Original Research Article

Techno Economic Assessment of Axial Flow Pumps in Thrissur Kole lands

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ABSTRACT

Water-logged areas in wetland paddy systems must be drained in the shortest time to initiate seed bed preparation. The short time for seed bed preparation demands the adoption of low head-high discharge pumps. Dewatering from these fields is mainly done by means of petty and para pump, a locally made crude form of axial flow propeller pump. The petty and para pump has low efficiency and requires significant installation cost and energy consumption. As a result, modern axial flow pumps are gradually replacing petty and para in order to reduce high operational costs. Hence it is necessary to assess the performance of the vertical submersible pump and vertical propeller pump to know the efficiency compared to traditional petty and para pumps. This study was conducted in Kole lands of Thrissur District in Kerala, India, during the year 2020-2022. Performance evaluation of 50 hp petty and para pump, vertical submersible pump and vertical propeller pump was done through field pumping test and the economic analysis was carried out by considering the capital investment costs, operating costs and benefits obtained from the cultivation of paddy in Thrissur Kole lands. The overall efficiency of 50 hp petty and para pump varied from 18.51 to 22.64 percent, with a mean of 20.58 percent. In the case of vertical submersible pump, the overall efficiency varied from 54.46 to 60.48 percent with a mean of 57.47 percent and the overall efficiency of vertical propeller pump ranged from 42.67 to 50.69 percent with a mean of 46.68 percent. The vertical submersible pump has the highest Benefit-Cost Ratio (BCR), Net Present Worth (NPW), Internal Rate of Return (IRR), and the lowest Payback Period (PP) and pumping costs among the three 50 hp axial flow pumps.

Keywords: Kole lands; axial flow propeller pump; petty and para pump; vertical submersible pump; vertical propeller pump.

1. INTRODUCTION

Rice production in the coastal districts of Kerala is heavily influenced by water management measures, particularly drainage requirements. The system of drainage of water from the bunded rice fields during the crop season is a unique aspect of paddy production process in these areas. Paddy is cultivated in the lowland regions of Kerala, such as Kuttanad, Kole, and Pokkali, which are places situated below MSL. The rice granary of Thrissur and Malappuram districts known as Kole lands, is located in central part of Kerala.

Kole lands in Thrissur and Malappuram districts spread partly along Thrissur, Chavakkad, Mukundapuram and Ponnani taluks [1]. The terrain with a saucer-like topography of Kole lands lies 0.50 to 1.50 m below MSL [2]. Kole lands cover an area of about 10325.5 ha in Thrissur district. Thrissur Kole is divided into Thrissur north Kole and Thrissur south Kole. North Kole covers 8056.8 ha and south Kole covers 2268.7 ha. The land is very fertile contains a lot of humus as it receives surface runoff from elevated area. The productivity of Kole lands is two to three times the average productivity of Kerala wetland paddy systems [3].

The waterlogged areas must be drained as soon as possible to begin seedbed preparation because of the limited time available for seedbed preparation. The low head-high discharge pumps are used for drainage. If water is impounded for a height of two meter, it is estimated that more than 200 Mm^3 of water is to be drained from the total cultivated area of Thrissur Kole fields. There are 315 axial flow pumps operating in Kole lands. Out of these, 239 are petty and para pumps, 54 are vertical submersible pumps and 22 are vertical propeller pumps.

