Middle East Journal of Applied Science & Technology (MEJAST)
Volume 8, Issue 4, Pages 68-77, October-December 2025

Improvement and on-farm evaluation of a locally fabricated spiral water pump for small scale Irrigation in Jimma Zone, Ethiopia

Abu Dedo Ilmi[1*], Teka Tesfaye[2] & Teklewold Dabi[3]

[1-3]Oromia Agricultural Research Institute, Jimma Agricultural Engineering Research Center, P.O. Box 386, Jimma, Ethiopia. Corresponding Author (Abu Dedo Ilmi) Email: abuhu2008@email.com[*]

DOI: https://doi.org/10.46431/mejast.2025.8405

Article Received: 02 October 2025 *Article Accepted: 15 December 2025* *Article Published: 19 December 2025*

ABSTRACT

Agriculture in Ethiopia is dominated by smallholder rain-fed systems, but low and erratic rainfall limits productivity and food security. Consequently, investment in small-scale irrigation has been identified as a key poverty reduction strategy. The Spiral Coil pump is a non-conventional water pump, which could be powered by the flow energy of river water without electricity or fuel. It is very useful, especially in rural areas, for farming and irrigation purposes. The Spiral Coil pump comes under the category of a low-to-moderate lift pump.

The experiment was conducted at Seka and Karsa wereda of Jimma Zone on Gibe and Bulbul River, respectively. Increasing the hose diameter leads to better coil pump performance. The pump was proven capable of delivering over 12 L/min of water under pressure heads of up to 12 m. The discharge of the pump at different heads was seen to decrease as the head increases. To improve the sustainability and performance of the pump, it is recommended to add a floating structure, allowing adjustment to water levels, increasing discharge, and extending its lifespan.

Keywords: Spiral Water Pump; Undershot Water Wheel; Small-scale Irrigation; Jimma Zone; Gibe River; Bulbul River; Ethiopia; Pump Discharge; Total Head (Pressure Head); Pump Efficiency; Hose/Coil Diameter; Multi-layer Coil; Dual-side Winding (Left & Right); River Flow Velocity.

1. Introduction

Agriculture in Ethiopia is dominated by smallholder rain-fed systems, but low and erratic rainfall limits productivity and food security. Consequently, investment in small-scale irrigation has been identified as a key poverty reduction strategy (Mitiku et al., 2016). Recent estimates indicate that the total irrigated area under small-scale irrigation in Ethiopia has reached to 853,000 hectares during the last implementation period of PASDEP-2009/10 and the plan set for development of small-scale irrigation is 1850,000 hectares, which is planned to be achieved by the end of the five years growth and transformation plan (GTP) (Mitiku et al., 2015).

In noting that farming is the primary occupation in rural areas, many organizations have worked to increase crop yield through improved irrigation techniques. Reliable irrigation techniques have been shown to increase crop yields between 100%-400%. The resulting increase in grain volume translates to increased sales and income, and allows farmers to cultivate higher-value crops, adopt new technologies, and increase financial returns. Despite the benefits of irrigation, too few farmers have a steady source of irrigation due to the financial limitations of acquiring commercial irrigation technologies.

In southwestern Oromia, the flow of the river is potential. Even though Diesel pumps are effective for irrigation with topographic problems of the area, the capital cost and fuel costs are too high for diesel pumps to be commonplace.

The Spiral Coil pump is a non-conventional water pump, which can be powered by wind energy or the flow energy of river water. It is very useful, especially in rural areas, for farming and irrigation purposes. Spiral Coil pump comes under the category of a low to moderate lift pump. The river flow-operated experimental setup is designed and constructed to analyze the performance of the spiral coil pump under different parameters (Patil et al., 2013).

