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Studies on solar pump capacity for irrigation in Konkan region

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Abstract
The Konkan region is characterized as high rainfall and hilly region and receives annual average rainfall ranging from 2500 to 4000 mm. Region receives solar energy for 8-9 months (Sept- May) in a year with average sunshine hour's ranges between 6.5 to 7.5 hrs/day. The Konkan region is a hilly area with varied topography due to which farmers have less land holdings, and variation in cropping pattern. The overall about 47.67% area is under cultivation out of total geographical area. Out of total cultivated area only 5.76% area is under irrigation during Summer and Rabi season. The 67.88% farmers belongs to the marginal farmers having land holding is less than one hectare to target the group of farmers the solar powered irrigation system was designed to fulfil the irrigation requirement of one hectare land holding of five district. The peak water requirement with combination of crop excluding paddy crop for one hectare area of five district was estimated as, 27 to 38 m^3 per day. The maximum energy and water horse power required to discharge the required amount of water was found to be of 1.7 kWh/day and pump horse power was less than 2 horse power. It was also observed that the farmers in Konkan region was not operate the pump to their full capacity due low land holdings. The pump was operate daily less than 3 hours to meet their water requirement. The SPV pump system can be generate excess energy about 4.5 to 5.5 kWh/day. The generated excess energy could be used to agriculture field operation by identifying the appropriate machinery.

Keywords: Drip irrigation, SPV pump, utilization of energy, water requirement

1. Introduction
Solar energy which is free and abundant in most parts of the world has proven to be economical source of energy in many application. The sun is a clean and renewable energy source, which produce neither greenhouse effect gas nor toxic waste through its utilization. Photovoltaic (PV) is a technology in which radiant energy from the sun is converted to the direct current (DC) electricity. The one of the major application of the solar photovoltaic is SPV water pumping system for the irrigation. The technique of solar based water pumping is essential technology to conserve valuable resources i.e. water and energy. The system is best suitable for water pumps which are designed to lift water for irrigation, horticulture, farming and various domestic uses. Solar based water pumping system is best alternative for areas where there is no electricity or have scarcity of other power source. This system can withstand extreme weather condition from hot, humid, rainy, and stormy to dusty. (Korpale *et al*., 2015) [10].

India achieved 5th global position in worldwide solar power generation by surpassing Italy. India have already implemented the scheme 'Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM), since 2019. The aim of this scheme is to add solar and other renewable capacity of 25,750 MW by end of 2022. The Scheme consists of three components:

A. 10,000 MW of distributed, ground-mounted, grid-connected renewable power plants.
B. The installation of 17.50 lakh independent solar-powered agricultural pumps, each with a 7.5 HP pumping capacity.
C. Solarizing 10 lakh agricultural pumps with individual pump capacities of up to 7.5 HP that are connected to the grid. (Ministry of New and Renewable Energy)

Based on the cropping system in konkan region, type of crop, crop duration and irrigation interval, the solar pumping system supplied under government scheme cannot operate to its full extend hence reduce the economic benefits.

During the ideal condition (no water requirement) of SPV pumping system, the huge converted power from SPV panel was wasted without any useful work. It is necessary to utilize the power available during ideal condition for useful gain. The available power from SPV system could be utilized for battery charging for Inverters, small equipment's, lighting, vehicles etc. with suitable charging system. The effective utilization of SPV pumping system for battery charging, grass cutting, weeding and in agricultural field operation will add the additional benefit to the user.

2. Material and Methods

2.1 Study area

Konkan region consist of five districts including, Palghar, Thane, Raigad, Ratnagiri, and Sindhudurg. Out of these five districts Raigad, Thane and Palghar constitute the North Konkan whereas Ratnagiri and Sindhudurg forms South Konkan. The study was conducted for Konkan region. The Konkan region is located between 15º60' N to 20º22' N latitude and 72º39' E to 73º48' E longitude. The Konkan region is a narrow terrain with width 60 km and length of 500 km with sea coast of 720 km in length. The study has been carried out in five district of konkan region in which all tehsil of each district has considered for the study.

2.2 Collection of data

The meteorological data required for estimation of pump capacity to calculate water requirement and need to be determine evapotranspiration rate for different stations. Weather data was collected for the region on monthly basis from NASA site. The meteorological data includes daily temperature, relative, sunshine hours, solar radiation and wind velocity at 2 m height for a period of 05 years (2017-2021). Other parameters like geographic locations, *viz*, latitude, longitude and altitude were also obtained for respective stations. The district wise data such as total land holdings of farmers, cultivated area, irrigated area, cropping pattern in region, major crops grown by farmers was collected for assessing the solar pump sizing in Konkan region.

