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Conference paper

Designing localized irrigation system powered by solar pumping system for various forms of green space

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Abstract

This article explores advancements in drip and sprinkler irrigation systems integrated with solar pumping technologies to enhance irrigation efficiency for square, circular, and irregular green spaces. It focuses on variations in flow rates and energy requirements based on design and layout changes. The study starts with designing and sizing irrigation systems, calculating crop evapotranspiration rates, assessing irrigation demands, and sizing pipes like supply lines and laterals. This phase also involves determining total dynamic head to evaluate the energy needs for the solar pump's operation. The next phase sizes a photovoltaic pumping system, specifying components like the solar array, battery storage, controllers, inverters, and cabling. The daily water flow for the irregular space is measured at 40 cubic meters, exceeding the square's 10 cubic meters and the circular's 12 cubic meters. Therefore, the photovoltaic generator for the irregular space must deliver 2616 watts peak, compared to 523.2 watts for the square and 627.8 watts for the circular configuration.

Keywords: *Green spaces, irrigation system, solar pumping system, sprinklers, drippers.*

1. Introduction

A significant challenge in the Saharan region is the scarcity of green spaces, worsened by limited water and energy resources for sustainable development. Innovative drip and sprinkler irrigation systems have emerged as efficient methods for targeted water application, ensuring essential resources are delivered to crops for optimal growth. To develop a suitable irrigation system for the region's needs, identifying a reliable energy source is essential, with solar pumping systems recognized for harnessing solar energy for sustainable irrigation. The design of gardens and green spaces has evolved, integrating advanced irrigation systems for the Saharan environment. Well-designed, installed, and maintained systems minimize resource loss and prevent degradation of essential natural resources for ecological balance. This research explores innovative, sustainable, and cost-effective irrigation techniques powered by solar energy to maximize water management efficiency in arid regions. The study will implement drip and sprinkler

irrigation systems alongside solar pumping technology to irrigate three geometric configurations of green space—square, circular, and irregular—each covering 300 square meters. This investigation will analyze how shape variations influence the irrigation network's design and implementation, including dripper and sprinkler arrangements and solar pumping configuration, focusing on the number of solar panels and batteries necessary for optimal energy efficiency.

2. Method and research

2.1. Design steps of drip and sprinkler irrigation networks

Designing an irrigation system requires evaluating water sources and quantities. Local conditions must also be assessed, including elevation, climate data (especially reference evapotranspiration ET_0), soil characteristics, and crop needs (type, growth stages, and timing). After gathering this essential information, follow these design steps:

1. Estimate Peak Water Requirement
2. Select Drippers and Sprinklers
3. Size Pipes (supply line, mainline, manifold, and laterals)
4. Calculate Total Dynamic Head
5. Calculate Required Power

- **Crop evapotranspiration**

Evapotranspiration ET_{crop} combines soil evaporation and plant transpiration and can be determined using the Penman-Monteith equation:

$$ET_{CROP} = ET_0 \cdot k_c \quad (1)$$

For drip irrigation design [9]:

$$ET_{CROP-drip} = ET_{CROP} \cdot k_r \quad (2)$$

$ET_{CROP-drip}$: crop evapotranspiration for drip irrigation (mm/day).

ET_0 : reference evapotranspiration (mm/day).

k_c : crop factor.

k_r : ground cover reduction factor.

- **Net depth of water application**

The quantity of water essential for evapotranspiration is defined by the net depth d_{net} supplied through irrigation. This amount, known as readily available moisture, is necessary for the crop throughout its growth cycle, ensuring the plant receives adequate hydration to thrive.

$$d_{net} = (FC - PWP) \cdot RDZ \cdot P \quad (3)$$

FC: soil moisture at field capacity (mm/m).

PWP: soil moisture at the permanent wilting point (mm/m).

RDZ: the depth of soil that the roots exploit effectively (m).

P: the allowable portion of moisture permitted for depletion by the crop before the next irrigation (%).

FC-PWP: available moisture (m).

- **Irrigation requirement**

- *For drip irrigation*

Gross irrigation requirement IR_g refers to the total depth or volume of water needed for crop growth, ensuring adequate moisture throughout the growing cycle. This measurement considers contributions from natural rainfall or nearby water bodies while accounting for losses through evaporation or seepage that affect water efficiency. It also evaluates operational inefficiencies during irrigation stages, including system design and timing, which impact agricultural productivity and sustainability.

$$IR_g = \frac{ET_{crop-loc}}{E_D} - R + LR \quad (4)$$

R: water received by plant from sources other than irrigation (for example rainfall).