A spiral tube water pump is a method of pumping water by using an undershot water wheel, which has a scoop connected to a spiral tube. As the wheel turns, the scoop will alternatively introduce either water or air into the spiral tube. The pressure from the hydrostatic head generated from the column of water introduced by the scoop is added to the pressure from previous scoops, and so as the wheel turns, it will increase the water pressure with every turn of the spiral. The main characteristic of the spiral water pump is that it can pump water without the input of electricity or fuel. It works with the power of the water flow. Once built, the spiral water pump can push water up to 30 meters high (vertical push) and up to 70 meters away (horizontal push) (Teka, et al., 2019). The water push (how far water will be pushed horizontally and vertically) depends on how big the wheel of the Spiral Water Pump is, and how much tube is put around the wheel. The spiral tube water pumps were installed to provide irrigation water from rivers to higher-level crop fields. The type, size, and thus material costs of a spiral water pump will depend on two parameters: first, the irrigation needs (how far the water needs to go and how much is used per day) and second, the available water flow (the velocity and depth of the water source). There is only an initial investment in material for the water wheel; after that, the pump should work without any further costs incurred. Therefore, the aim of the research is to improve and evaluate the existing spiral water pump for using the available water potential for irrigation.

1.1. General Objective

To improve the design and evaluate the performance of a locally fabricated spiral water pump for use in small-scale irrigation systems in rural Ethiopia.

1.1.1. Specific Objectives

To modify and fabricate an existing spiral water pump using locally available materials.

To evaluate the performance of the pump in terms of discharge, head, and efficiency under different pipe diameters and coil configurations.

2. Materials and Methods

2.1. Material

Pump manufacturing material – sheet metals, square pipes, different diameter plastic water pipes, bolts, and nuts. Instruments for data collection – stopwatch, 22L container, tachometer.

2.2. Methods

2.2.1. Study Area

The study was conducted in two selected sites in Jimma Zone, Oromia Regional State, Ethiopia—Gibe River in Seka Chokorsa Woreda and Bulbul River in Kersa Woreda. These areas were chosen due to their proximity to perennial rivers with adequate flow velocity and volume, which are essential for testing river-powered irrigation technologies like the spiral water pump.

Jimma Zone is located in southwestern Ethiopia, between latitudes 7°15′N and 8°56′N and longitudes 35°52′E and 37°37′E. The region experiences a humid subtropical climate characterized by high annual rainfall ranging from

1,200 mm to 2,000 mm, and average annual temperatures between 12°C and 28°C. The rainy season typically spans from May to October, while the dry season extends from November to April Abate & Dibaba (2023).

The selected rivers, Gibe and Bulbul, maintain sufficient baseflow throughout the year, making them suitable candidates for sustainable water lifting experiments. The local topography is moderately sloped, and the communities predominantly practice smallholder mixed farming, relying on seasonal rainfall and limited irrigation systems.

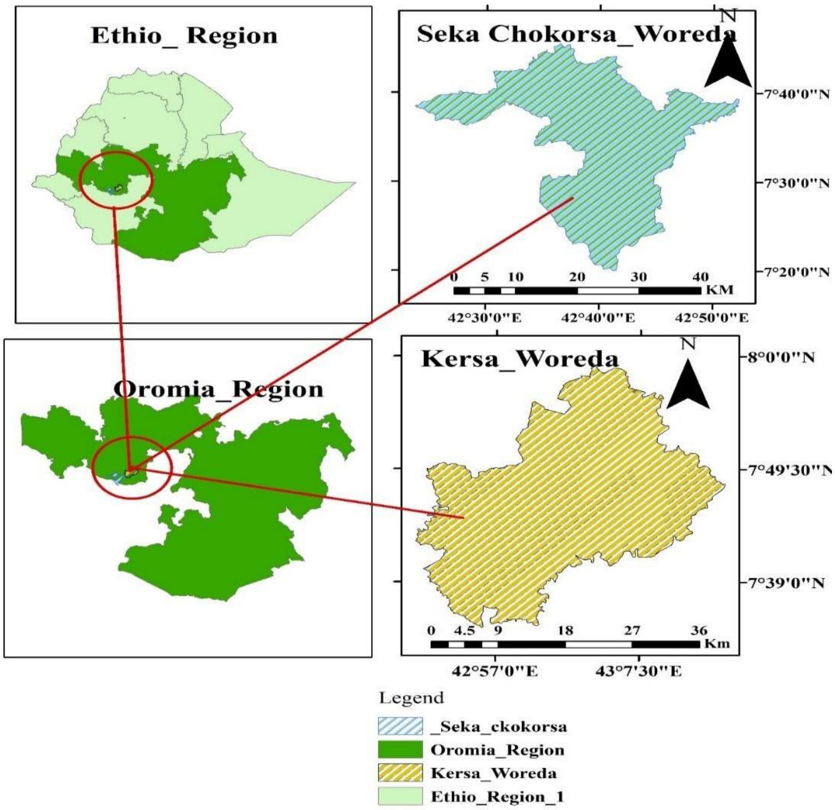

Figure 1. Study area map

Important Parameters Related to Spiral Tube Water Wheel Pump Performance

River flow: The speed of the water is directly proportional to the rotational speed of the water wheel.