2.3 Assessment of SPV pump sizing

2.3.1 Reference evapotranspiration (ETo)

There are many analytical and empirical equations that are currently used to calculate reference evapotranspiration (ETo) involving one or more climatic data. The Food and Agricultural Organization (FAO) Penman- Monteith method was used to determine reference evapotranspiration. (Allen *et al*. 1998).

$$ET_0 = \frac{0.408\,\Delta(Rn-G)+\gamma\left(\frac{900}{T+273}\right)u2(e_s-e_a)}{\Delta+\gamma(1+0.34\,u2)} \quad \ldots 1$$

Where,
ETo = Reference evapotranspiration, mm/day
Rn = Net radiation at the crop surface, MJ /m^2/ day
G = Soil heat flux density, MJ /m^2/ day
T = Mean daily air temperature at 2 m height, ℃
u2 = Wind speed at 2 m height, m/s
es = Saturation vapour pressure, kPa
ea = Actual vapour pressure, kPa
es-ea = Saturation vapour pressure deficit, kPa
Δ = Slope vapour pressure curve, kPa /℃
γ = Psychometric constant, kPa /℃

2.3.2 Kc Values for selected Crops

Crop coefficients are properties of plants that are used to predict the evapotranspiration as compared to the reference grass. Hence ETo and Kc together can predict the water requirement of a plant. These are different for different plants and at different stages of its growth. The Kc values for respective crop was taken from FAO-56.

2.3.3 Water requirement of the plant

Peak water requirement of the plant was evaluated to decide the pump size of water. (Ingale *et al*., 2020) [9]

$$W = \frac{crop\ area \times ETo \times kc \times wa}{Emission\ Uniformity} \quad \ldots 2$$

Where,
W = Peak water requirement, lit /day/plant
Crop area = row to row spacing, m × plant to plant spacing of the crop, m
Kc = Crop coefficient
WA = Wetted area
Eu = Emission uniformity of drip system

2.3.4 Total dynamic head

The total dynamic head (TDH) is composed of the total static head (hs), friction head losses (hf), and minor head losses (hm). The average total head of 25 meter was consider for design of solar pumping system. (Salilih *et al*., 2020) [13]

$$TDH = hs + hf + hm \quad \ldots 3$$

Where,
hs = Static head
hf = Friction head loss
hm = Minor head loss

2.3.5 Hydraulic energy

The daily energy required to pump water was calculated using following equation.

$$E_H = \frac{\rho \times g \times Q \times H}{3600} \quad \ldots 4$$

Where,
E_H = Hydraulic energy, Wh/day
Q = Total daily flow of water required, m^3
H = Total head, m
ρ = Density of water, 1000 kg/m^3
g = Gravitational constant, 9.81 m/s^2

2.3.6 Pump horse power, hp

Total pump horse power required to lift the water from the particular head and discharge is calculated with the following formula,

$$HP = \frac{Q \times TDH}{75 \times \eta} \quad \ldots 5$$

Where,
HP = Horse power, hp
Q = Discharge, lit/ sec
TDH = Total dynamic head, m

2.4 Design of solar array

2.4.1 Wattage of PV panel

Total wattage panel is determine after calculating hydraulic energy with following formula (Narale *et al*., 2013) [4]

Wattage of PV panel = $\frac{E_H}{H}$ …6

Where,
E_H = Total hydraulic energy
H = Peak Sunshine hour

2.4.2 Total wattage of PV panel considering system losses
(Narale *et al*., 2013) [4].

Total Wattage, kWh = $\frac{\text{Wattage of panel}}{\eta s \text{ X Mismatch factor (0.85)}}$ …7

Where,
η_s = System efficiency

2.4.3 Solar panel required
The total solar panel required for water pumping can be calculated once know the total wattage of PV panel considering system losses, including pump efficiency (Narale *et al*., 2013) [4].

Number of solar panel required = $\frac{\text{Total wattage of panel}}{\text{power of one panel}}$ …8

3. Results and Discussion
3.1 Overview of area under cultivation and irrigation in Konkan region
The preliminary data regarding the cultivated area, irrigated area and their distribution in the region was collected from various sources and is presented in the Table 1 the data of total geographical area revealed that overall 47.67% area was under cultivation during the year 2015-2016. Out of the cultivated area, only 5.76% area is under irrigation during Rabi and Summer season. Maximum area under irrigation during the 2015-16 was in Raigad district with 19.45% and minimum was found in Ratnagiri district is about 0.18%.
The major reason for very less area under irrigation is due to the topography of the region and thus very less infrastructure for irrigation supply could be created through irrigation system. Mainly the irrigation in the region is done through ground water or stored surface water harvested in the pond. The asses to electricity in isolated agriculture fields is another reason for irrigation thus, the solar powered irrigation system (SPIS) may play vital role in increasing the area under irrigation in the region.