LR: amount of water required for leaching of salts.

E_D : field application efficiency of drip irrigation system.

- *For sprinkler irrigation*

The gross depth of water application d_{gross} is a critical measurement defined as the net irrigation depth needed for optimal crop growth, divided by the efficiency of the irrigation system used. This calculation must also consider potential water losses from leaks, evaporation, or inefficiencies in the piping infrastructure delivering water to the crops.

$$d_{gross} = \frac{d_{net}}{E_S} \quad (5)$$

E_S : The farm irrigation efficiency of sprinkler irrigation system.

- **Total dynamic head**

Total Dynamic Head, commonly referred to by the acronym TDH, represents the comprehensive overall head required to ensure the steady maintenance of adequate pressure at the outlet of the dripper. This vital and indispensable parameter is ascertained through the utilization of the following equation [6]:

$$TDH = (Sl + Fs + Fc + Fml + Fmn + Fl + Op)10\% + De \quad (6)$$

Sl: The suction lifts.

Fs: Friction losses in the supply line.

Fc: Friction losses in the control head.

Fml: Friction losses in mainline.

Fmn: Friction losses in manifold.

Fl: Friction losses in the laterals or drip lines.

Op: The drippers or sprinklers operating pressure.

De: The difference in elevation between the water level and the highest point on the land.

10%: for friction losses in fittings.

Friction loss, denoted as (F), in piping systems—including supply lines, main trunk lines, manifolds, and lateral connections—significantly influences the length of pipes and their material composition. Materials such as Polyethylene (PE) for flexibility, Polyvinyl Chloride (PVC) for lightness and corrosion resistance, Asbestos-Cement (AC) for strength, and Aluminum for its strength-to-weight ratio each affect performance in distinct ways. This

friction loss can be accurately assessed and quantified through established calculation methodologies and procedures recognized by the engineering community, ensuring reliable analysis for pipeline system design and optimization

$$F = h_l \cdot L \cdot f \quad (7)$$

Where:

h : head loss, it is determined by the charts in reference (%) [9].

L : length of pipe (m).

f : reduction coefficient for multiple outlet lines [9].

2.2. Photovoltaic sizing

Critical data essential for designing a solar pumping system includes several key components that must be evaluated:

- Understanding daily and monthly water consumption needs is vital to ensure the solar system meets demand throughout the year, providing consistent service.
- The installation location must be identified with accurate coordinates and an assessment of potential shading obstructions, like trees or structures, that could impact solar panel performance during daylight.
- Water delivery specifications should be defined, including the vertical elevation from the pump to the delivery point and the horizontal distance from the pump to the delivery point, as these factors affect system efficiency and effectiveness.
- Additionally, determining the maximum energy output capacity of the photovoltaic generator is crucial, as it dictates the performance and reliability of the solar pumping installation during its operational life.

Sizing a photovoltaic pumping system should be customized to address unique requirements, objectives, and financial constraints of the project, ensuring a tailored approach that maximizes efficiency, sustainability, and long-term viability

• Sizing and specifying an array

The solar array design is formulated and crafted based on a comprehensive calculation of the generator capacity required for the efficient operation of a solar-driven pump, essential for optimal performance in various environmental conditions. This process also involves the precise determination of the technical specifications of the solar panels used in the system, focusing on the peak power (P_p) output, a critical parameter for evaluating and enhancing overall system efficiency

$$P_p = \frac{2.725 \cdot Q_d \cdot TDH}{\eta_{mp} \cdot k \cdot Irr} \quad (8)$$

Q_d : daily flow (m³/day)

η_{mp} : motor pump efficiency.

K : the coefficient k takes into consideration all the drops in panels efficiency, cables and inverters.

Irr : average annual irradiation kWh/m²/day.

• Sizing and specifying batteries

Batteries are specifically engineered and meticulously designed to effectively accommodate and precisely manage the energy output that is dictated by a comprehensive and thorough assessment of the capacity that is denoted as C ,

which represents an essential measurement in the context of energy storage systems in various applications.

$$C = \frac{E_c \cdot N}{D \cdot U} \quad (9)$$

N: number of days of autonomy.

D: maximum depth of discharge acceptable by the battery.

U: system voltage.