Petty and para, a crudely built axial flow propeller pump made locally, are the major pumps used to dewater the field. Even though it serves the purpose of dewatering, it is highly inefficient. Its efficiency is less than 30 percent and requires significant installation cost and energy consumption [2]. When the water level in the sump drops, additional para should be fitted in order to continue the pumping. Before the onset of southwest monsoon, pump should be dismantled. Thus, the operation of petty and para is hectic and laborious. But farmers are continued to use petty and para because of the government subsidy for its installation and electricity charges. Some areas of the Kole lands use vertical propeller pumps and vertical submersible pumps which have efficiency of more than 40 percent. These types of pumps ensure saving of electricity charges, labour costs, loading, unloading and transporting charges of the pump from the storehouse to the pumping station. Hence a study was conducted to assess the performance of petti & para pumps, vertical submersible pump and vertical propeller pump with respect to its efficiency and cost economics.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in Kole lands of the Thrissur district in Kerala. Kole lands is located between 10º17'N to 10º 37'N latitudes and 76º 05'E to 76º 15'E longitude. Tropical humid monsoon type climate is prevailing in Kole lands. The area has an average minimum temperature of 21 °C and an average maximum of 38 °C [1]. As in other parts of the state, Kole lands also receives two well-defined rainy seasons: the South-West and North-East Monsoons. The average annual rainfall recorded in the Kole lands is 2757 mm [1] and the average evaporation in the Kole land is 5.8 mm per day [1]. The location map of the study area is shown in Fig.1.

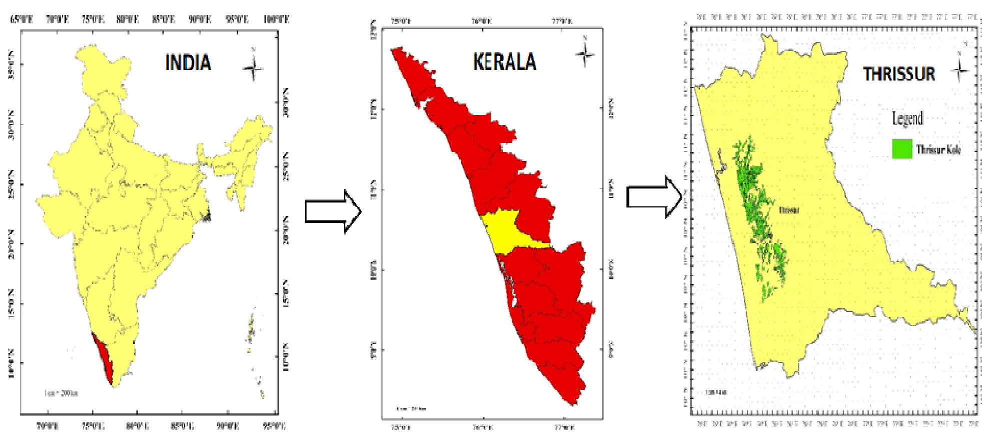


Fig.1 Location map of Thrissur Kole lands

2.2 Details of axial flow pumps operating in Thrissur Kole lands

Three different types of axial flow pumps are operating in Thrissur Kole lands. They are petty and para pumps, vertical submersible pumps and vertical propeller pumps.

2.2.1 Petty and para pump (PPP)

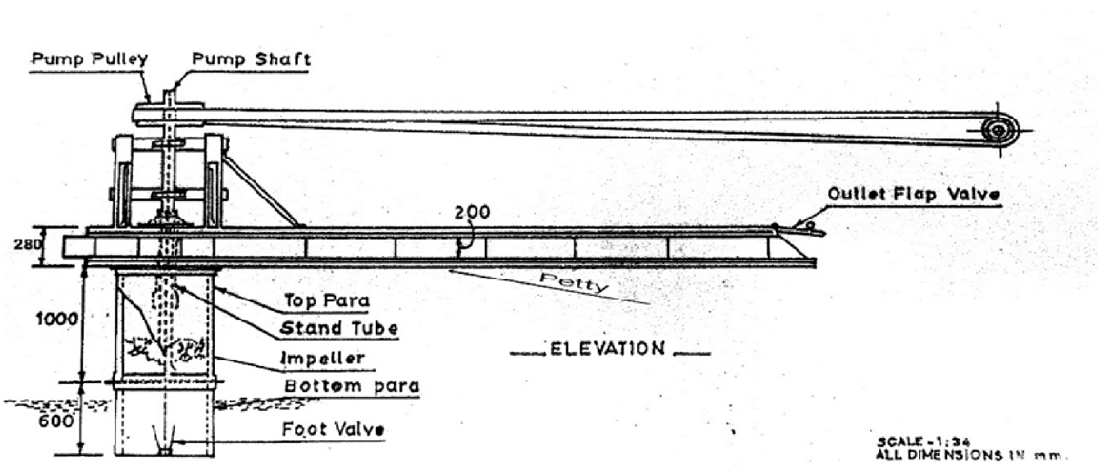
drum called ‘Para’. Due to the rotation of the impeller, the hydrodynamically stimulated water rushes axially upward via ‘Para’, twists 90 degrees, and exits through a horizontal, rectangular wooden outlet called ‘Petty’. The impeller is made of cast iron, and the blades are made of mild steel. Three to six blades can be found on an impeller. The blades are attached to the impeller shaft, which is composed of mild steel. A flat quarter turn belt with a length of 6 to 10 m and a width of 20 cm drives the impeller shaft [4]. Components of 50 hp petty and para pump is shown in Fig 2 (a).