Table 1: District wise distribution of cultivated and irrigated area

District	Geographical area, ha	Cultivated area (2015-16), ha	Cultivated area, %	Irrigated area (2015-16), ha	Irrigated area of Cultivated area,%
Palghar	399227	145799	36.52	2769	1.99
Thane	332986	128924	38.72	10481	8.13
Raigad	635473	314241	49.45	61113	19.45
Ratnagiri	891733	515039	57.76	944	0.18
Sindhudurg	514918	219093	42.55	872	0.40
Total	2774337	1323096	47.69	76179	5.76

(Agriculture Census 2015-16)

3.2 Land holdings for agriculture
To target the group of farmer for evaluating feasibility of SPIS, the data on land holding of agriculture was collected is presented in Fig 1. The data revealed that the majority of farmers in Konkan region falls under marginal category with up to 67.88% farmers having land holding less than 1 ha, followed by the small farmers about 15.86% whose land holding between 1-2 hectares according to the agricultural census 2015-16. Major category of farmers is under marginal and small land holding, thus this group was mainly focused for the feasibility evolution study of SPIS.

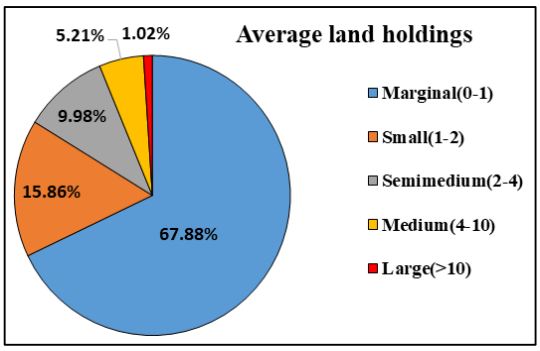

Fig 1: Average land holdings of farmers in Konkan Region

3.3 District wise Irrigated area under different crops in Konkan region
3.3.1 Crop wise total irrigated area in Palghar district
From the study it was found that out of total 2769 ha of area about 898 ha area in Palghar district is under irrigation for Sapota crop and it is about 32.43% of total irrigated area, similarly sapota, paddy, vegetables and other crops comprise more than 90% irrigated area. The paddy is included in this area but the paddy was not considered to irrigate with drip system.

Table 2: Crop wise total irrigated area in Palghar district

Sr. No.	Crop	Irrigated area, ha	Percentage of irrigated area
1	Mango	36	1.3
2	Coconut	148	5.3
3	Sapota	898	32.43
4	Vegetables	203	7.33
5	Paddy	998	36
6	Flowers	127	4.5
7	Other	359	12.96
	Total	2769	100%

(Agriculture Census 2015-16)

3.3.2 Crop wise total irrigated area in Thane district
From the study it can be seen that out of total 10481 ha area 460 ha area in Thane district is under Fodder crop and it is about 50.59% of Total irrigated area, it was observed that in Thane district the fruit crops are grown on very less land. But the maximum area is covered by the fodder crops and Rabi paddy. Again mainly Paddy and fodder crops comprise about 90% of total irrigated area. Vegetables are also contribute 4.3% of total irrigated area. The detailed crop wise area distribution is shown in Table 3.

Table 3: Crop wise total irrigated area in Thane district

Sr. No.	Crop	Irrigated area, ha	Percentage of irrigated area
1	Banana	45	0.42
2	Vegetables	460	4.3
3	Paddy	3951	37.69
4	Fodder crop	5303	50.59
5	Other	722	6.9
	Total	10481	100%

(Agriculture Census 2015-16)

Table 4: Crop wise total irrigated area in Raigad district

Sr. No.	Crop	Irrigated area, ha	Percentage of irrigated area
1	Mango	22162	36.26
2	Cashew	9966	16.3
3	Coconut	710	1.16
4	Vegetables	1093	1.788
5	Paddy	13779	22.54
6	Oilseed	725	1.18
7	Banana	11091	18.14
8	Other	1587	2.59
	Total	61113	100%

(Agriculture Census 2015-16)

3.3.3 Crop wise total irrigated area in Raigad and Ratnagiri district

Raigad and Ratnagiri districts are well-known for the mango crops, most of fruits crops are grown in both the district. It was observed that the in Konkan region the maximum area is under mango crop in the Raigad district among the other district. Total 22162 ha area is under the irrigated mango crop which was 36.26% of total irrigated area of 61113 ha. Mango, cashew, paddy and banana crop comprise more than 90% in the Raigad district and Followed by the Ratnagiri district occupies the 308 ha area under mango crop which is 32.62% of area is under irrigated mango out of 944 ha irrigated area. Mango, paddy and other crops comprise more than 90% in Ratnagiri district. The crop wise area distribution are presented in the Table 4 and Table 5 respectively.