- **Sizing a controller**

The rated input current of the charge controller, which is often referenced and discussed in a wide array of technical conversations, detailed documents, and scholarly literature, is commonly denoted by the term I_{rated} . This specific value can be accurately determined by utilizing the essential equation outlined in the pertinent reference number [13], which provides clear guidelines for its calculation

$$I_{rated} = (N_{PV-parallel} \cdot I_{sc}) 1.25 \quad (10)$$

I_{sc} : short circuit current.

$N_{PV-parallel}$: number of PV modules in parallel.

1.25: safety factor.

- **Sizing and specifying an inverter**

When the power capacity of the inverter exceeds the maximum output generated by the photovoltaic (PV) system, it becomes critically important to thoroughly assess its capability to fulfill the highest power requirements of the pump efficiently. The complete volt-amperes rating of an inverter, which is represented as VA_{invt} , can be calculated by utilizing the formula provided in reference [14]

$$VA_{invt} = P_p (0.8) \quad (11)$$

3. Results and discussion

The study examines three geometric configurations of green spaces—square, circular, and irregular—each with an area of $300m^2$. Illustrated in Figure 1, these design alternatives showcase various arrangements of vegetation and irrigation systems, tailored to each shape. While the layouts differ notably in shape and design elements, all configurations harmoniously blend palm trees, lush grass, colorful flowers, and aromatic species to enhance the aesthetic and ecological value of these outdoor spaces.

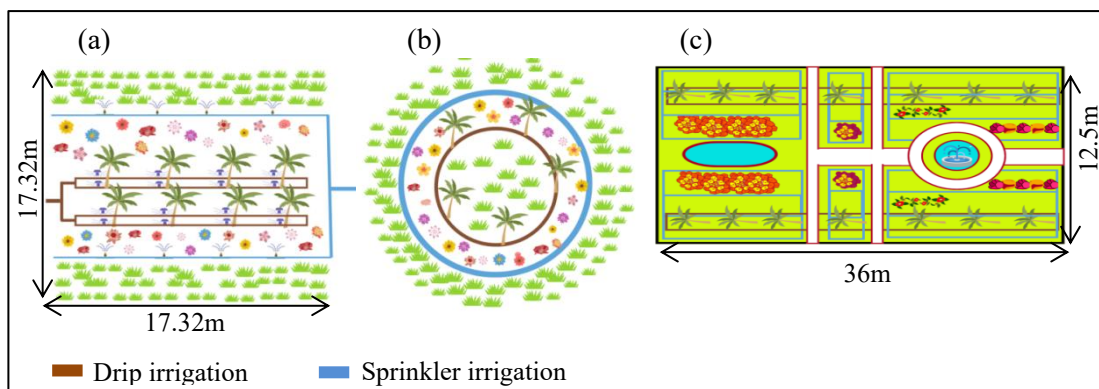


Figure1: The three green space forms dimensions, they should be listed as: (a) square; (b) circle; (c) random shape.

The soil type under investigation is sandy loam, identified through analysis with a moisture content of 90 mm/m

[10]. This examination focuses on plant species with high water needs, emphasizing the requirements of palms and grasses. The monthly evapotranspiration rates for palms (ETP_{palm}) and grasses (ETP_{grass}), along with climatological data influencing these rates, are presented in the figures below.

