud computing, ML and AI for monitoring, tracking, analysing operation and making it automated. The integrity of these technical innovations has showed excellent impact on the growth of agricultural product. The motive of smart HAEHs are; increase in sustainable agricultural products and income, eliminating greenhouse emission, reducing the adverse effect of global warming and building resilience towards climatic change in the environment.
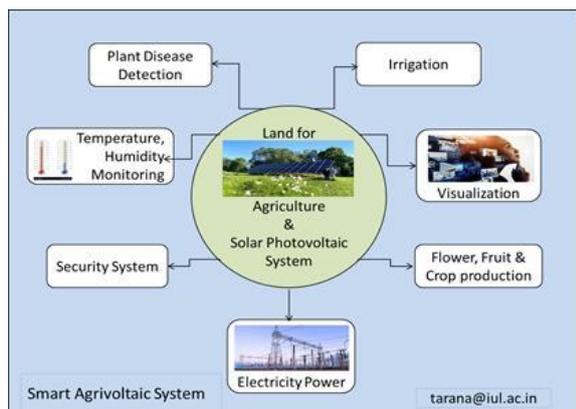
Figure 8. Block diagram of smart hybrid agri-energy harvesting system
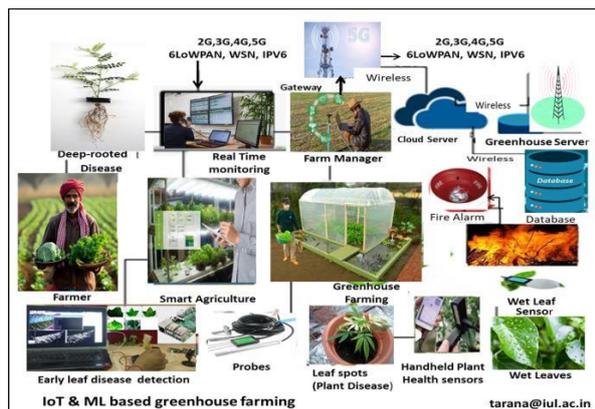
Figure 9. IoT and ML based greenhouse farming

The block diagram of smart HAEHs is shown in figure 8.The first greenhouse farming technique took place in 19th century at France and Netherland [31]. Greenhouse farming is planned to produce crops in any climatic condition by controlling the parameters suitable for the growth of the particular crop. Greenhouse soon became popular and penetrated into the industry for commercial marketing of crops [31]. Currently Internet of Things is very familiar, making its own benchmark with new heights. It is transforming information of actual world in to stylish and intelligent devices. With the approach of IoT technology, conventional farming has transformed toward smarter and advance farming. In conventional greenhouse farming, each and every problem was assessed by the farmers which took time, labour and cost. However with the advancement of IoT technology, greenhouse farming operations can be monitored and controlled effectively and is considered as smartest technical application. Integrity of IoT technology with greenhouse enhances the productivity of crop with least labour charges [32]. The IoT based greenhouse farming mainly focus towards irrigation, crop disease control, environment for healthy plants and production [33]. Farming safety is top-most difficulty which can be achieved by applying IoT technology, which involve sensors, high pixel video, and drones for monitoring [34,35,36]. The commercial sensors used in IoT technology have proved effective growth in agricultural production with minimum cost. The basic motive is to enhance crop production with quality, optimize resources techniques and reduce human intervention [37]. Research show that IoT based farming provide maximum benefits in greenhouse farming such as water quantity in soil, humidity content, amount of chlorophyll in plant for photosynthesis, irrigation operation, monitoring and controlling [38]. The utility of IoT tool, ICT tool, and wire-free sensor