Table 5: Crop wise total irrigated area in Ratnagiri district

Sr. No.	Crop	Irrigated area, ha	Percentage of irrigated area
1	Mango	308	32.62
2	Cashew	26	2.75
3	Vegetables	39	4.13
4	Paddy	462	48.94
5	Other	109	11.54
	Total	944	100%

(Agriculture Census 2015-16)

3.3.4 Crop wise total irrigated area in Sindhudurg district

After investigation it was observed that the Paddy, cashew other crops comprise more than 90% over total irrigated area. Cashew crop was majorly grown crop in Sindhudurg district covered with the 81 ha irrigated area having a contribution of 9.28% of total irrigated area of 872 ha. The total area distributed by crops is presented in Table 6.

Table 6: Crop wise total irrigated area in Sindhudurg district

Sr. No.	Crop	Irrigated area, ha	Percentage of irrigated area
1	Mango	31	3.55
2	Cashew	81	9.28
3	Coconut	13	1.49
4	Vegetables	37	4.14
5	Paddy	365	41.85
6	Other	345	39.49
	Total	872	100%

(Agriculture Census 2015-16)

3.4 SPV Pump size requirements for Konkan region

3.4.1 Peak water requirement to irrigate the different crops in one hectare area

From the cropping pattern and average land holdings it was calculate the season-wise daily water requirement for the crops using evapotranspiration rate (ETo), the calculated seasonally water requirement is shown in table for the combination of crops such as Mango, Cashew, Coconut, Sapota, Vegetables and other crops. The total irrigated area in each district is then distributed crop wise in the percent of total irrigated area excluding the paddy because the paddy crop was not consider for designing the solar pump and irrigating with drip irrigation. After converting the obtained area is then distributed over 1 hectare land. The water requirement has been calculated by considering the peak water requirement for the different crops over a 1 ha land holding. This was the peak water requirement in any month and variation of mix crop. It was found that the water requirement varies by season to season. In the summer season there is peak water requirement for farmers growing crops. It was revealed that the water requirement was more when there is combination of crops compare to the major sole crops over one hectare area. Hence the pump and solar array size was designed by considering the mixed crop.

Table 7: District wise peak water requirement and pump power requirement for mix crops (1 ha area)

District	Peak Water requirement, Lit/day		Energy required, kW		Water horse power, hp	
	Summer	Rabi	Summer	Rabi	Summer	Rabi
Palghar	32004.4	17265.6	1.4	0.922	1.65	0.89
Thane	38426.1	18992.7	1.7	1.03	1.98	0.98
Raigad	27476.0	13030.2	1.2	0.7	1.4	0.7
Ratnagiri	31453.4	14511.2	1.4	0.7	1.6	0.7
Sindhudurg	36032.5	18219.8	1.6	0.9	1.9	0.9

It was observed that in thane district the water requirement is higher than any other district in both the Summer and Rabi season. It was due high evapotranspiration rate in summer or in Rabi season. It was observed that in thane district fodder crops were grown on large scale about 50.59% over total irrigated area followed by the vegetables. The crop water requirement of this crop is 38426.1 lit/day in summer and 18992.7 lit/day in Rabi season, this water requirement was excluding the paddy crop. The energy required to lift that water is 1.07 kWh/day and 1.03 kWh/day respectively. It can be concluded that 2 hp pump size will be sufficient for thane district. But in government scheme 3 hp or 5 hp pump are available. This capacity of pump was not feasible for the farmers in the konkan region. It was found the pump size ranges within 1.5 to 2 hp was sufficient to fulfil the irrigation requirement by considering the drip irrigation in Konkan region.

4. Conclusions

1. The peak water requirement for irrigating the one hectare of land required 38 m³/ day in summer and 18 m³/ day in Rabi respectively, by considering the mixing of one or more crops.
2. The 67.88% farmers in the Konkan region falls under the marginal category which land holdings is less than one hectare.
3. The smaller pump between 1.5 to 2 hp was enough sufficient to meet the daily water requirement of konkan region, this size of pump is not included in the government scheme like PM (KUSUM) and Mukhyamantri Saur Krishi Pump Yojna.

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