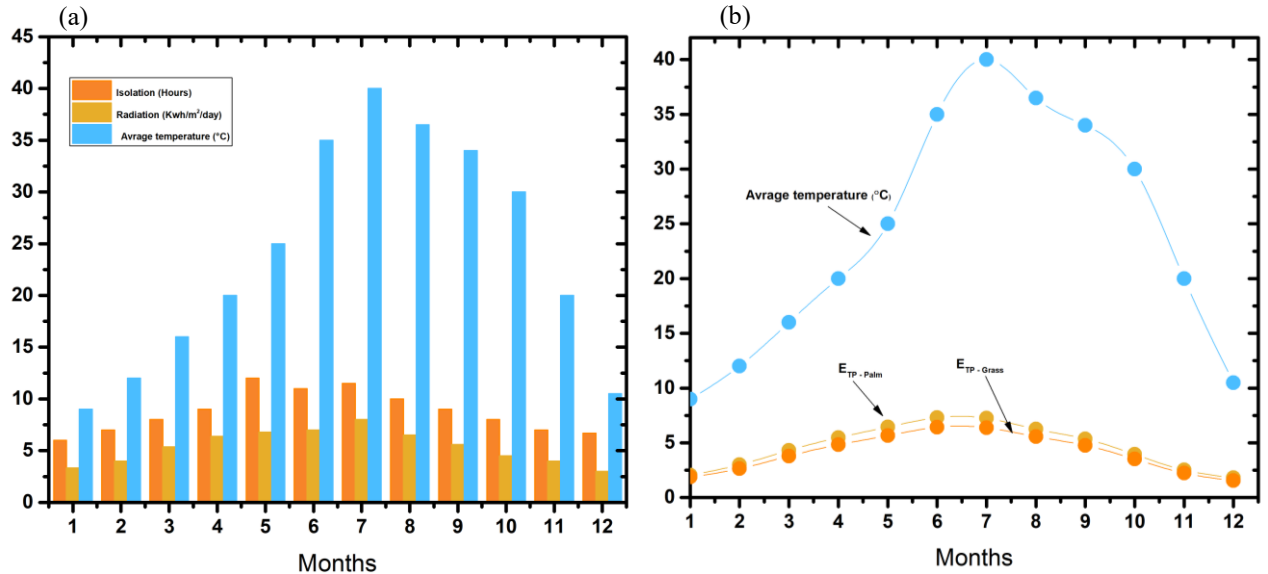


Figure 2: Monthly evaluation of insolation, radiation, average temperature and crop evapotranspiration (Data are estimated by CROPWAT software in year 2021).

The histogram presented in figure (a) illustrates the monthly fluctuations experienced in insolation (I), solar radiation (S_r), and average temperature (T_{av}) from the beginning of January through to the end of July. During this specific period, the values for I , S_r , and T_{av} exhibit a distinctly notable upward trend, which is subsequently followed by a gradual decline as the months progress toward December. These observable changes are primarily the result of the Earth's axial rotation and its tilt in relation to the sun. Solar radiation reaches its peak at a substantial value of 8 kWh/m²/day, while the total duration of insolation amounts to an impressive 12 hours; furthermore, the average temperature rises to a notable high of 40°C in July, which signifies the height of the summer season. This climatic phenomenon can be understood through the lens of the Earth's axial tilt, which causes the northern hemisphere to tilt toward the sun during the summer months, thereby allowing sunlight to strike the surface at nearly a vertical angle, which has a significant impact on both temperatures and prevailing weather patterns. In contrast, during this same time period, the southern hemisphere experiences markedly different climatic conditions [22]. Figure (b) provides a visual representation of the monthly average temperature along with the corresponding evapotranspiration rates for grass and palm vegetation, effectively highlighting the intricate relationship that exists between these two variables. The rates of evapotranspiration are inherently linked to the variations observed in temperature; thus, it becomes clear that fluctuations in temperature directly influence the rates of crop evapotranspiration. Following a thorough analysis of the primary data collected, three innovative irrigation networks were subsequently developed, utilizing both drip and sprinkler systems specifically tailored for three distinct types of green spaces. These advanced irrigation systems incorporate three unique solar pumping configurations that have been meticulously optimized for maximum efficiency [15, 16]. Furthermore, Table (1) and figure (3) provide a comprehensive assessment of hydraulic photovoltaic sizing outcomes, thereby offering valuable insights into the performance and overall

efficiency of these systems when applied to real-world scenarios and applications.

Table1: Configuration of drip and sprinkler irrigation network [17,18].

		Square	Circle	Random shape
Drip irrigation	Number of drippers	20	16	48
	TDH (m)	20	27	2
	Q_h (m ³ /h)	0.3	0.25	7.5
	Pr (w)	30	32	909
Sprinkler irrigation	Number of sprinklers	3×(PRO-VAN Nozzles MOD10)	3×(430R)	24×(IPN-8H)
	TDH (m)	30	24	30
	Q_h (m ³ /h)	2	2.5	3
	Pr (w)	242	303	454.54

The table comparing two irrigation methods: "Drip irrigation" and "Sprinkler irrigation," applied to three different geometric shapes: "Square," "Circle," and "Random shape."