2.2.2 Vertical submersible pump (VSP)

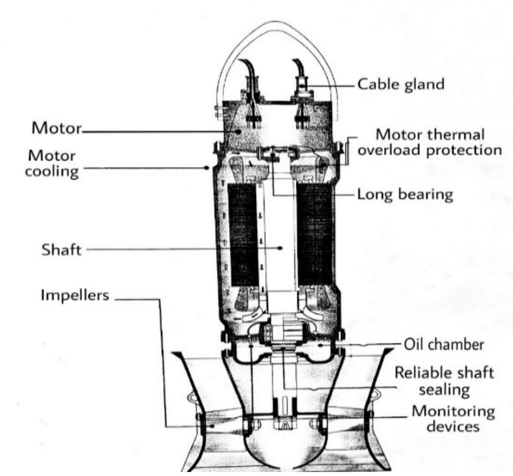
The shaft of a vertical submersible pump is made of stainless steel and is powered by a dry type induction motor. Cable glands enable four-stage sealing, which guarantees a pressure-resistant, moisture-proof seal even when the sheath is damaged. It also provides a dry environment for the pump. To prevent the pump from overheating and losing power, the motor's thermal overload protection is used. An oil chamber is fitted to lubricate and cool the mechanical parts efficiently. The parts of a 50 hp vertical submersible pump is shown in Fig. 2 (b).

2.2.3 Vertical propeller pump (VPP)

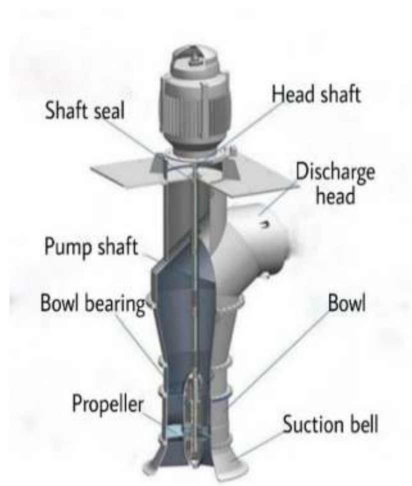
A vertical propeller pumps consists of a bowl assembly, a column assembly, and a drive unit assembly. A suction bell arrangement is made to allow water to enter steadily with minimum loss as possible. The pump’s shaft is made of high-tensile steel. Flow from the column pipe to the discharge pipe is directed by the discharge head. Fig.2 (c) shows components 50 hp vertical propeller pump.



(a)



(b)



(c)

Fig. 2 (a) Components of petty and para pump (b) Components of vertical submersible pump (c) Components of vertical propeller pump

2.3 Evaluation of the characteristics of axial flow pumps

district were selected for performance evaluation studies. The performance was evaluated by field pumping test. In order to carry out the pumping test, petty and para pump and vertical submersible pump were operated continuously for 8 hours and vertical propeller pump was operated continuously for 15 days. Observations on head, discharge, current, voltage and power were taken during the test.