Blade: It is a flat surface attached to the tip of the spoke of a water wheel. The force exerted by the water on the flat plate causes the water wheel to rotate. The size of the plate is directly proportional to the force exerted on the blade, keeping velocity constant. The more blades there the greater the torque on the water wheel. However, after a certain number of blades, the torque decreases due to the blockage of water by the subsequent blade. Therefore, the number of blades should be arranged in such a way that only one blade is fully immersed at a time.

Diameter of wheel: The diameter of the Water wheel is one of the primary parts; it uses the energy of the flowing water to produce useful energy. The larger the diameter of the wheel, the greater the head generated.

Number of coils: The Number of coils is directly proportional to the head generated.

Spoke: It is a long bar connecting the center of the wheel, and it supports the frame of the blade. The main function of the spoke in a water wheel is to support.

Hollow shaft: It acts as a supporting device and helps in rotating the spiral wheel. Water collected by the spiral tube is discharged at the outlet with the help of a hollow shaft.

Spiral tube: It is a long tube coiled eccentrically on the hollow shaft, which collects water at each rotation.

Scoop: Scoop is typically made from a larger diameter pipe and can be used to vary the amount of water taken in with each revolution. The scoop should be enclosed in wire mesh to prevent debris from entering the coils.

Rotary Joint: The spiral wheel hollow shaft, which collects water from the spiral tube continuously rotated, and it is not possible to rotate the whole delivery pipe. Therefore, there is a need for a joint between the hollow shaft and the delivery pipe, which can provide a frictionless surface to rotate the outlet of the tube smoothly and air airtight chamber to prevent leakage of water.

2.3. Working Principle of Spiral Pump

A spiral pump is used to pump water from a lower head to a higher head region. This pump uses a rotating pipe coil to pump water. The spiral tubes are fixed to the wheel so that the spiral pipes rotate, as the wheel itself rotates. The water collector connected to the outermost end of the spiral tube gulps in a good quantity of water and delivers this into the spiral tube as it rises above. This core of water passes through the spiral, followed by a core of air as the wheel rotates. A new core of water is formed on every revolution, and a new core of air. Thus, a series of cores of water and air are formed within each spiral pipe as the wheel rotates. Both spiral tubes deliver their water and air into the axle of the wheel, and there it is led off through a water seal to a static rising pipe, which delivers water to the Header tank. As the wheel revolves, a pressure head develops within each coil of the spiral tube, water in the rising coils being higher than in the descending coils. These cores of water in the spiral tube compress the air between them as they travel around the spirals, and both water and air are expelled under pressure into the axle. The flow of water up the static rising pipe is also accelerated by the compressed air escaping and expanding from the outlet at the axle of the wheel. This effect also helps to lift water to the header tank.

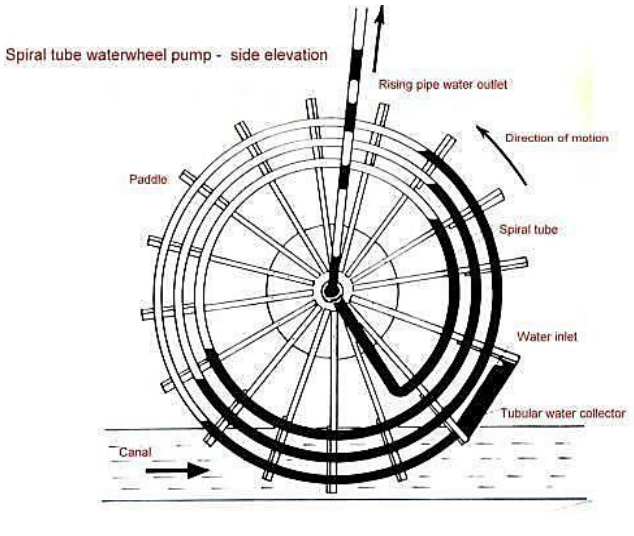

Figure 2. Cross-section of a spiral pump

Possible Modification Undertaken

✓ The length of the blade wheel was reduced to 0.75 meters for portability.