network faces financial, technical and environmental challenges in farming [39]. As the sensors and other devices are interconnected, big data is collected. This big data can be analyzed to forecast the perception, quick decision- making, controlling, directing and managing the system [40]. Best approach for it is Machine- Learning (ML). Machine-learning (ML) tool can solve surplus problems with the help of interconnected devices. Decision and actions can be taken faster by ML tool rather than human with minimum efforts [40]. IoT and ML based greenhouse farming [31] is shown in figure 9. An IoT based automated greenhouse require many sensors to track the environment condition and maintain the record of the climatic condition. Once the record fulfils the criteria necessary for plant growth, the signal is transferred to the host through microcontroller. The host of the database will acknowledge back the findings to the controller unit. With suitable ML tool, the farm manager will measure the climatic condition and maintain a record of water utilization of soil for a longer period to obtain best productive results. Farooqui et al [31], in his research utilized ML tool and artificial intelligence in designing the greenhouse totally automated for real time early stage detection of disease and decision making. Moreover the author implemented the artificial neural network in the farming for the farmers to maintain the record of fruit and crop's ripening and also the status of plant's health.

Conclusion

With the declination in manufacturing cost of the solar panel and enhancement in power conversion efficiency, solar photovoltaic system has become very popular in energy sector. Previously rooftop was utilized for generation of solar power. Entrepreneurs are finding solutions to enhance the demand of agricultural land for ground mounted solar power plant for electricity generation. Solar power plant is deployed on the agricultural land, increasing the financial benefits of crop production and energy generation at the same time. It is also resolving the problem of shortage in power and agricultural products. The sustainability development goals are achieved i.e. no poverty (SDG-1), zero hunger (SDG-2), affordable and clean energy (SDG-7), climatic action (SDG-13), life on land (SDG-15), thus fulfilling 2030 Agenda under Paris Agreement. This study shows the impact of various types of on crop yield. Studies also showed the impact of static and dynamic solution of plant growth under PV module. HAEHs are advancing day by day with the utility of AI and IoT. Smart farming is an approach that associates administration and regulating agriculture using innovations examples are IoT, robots, drones, and AI to increase the agricultural production

with good quality and eliminating the human employment required for production thus reducing labour cost.

Acknowledgement

Reference

1. UN conference in Environment,(1972, June 5-6) Stockholm, Sweden https://www.un.org/en/conferences/environment/

2. United Nations Conference on Environment and Development, (3-14 June 1992) Rio de Janeiro, Brazil, https://www.un.org/en/conferences/environment/rio1992

3. Chandel T.A.,Green (2022, Sept. 5) Entrepreneurship and Sustainable Development for the Book,"International Perspectives on Value Creation and Sustainability through Social Entrepreneurship, pp 173-208, 2022. ISBN10: 1668446669, IGI global 2022, Ch.9 DOI:10.4018/978-1-6684-4666-9.ch009, https://www.igi-global.com/chapter/green- entrepreneurship-and-sustainable-development/309830

4. Barron-Gafford, G. A., Pavao-Zuckerman, M. A., Minor, R.L., Sutter, L. F., Barnett-Moreno, I., Blackett, Macknick, J.E., (2019) Agrivoltaics provide mutual benefits across the food–energy–water nexus in dry lands. Nature Sustainability, 2(9) pp 848-855, 2019.

5. Goetzberger, A.; Zastrow, (1981) A. On the co-existence of solar-energy conversion and plant cultivation, Int. J. Sol. Energy, 1, pp55–69 https://www.osti.gov/etdeweb/biblio/7076063

6. Cuppari, R.I, Higgins, C.W, Characklis, G.W,(2021) Agrivoltaic and weatherrisk: A diversification strategy for landowner. Applied Energy 291,116809

7. Nordberg, J.W, Caley, M.J, Schwarzkopf, L, (2021)Design of solar farm for synergistic commercial and conservation outcomes, Sol. Energy 288. pp: 586-593

8. Iries, N Kawahara, N Esteves, A.M, (2019) Sector wide social impact scoping of agrivoltaic system: A case study in Japan, Renew. Energy 139, 1463-1477

9. Pascaris, a.S/, schelly, C., Burnharm, L. (2021) Integrating solar energy with agriculture: industry perspectiveon the market, community, and socio-political imension of agrivoltaic. Energy Res. Social Sci 75,102023