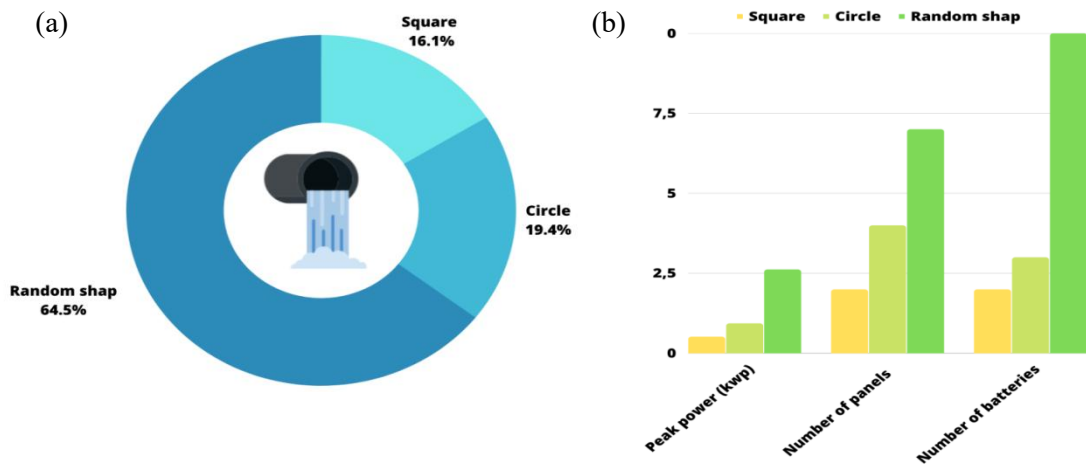
Under the "Drip irrigation" section:

- **Number of drippers:** This row indicates the number of drippers used for each shape (20 for Square, 16 for Circle, 48 for Random shape).
- **TDH (m):** Represents the Total Dynamic Head in meters (20 for Square, 27 for Circle, 2 for Random shape).
- **Q_h (m³/h):** Denotes the flow rate in cubic meters per hour (0.3 for Square, 0.25 for Circle, 7.5 for Random shape).
- **Pr (W):** Shows the required power in Watts (30 for Square, 32 for Circle, 909 for Random shape).

Under the "Sprinkler irrigation" section:

- **Number of sprinklers:** This row indicates the number of sprinklers used, along with their nozzle types or models (3-(PRO-VAN Nozzles MOD10) for Square, 3-(450R) for Circle, 24-(IPN-8H) for Random shape).
- **TDH (m):** Represents the Total Dynamic Head in meters (30 for Square, 24 for Circle, 30 for Random shape).
- **Q_h (m³/h):** Denotes the flow rate in cubic meters per hour (2 for Square, 2.5 for Circle, 3 for Random shape).
- **Pr (W):** Shows the required power in Watts (242 for Square, 303 for Circle, 454.24 for Random shape).

In summary, the table provides a detailed comparison of key variables in the design of two irrigation systems, allowing for an evaluation of efficiency and performance for each geometric shape and irrigation type.



Results of photovoltaic sizing [19].

Figure3:

Figure (a) presents a detailed representation of essential daily water flow requirements critical for effective irrigation practices. Figure (b) outlines three configurations of solar pumping systems that could be considered for various irrigation scenarios. The irregularly shaped area demands a substantial volume of water—40 m³/day—constituting 64.5% of overall irrigation needs, contrasting with the square configuration requiring only 10 m³/day and the circular configuration needing 12 m³/day. This disparity in water requirements arises from the complexities of designing and optimizing an efficient irrigation network, akin to the Hama Garden's system, which uses 48 drippers and 24 IPN-8N sprinklers, requiring a robust 2-horsepower pump to meet its substantial flow needs. In contrast, the square and circular setups use only 20 drippers and three sprinklers each, with flow rates of 10 m³/day for the square and 12 m³/day for the circular, demonstrating the efficiency of simpler designs. Consequently, a half-horsepower pump suffices for the square configuration, while the circular design needs a slightly more powerful 1-horsepower pump to meet its unique water needs. This situation leads to increased energy demands for the photovoltaic (PV) system for the irregular area, necessitating an energy output of 2616 wp, in stark contrast to the lower energy needs of the other configurations: 523.2 wp for the square and 627.8 wp for the circular. As a result, the number of solar panels and batteries varies significantly; the irregular area requires 7 solar panels and 5 batteries, while the square configuration uses only 3 panels and 3 batteries, and the circular design has 2 panels and 4 batteries to meet its energy demands. Effective management of the PV system is crucial for sustainability; a smart solar controller rated at 150/100 is essential for the irregular setup, while a less robust controller rated at 100/30, along with a Phonix 12V/375VA inverter, suffices for the other configurations.