2.3.1 Head calculation

The static head of petty and para was measured from the water level in the sump to the center of petty using a measuring tape. For vertical submersible pump and vertical propeller pump, it was measured from the water level in the sump to the center of the delivery pipe. The total head was calculated by adding frictional loss and velocity head to the static head. Head loss due to friction was calculated using Darcy-Weisbach equation

$$H_f=\frac{4*f*l*v^2}{2*g*d} \quad (1)$$

Where, f = Friction factor
l = Length of pipe (m)
v= Velocity of flow (ms^{-1})
g= Acceleration due to gravity (m^2s^{-1})
d= Inside diameter of the pipe (m)

(For the petty side ‘d ‘was taken as the width of petty). Flow through the pipe was turbulent so friction factor was calculated using the equation

$$f=\frac{0.316}{Re^{0.25}} \quad [5] \quad (2)$$

where, Re=Reynolds number
Reynolds number was calculated using the equation

$$Re= \frac{v*d^2}{\nu} \quad (3)$$

Where v = Flow velocity (ms^{-1})
d = Diameter of the pipe (m)
v = Kinematic viscosity

$$\text{Velocity head}=\frac{v^2}{2*g} \quad (4)$$

2.3.2 Discharge measurement

Discharge of petty and para pump was measured by area- velocity method**.** Discharge from the pump was diverted to an open channel of length 20 m, width 1.43 m. A vertical axis current meter was placed across the channel to measure the flow velocity. Discharge in m^3s^{-1} was calculated using the equation

$$Q = A*V \quad (5)$$

Where,
Q= Discharge (m^3s^{-1})
A=Area of cross-section of the channel (m^2)
V=flow velocity (ms^{-1})
Area (m^2**)** =Channel width (m)×Channel depth (m)

Discharges of the vertical submersible pump and vertical propeller pump were measured using a portable ultrasonic flow meter (Fig.3) at varying heads. TransPort PT 900 portable ultrasonic flow meter was used for the discharge measurement (Fig.3).

Fig.3 Ultrasonic flow meter mounted on the delivery pipe of vertical submersible pump

Input voltage and input current were measured by connecting the clamp meter to the input supply. The power factor was measured from the energy meter. Input Horse Power was calculated using the equation as follows

$$\text{Input Horse Power (IHP)} = \sqrt{3} * V * I * \cos\phi \quad (6)$$

Where,

V=Voltage (V)

I=Current (A)

cosø=Power factor

Water Horse Power was calculated using the equation

$$\text{Water Horse Power (WHP)} = \frac{Q*H}{76} \quad (7)$$

where,

Q=Discharge (lps)

H=Total head (m)

Overall efficiency of the pump was calculated using the equation

$$\text{Overall efficiency of the pump} = \frac{WHP}{IHP} * 100 \quad (8)$$

2.4 Economic analysis of axial flow pumps

The capital investment costs, operating costs, and benefits obtained from the cultivation of paddy using axial flow pumps were estimated. The economics was worked out in terms of the Benefit-Cost Ratio (BCR), Net Present Worth (NPW), Internal Rate of Return (IRR) and Payback Period (PP). The investment costs include the cost of the pump and installation cost. The operating costs include operation and maintenance costs, cost of electricity, cost of cultivation, and operator's wage. The benefit is the income obtained from the cultivation of paddy from the dewatered area. The basic data required for the estimation were collected by field survey.

Operation and maintenance cost of 50 hp petty and para includes the cost to dismantle the petty and para before the southwest monsoon season, the cost to assemble and install the petty and para after the monsoon, the cost of applying fish oil on the petty and para and the cost to change the belt and bearings. There is no maintenance cost for 50 hp vertical submersible pumps and 50 hp vertical propeller pumps for the first two years of the warranty period. Thereafter up to 10 years, annual maintenance cost is considered as 0.5 percent of the cost of pump and after that for the next 10 years it was taken at 1.0 percent of the total cost of pump. The cost of electricity for pumping was calculated by considering the average annual energy consumption of each axial flow pump. The cost of cultivation per ha was calculated by considering the costs of field preparation, fertilizer application, plant protection and harvesting cost.