✓ Increasing the number of turbine blades.

✓ Winding the spiral tube on both the right and left sides to increase the pump discharge.

✓ The prototype was manufactured from a metallic material instead of wood.

Fabrication of Water Wheel

The water wheel consists of two flanges made of mild steel, 32 cm in diameter and 0.6cm in thickness, with an inner hole drilled to 5cm, which is connected to a shaft. 10 spokes of Mild Steel square pipe of 1x25x40mm dimensions and a length of 84 cm bolted together to the flanges at the center from one side. Flat bars, 60 cm in length and 2 mm thick, are bolted to the spokes in between for support. Mild steel plates of dimension (0.2X0.75) m2 are welded to a frame by arc welding to form the blades, which are fitted to the spokes with a nut and bolt.

Figure 3. Shows fabrication process

Parameters Measured

✓ Time taken to fill the known volume of the container.

✓ Number of rotations (RPM) of the spiral wheel.

✓ Total head.

✓ River flow.

Parameters Estimated

Pump discharge: The Discharge was calculated for two levels of pipe diameter (0.5 and 1inch), winding the spiral tube on both right and left sides. The pump discharge in m3/s is calculated by dividing the amount of water filled into the known volume by the measured time. The discharge or capacity of the pump was calculated by,

$$Q = \frac{V}{t} \qquad (1)$$

where Q =discharge of the pump, L/s; V = volume of water to fill the measuring drum, L; t = time required to fill the drum, s.

Efficiency of the water pump (η) is equal to the Power output (the power gained) by the fluid from a pump divided by the maximum power of the flow, (Power input in a water wheel).

$$Pi = \frac{1}{2}\,\rho A V^3 \qquad (2)$$

where Pi = power input; ρ = density of water =1000 kg/m^3; A = area of the blade = m^2; V = velocity of the flowing water (From our experiment data) Area of the blade A = L*W Length of the blade (l) = 0.75m; Width of the blade (w) = 0.2m. The radius of water wheel turbine blades (R) = 0.931m; Calculated rotational speed of the water wheel (RPMc) = V/R. The Power output (the power gained) by the fluid from a pump,

$$Po = \rho h\, Q\, g \qquad (3)$$

where ρ = density (kg/m^3); Q = volume flow rate (m3/s); h = head (m); g = acceleration of gravity (9.81 m/s^2).

3. Result and Discussion

3.1. Testing of Gibe River

For the selection of the best performing arrangement, testing was carried out in Jimma zone, Saka Chokorsa wereda, at Gibe River with a river flow rate of 0.79 m3/s. Different pipe sizes and winding side of coiled pipe configuration as an option were tried with the same river flow rate and pumping head of 3 meters and horizontal distance of 42 meters with an inch pipe diameter.