4. Conclusion

An accurate and well-structured methodology for calculating and sizing irrigation components is absolutely essential for the effective execution and implementation of optimal drip and sprinkler irrigation systems, particularly those that incorporate innovative solar pumping technologies. These advanced irrigation approaches significantly contribute to reducing the overall costs of the system by efficiently decreasing the usage of water, minimizing labor requirements, and lowering energy consumption. This comprehensive study thoroughly investigates the intricate interplay between the design of green spaces—taking into consideration critical elements such as the form, variety, and strategic arrangement of vegetation and trees—the thoughtful layout of irrigation systems, and the effective

incorporation of photovoltaic systems. The primary objective of this extensive project is to provide both the general public and those individuals tasked with the management and maintenance of municipal green areas with the essential tools and valuable resources necessary to promote the efficient and sustainable use of water in outdoor irrigation practices.

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References

1. Charles ; Mourice, P. les réseaux d'irrigation théorie, technique et économie des arrosages (6rd edt.61 boulevard Saint-Germain-75005 Paris 1983).
2. Chancelier, L ; Laurent, E. l'électricité photovoltaïque (COOPERATION FRANCAISE,Ademe 1995).
3. Urban green space intervention and health (Wold heath organization, EROPEAN ENVIRONMENT AND HEALTH PROCESS 2017).
4. <https://www.aps.dz/ar/regions/109002-2021-06-26-12-18-25>.
5. Drip irrigation handbook understanding the basics (NETAFIM, 2015).
6. Hadja, G; Mebarka, D; Abdelhak, M. Irrigation Network Requirements for Watering Urban Green Space in Semi-arid Region. The 3rd International Conference On Water Security And Management (WSM 2021), 12/03/2021 Sanya (China).
7. Shehzad, A; Ajaz. Design and Operations Manual Pressurized Irrigation Systems Volume I (Lahore, Pakistem , Decembre 2013) (pp. 231-233)
8. Mthieu, C; Audoye, P; Chossat, J. Bases techniques de l'irrigation par aspersion. (LAVOISIER 2007).
9. Andrees, P; Kren,S. Localized irrigation systems planning, design, operation and maintenance Volume IV (FAO Sub-Regional Office for East and Southern Africa (SAFR),Harare 2002).
10. Sprinkler irrigation system planning, design, operation and maintenance Volume III Module8.
11. Cordova, M; Carrillo-Rajas, G; Crespo, P; Wilcox, B; Céleri, **R**. Evaluation of the Penman-Monteith (FAO 56 PM) Method for Calculating Reference Evapotranspiration Using Limited Data (Mountain Research and Development, 35(3):230-239 (2015)).
12. Solar-powered pumping in agriculture: A guide to system selection and *design* (NSW Farmers Association with the assistance of Global Sustainable Energy Solutions Pty Ltd. (GSES) and funding from the NSW Office of Environment and Heritage) (p. 9).
13. Bhatia, A. Design and sizing of solar photovoltaic system (CED Continuing Education and Developement,Inc. 22 Stonewall Court Woodcliff Lake, NJ07677).
14. Krishnamoorthi, M; Kaviyarasu, S. Solar Pump with Solar Panel Tilting Arrangement. *International Research Journal of Engineering and Technology (IRJET)*. e-ISSN: 2395 -0056 / p-ISSN: 2395-0072. Volume: 03 Issue: 05 May-2016.
15. Technical manual for ideal micro irrigation systems (international development enterprises, 10403 WEST COLFAX, SUIT 500 LAKEWOOD, CO 80215, USA).
16. Tiwari, K. N; Rajput, T. B. S. Micro-Irrigation Systems Design.

17. Landscape Irrigation Catalogue (Irritol, 2015).
18. Landscape Irrigation Design Manual (Rain Bird).
19. General pumps, S.L. DOMESTIC PUMPS 50 Hz, POL. Ind. El Oliveral (U.E.7, Nave nº1)- Calle W 46394 Ribarroja del Turia – Valencia Spain.
20. Catalogue PRODUITS SOLAIRES PHOTOVOLTAIQUES (Condor).
21. Datasheet-Phoenix-Inverter-VE.Direct-250VA-1200VA-FR.
22. JAC 11th Class Fundamental of Physics Geography Chapter 9 Solar Radiation, Heat Balance & Temperature Book 2021-22, Jharkand Board.