2.4.1 Benefit-Cost ratio (BCR)

It is the ratio of present worth of the benefits (cash inflows) to the present worth of the costs (cash outflows).

$$\text{Benefit-Cost ratio (BCR)} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}} \quad (9)$$

where,

B_t= Benefit accrued in each year of project period in rupees

C_t = Cost incurred in each year of project period in rupees

t = Time period of project life, reckoned in years (one year).

n= Number of years of anticipated project life (20 years).

i= Discount rate selected on the basis of cost of capital (10 percent).

2.4.2 Net Present Worth (NPW)

The difference between the present worth of the benefits (cash inflows) and costs (cash outflows) over time is known as NPW.

$$\text{Net Present Worth} = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} \quad (10)$$

2.4.3 Internal Rate of Return (IRR)

IRR is the annual discount rate at which the present worth of two streams of cash- flow are equal or the discount rate at which net present worth is equal to zero.

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad (11)$$

2.4.4 Payback Period (PP)

The payback period is the number of years required to recover the original cash investment.

$$\text{Payback Period} = \frac{\text{Investment}}{\text{Cash flow per year}} \qquad (12)$$

2.4.5 Cost of pumping of axial flow pumps

Estimation of the cost of pumping is essential to compare the relative cost of different types of pumping installations. The cost of pumping per year of 50 hp petty and para, vertical submersible, and vertical propeller pumps were calculated by considering the fixed and variable costs of pumping. Fixed costs include annual interest cost and depreciation. Variable costs include electricity cost, operation and maintenance cost, and operator’s wages. Depreciation was calculated using the straight-line method. The interest rate was taken as 10 percent of the cost of the pump. Petty and para pump has a useful life of seven years, and the useful life of the vertical submersible pump and vertical propeller pump is taken as 20 years.

3. RESULTS AND DISCUSSION

3.1 Performance evaluation of axial flow pumps

A 50 hp petty and para pump was tested at different heads. The performance curve of the pump was plotted with discharge (m^3h^{-1}) against the head, Input Horse Power (IHP) and overall efficiency as shown in Fig.4. The pump discharge varied from 2,172.46 to 1,153.15 m^3h^{-1} when the total head varied from 0.98 to 1.82 m. During this the pump's overall efficiency dropped from a maximum of 22.64 to 18.51 percent, with a mean value of 20.58 percent. The overall efficiency increased (18.51 to 22.64 percent) as the head increased (0.9 to 1.36 m) and reached a maximum of 22.64 per cent. The pump showed a discharge of 1834.75 m^3h^{-1} and IHP of 40.18 hp, when the head was 1.36 m, and thereafter, the further increase in the head (1.36 to 1.82 m), decreased the efficiency (22.64 to 19.26 percent).

The performance characteristics curve of vertical submersible pump is shown in Fig.5. When the total head varied from 2.9 to 3.56 m, the pump discharge varied from 2,282 to 2,141 m^3h^{-1}. The pump showed an efficiency of 54.46 percent against the highest discharge of 2,282 $m^3h^{-1}$and a total head of 2.9 m. The overall efficiency topped to the maximum value of 60.48 percent against the total head of 3.56 m, and a discharge rate of 2,141 m^3h^{-1}. The input power corresponding to this efficiency was 46.04 hp. The pump's overall efficiency varied from a maximum of 60.48 to a minimum of 54.46 per cent, with a mean value of 57.47 per cent.