10. Braik A., Makahalfi, A.Ibrahim,(2021) A., Review of agrivoltaic system in Palestine. In: 2021 IEEE Jordan International Conf on electrical Engineering and Information Technology (JEEIT) pp. 176-180

11. Moredo, G.P., Munoz-Garcia, M.C., (2021)Techno-economic viability of agro-photovoltaic irrigation arable land in the EU-Med region: a case study in south western splain, Agronomy 11 (3), 593

12. Trommsdorff, M., Kang, J., Ehmann, A., (2021) Combining food and energy production: design of an agrivoltaic system applied in arable and vegitable farming in germany. Renew. Sustain. Energy Rev. 140, 110694 .

13. Cosgun, A.E (2021)The potential of agrivoltaic system in Turkey. Energy rep.7, pp 105-111

14. Willockx, B., herteleer, B., Capelle, J., ()2020) Theoritical potential of agrivoltaic system in Eorope: a preliminary study with winter wheat, In: 2020 47th IEEE Photovoltaic zSpecialist Conference (PVSC) pp.996-1001., 2020

15. Durga, N., Trommsdorff, M, Vorast, M., Patwardhan, S.M, (2021) Potential agrivoltaic to contribute to socia-economic sustainability: a cse study in Maharashtra, India, AIP Conf. Proc, 2361, 0440001

16. Kampanalaistit, M., Setthapun, W., Jansri, S.N., (2022) Efficiency Improvement of ground mounted solar power generation in agrivoltaic sytem cultivation of Bok choy under the panel. Int.J.Renew. Energy Dev. 11(1), pp 103-110

17. Randle-Boggies, R.J, Lara, E., Onyango, J., Hartley, E.E., (2021) Agrivolatic East Africa: opportunities and chellenges. AIP Conf. Proc, 2361, 090001

18. Kostik, N., Bobyl, A. Salamov, I., (2020)The potential of agrivoltaic systems in the south region of Russian Federation, IOP Conf. Ser. Earth Environ. Sci, 578(1)12047

19. Daisuke Y, Teruya T., Masaaki K., Kenji A., Kensuke N., (2023) Agrivoltaic system: Estimate of photosynthetic photon fli=ux density under solar panel based on solar irradiation data using all- climate solar spectrum model, Clenar Engineering and Technology 12(2023) 1000584

20. Axel W., Andrea E., Sabine Z., Iris L., Stephan S., Petra H., (2019) Agrophotovoltaic systems: applications, challenges, and opportunities. A review, Agronomy for Sustainable Development 39: 35 https://doi.org/10.1007/s13593-019-0581-3, 2019

21. Thakur P.K., (2023) Traditional Agriculture System: A need of hours for Modern World, Acta Scientific AGRICULTURE (ISSN: 2581-365X), Volume 7 Issue 1

22. Nimay C.G., Ramesh C.M. (2022) Design of agrivoltaic system to optimize land use for clean energy food production: a socio economic and environmental assessment, Clean Technologies and Environmental Policy (2022) 24:2595–2606 https://doi.org/10.1007/s10098-022-02337-7

23. Adis D., Hannah J., Clara B., Gabriela I., (2019) Connections between the Paris Agreement and the 2030 Agenda, September 2019 by Stockholm Environment Institute, Stockholm, Sweden, https://sdgs.un.org/sites/default/files/2023-01/connections-between-the-paris-agreement-and-the- 2030-agenda.pdf

24. Rockström, J., Steffen,W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E. F.,, Nykvist, B. (2009). A safe operating space for humanity. Nature, 461(7263), 472.