The vertical propeller pump's performance characteristics curve is depicted in Fig.6.Total head varied from 2.16 to 3.23 m. The pump discharge varied from 2,090 to 1,820 m^3h^{-1}. The pump's overall efficiency dropped from a maximum value of 50.69 to a minimum value of 42.67 percent, with a mean value of 46.68 percent. The overall efficiency increased (from 42.67 to 50.69 per cent) as the head raised (from 2.16 to 2.75 m) and reached a maximum of 50.69 per cent. The discharge of the pump was 1967 m^3h^{-1} when the head reached 2.75 m and the input power corresponding to this head was 39.02 hp. Thereafter, for the further increase in the head from 2.75 to 3.23 m, efficiency decreased from 50.69 to 47.95 percent.

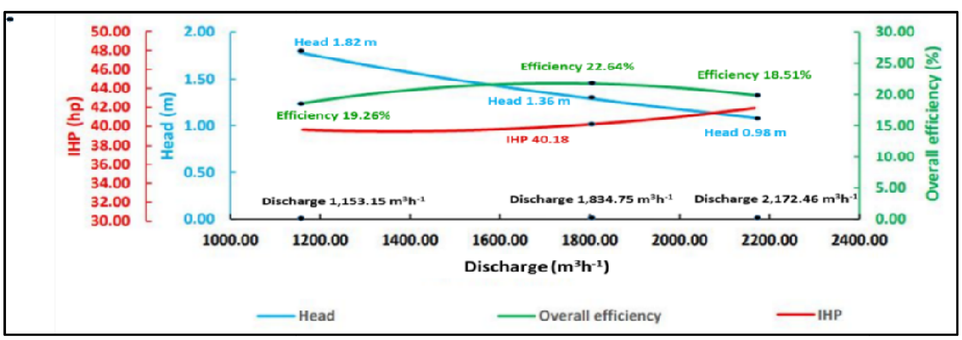


Fig.4 Performance curve of 50 hp petty and para pump

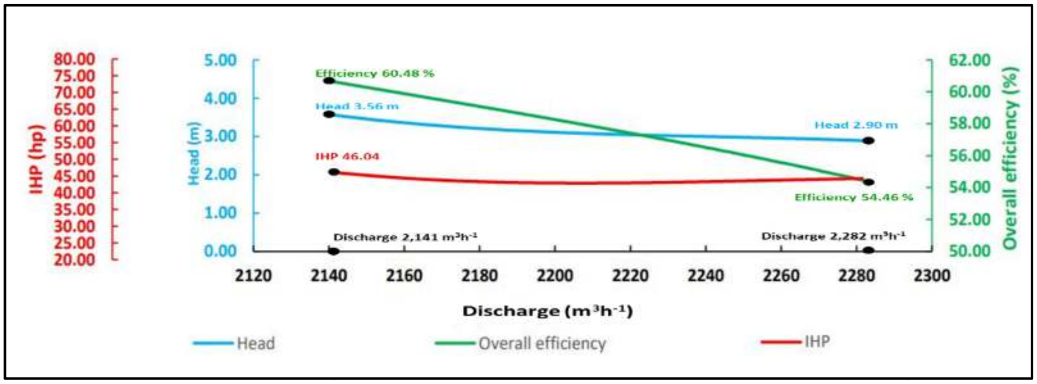


Fig.5 Performance curve of 50 hp vertical submersible pump

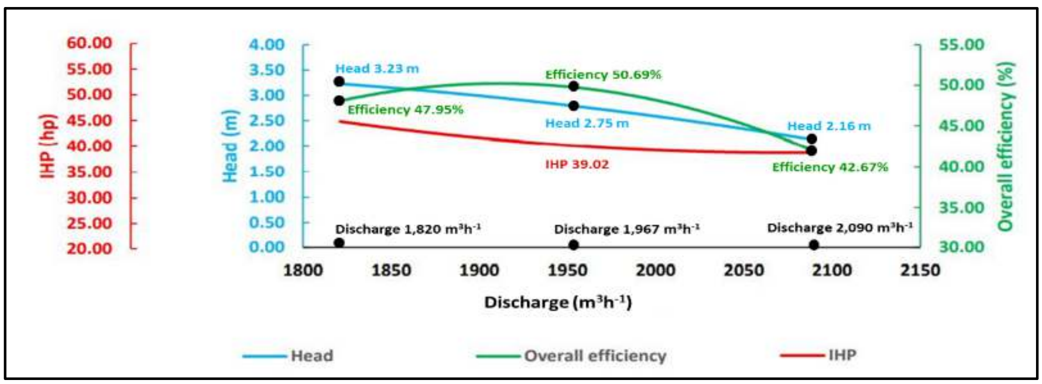


Fig.6 Performance curve of 50 hp vertical propeller pump

3.2 Economic analysis of axial flow pumps

The BCR, NPW, IRR and PP with respect to petty and para pump (PPP), vertical submersible pump (VSP) and vertical propeller pump (VPP) were calculated and the results are shown in Table 1.

Table 1 Results of economic analysis of various pumps

Sl no	Parameters	PPP	VSP	VPP
1	**BC ratio**	1.66	2.02	1.99
2	**NPW (₹ in lakhs)**	164.0	517.8	456.2
3	**IRR (%)**	238	329	319
4	**PP (years)**	0.95	0.30	0.31

Among the three axial flow pumps, the 50 hp vertical submersible pump has the highest BCR, which was 2.02, followed by the vertical propeller pump, which was 1.99, and the petty and para pump, which has the lowest BCR (1.66). Similarly, the NPW value for the vertical submersible pump was the highest, and it was ₹ 517.8 lakhs. The vertical propeller pump's NPW value was ₹ 456.2 lakhs, and the NPW of petty and para was ₹ 164.0 lakhs. The IRR of petty and para was 238 percent, whereas it was 329 percent for vertical submersible pump, and 319 percent vertical propeller pump. The PP for the 50 hp vertical submersible, vertical propeller, and petty and para pumps were 0.30,0.31 and 0.95 years respectively. The results of the economic analysis showed that the operation of vertical submersible pumps and vertical propeller pumps was economically more viable than petty and para pumps.

The cost of pumping per year & per ha of 50 hp petty and para pump, vertical submersible pump, and vertical propeller pump were calculated and are shown in Table 2. The cost of pumping in a year was ₹ 9.64 lakhs for 50 hp petty and para, whereas it was ₹ 6.95 lakhs for 50 hp vertical submersible pump and ₹ 7.21 lakhs for 50 hp vertical propeller pump. The cost of pumping per ha for 50 hp petty and para pump, vertical submersible pump, and vertical propeller pump were ₹ 25,707, ₹ 7,502 and ₹8,702 respectively. The results showed that the installation of vertical submersible pump and vertical propeller pumps were more profitable than petty and para pump.

Table 2 Cost of pumping of axial flow pumps

Sl no	Cost heads	Types of pumps		
		PPP	**VSP**	**VPP**
	Fixed cost			
1	Annual interest cost (₹)	55,000	1,21,000	1,10,000
2	Annual depreciation (₹)	1,28,571	99,000	90,000
	Variable cost			
3	Cost of electrical energy (₹)	4,92,490	2,49,543	2,92,060
4	Operation and maintenance cost (₹)	50,000	16,500	15,000
5	Operator’s wages (₹)	1,80,000	1,80,000	1,80,000
6	**Cost of pumping/year (lakhs)**	**9.64**	**6.95**	**7.21**
7	**Cost of pumping per ha (₹)**	**25,707**	**7,502**	**8,702**

4.CONCLUSIONS

A research study was conducted to assess the efficiency and cost economics of various axial flow pumps operating in Thrissur Kole lands. Among the three 50 hp axial flow pumps, the vertical submersible pump has the highest overall efficiency, BCR, NPW, and IRR, followed by the vertical propeller pump and petty and para pump. The PP and cost of pumping of vertical submersible pumps were also the lowest. Considering the operating cost per ha, efficiency, energy consumption, and economics of pumping, it is recommended that the water management system in Kole lands will be more efficient, if all petty and para pumps are replaced with modern axial flow pumps in the near future.

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