25. Sarr, A.; Soro, Y.M.; Tossa, A.K.; Diop, L. Agrivoltaic, (2023) A Synergistic Co-Location of Agricultural and Energy Production in Perpetual Mutation: A Comprehensive Review. Processes 2023, 11, 948. https://doi.org/10.3390/pr11030948

26. Ifechukwude I.A., Precious E., U., (2022, Aug)) Trends in greenhouse farming technology: A review, Journal of Food Agriculture and Environment 19(2):69-74, DOI:10.1234/4.2022.5613

27. Sandeep K., Vinod K.Y., Kavita B., Mohit K., (2022, Sept- Oct) Design and Construction of Greenhouse in India, Agri Articles (e-Magazine for Agricultural Articles), Volume: 02, Issue: 05, ISSN: 2582-9882, https://agriarticles.com/wp-content/uploads/2022/09/E-02-05-15-57-61.pdf

28. Nicolás Castilla and Esteban Baeza, Greenhouse site selection, Good Agricultural Practices for greenhouse vegetable crops, Principles for Mediterranean climate areas, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 2013 , ISBN 978-92-5-107649-1, https://www.fao.org/3/i3284e/i3284e.pdf

29. Dodi Y.S., Warsito, R.M., Nurfiana, R.S., (2022) A Systematic Literature Review: Internet of Things on Smart Greenhouse, International Journal of Advanced Computer Science and Applications, Vol. 13, No. 12

30. Muhammad S.F., Rizwan J., Shamyla R., Zabihullah A., (2022. Jan) Internet of Things (IoT) Technologies in GreenhouseFarming: A Systematic Literature Review, IEEE Access PP(99):1-1, DOI: 10.1109/ACCESS.2022.3204066

31. Muhammad Shoaib Farooq , Rizwan Javid, Shamyla Riaz , Zabihullah Atal, IoT Based Smart Greenhouse Framework and Control Strategies for Sustainable

Agriculture, IEEE Access, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9875288

32. S. Ratnaparkhi , Suvaid Khan, Chandrakala Arya, Smart agriculture sensors in IOT: A review,‟‟ 1496 Mater. Today, Proc., vol. 46, no. 18, pp. 1–6, 2020,

33. E. M. Gross, B. P. Lahkar, N. Subedi, V. R. Nyirenda, L. L. Lichtenfeld, 1498 and O. Jakoby, (2018) Seasonality, crop type and crop phenology influence 1499 crop damage by wildlife herbivores in Africa and Asia,‟‟ Biodiversity Conservation, vol. 27, no. 8, pp. 2029–2050, 2018

34. M. R. Conover, E. Butikofer, and D. J. Decker, (2018)Wildlife damage to crops: 1502 Perceptions of agricultural and wildlife leaders in 1957, 1987, and 2017,‟‟ 1503 Wildlife Soc. Bull., vol. 42, no. 4, pp. 551–558

35. Lova R. K. & V. Vijayaraghavan, (2020) IoT technologies in agricultural 1505 environment: A survey,‟‟ Wireless Pers. Commun., vol. 113, no. 4, 1506 pp. 2415–2446, 2020

36. Ullah I. F. M., Aman M., & Kim D., (2022) An optimization scheme for IoT 1508 based smart greenhouse climate control with efficient energy consumption, Computing, vol. 104, no. 2, pp. 433–457

37. Antony A. P, Leith K., Jolley C., J. Lu, Sweeney D. J., (2020) A review 1514 of practice and implementation of the Internet of Things (IoT) for small- 1515 holder agriculture,‟‟ Sustainability, vol. 12, no. 9, p. 3750

38. Mekonnen Y., Namuduri S., Burton L., A. Sarwat, and Bhansali S., (2019) Machine learning techniques in wireless sensor network based precision agriculture, J. Electrochem Soc., vol. 167, no. 3, 1519 Art. no. 037522

39. A. Sharma, A. Jain, P. Gupta, and V. Chowdary, (2020) Machine learning 1521 applications for precision agriculture: A comprehensive review,‟‟ IEEE 1522 Access, vol. 9, pp. 4843–4873

40. R. Akhter and S. A. Sofi, (2021) Precision agriculture using IoT data analytics and machine learning, J. King Saud Univ.-Comput. Inf. Sci., vol. 34, 1525 no. 8, pp. 5602–5618