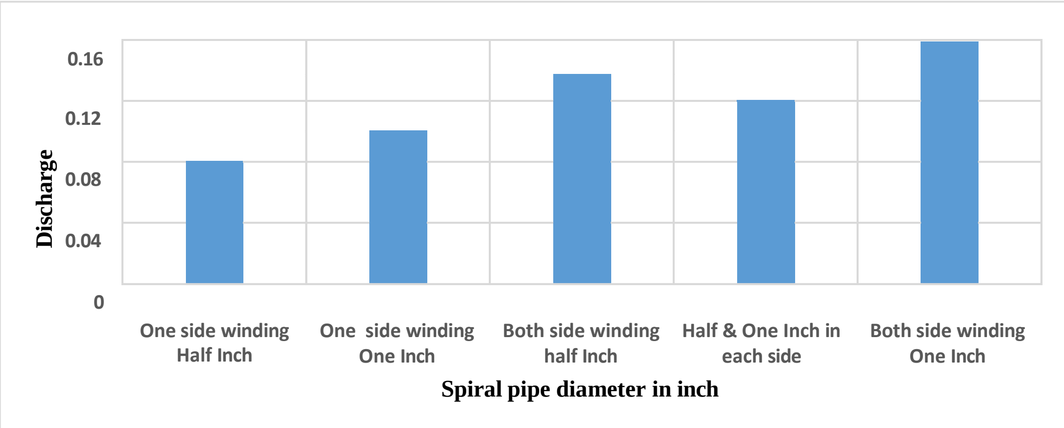

Figure 4. Spiral pipe diameter versus Discharge

As shown in the figure, when the coil pipe diameter increases from half to one inch diameter the water discharge in liters per second increases. Similarly, both left and right side windings are better. According to (Kassab et al., 2006), increasing the hose diameter increases the pump flow rate, which is collected at different heights. For small values of hose diameter, changes in pump discharge and head are small relative to those obtained in the case of a large inch hose diameter. Therefore, the use of a larger size hose is one of the major important design parameters for a coil pump.

An improvement in the coil pump performance with the increase of the coil hose diameter can be attributed to two effects: First, increasing the diameter of the coil tube results in a reduction in the friction loss within the hose and leads to a better pump performance. Second, increasing the diameter of the coil increases the pump inlet area as well as the mean pump outer diameter. This leads to an increase in the amount of air and water entering the pump, which leads to improved pump performance.

Using a multi-layer coil pump with the pump intake placed at the top end of the upper layer improves the pump performance. This effect is the same as increasing the outer diameter of the case of only one layer. In both cases, the

Middle East Journal of Applied Science & Technology (MEJAST)
Volume 8, Issue 4, Pages 68-77, October-December 2025

circumferential distance of the pump inlet increases due to the increase in the pump outer diameter. Consequently, the period for both air and water intake increases, resulting in an improvement in the coil pump performance. The increase in the air intake results in an increase in the effective motive pumping power, and consequently, the pressure head. While increasing the amount of water intake results in an increase in the flow rate. Both effects combine to produce better pump performance. In addition, it is essential to note that increasing the coil inner diameter has the same effect as the other two previously mentioned parameters, and for the same reasons, in conjunction with the reduced friction on the flow within the coil.

3.2. Testing of Bulbul River

By taking different heights of the output, other parameters are measured. The average rpm of the wheel is measured by a tachometer, and it is found to be 5.28, 6.94, and 7.53 rpm on the water wheel during the load condition. To measure the discharge rate, a procedure is followed to count the time required to fill a 22-liter bucket at 12.75, 6.5m, and at the shaft level. As shown in Figure 3 result of pump testing at Karsa wereda of Bulbul River with a river flow rate of 2.04 m^3/s, increasing the pumping head decreases the spiral pump revolution per minute (rpm) and discharge in liters per second.

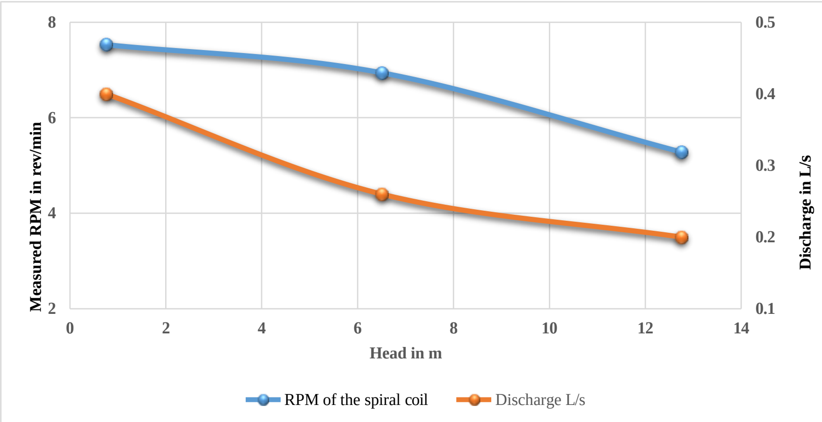

Figure 5. Discharge, Measured Revolution versus Head in meters

According to Dubey (2016), the discharge of the pump at different heads was seen that as the head increases, the discharge decreases.

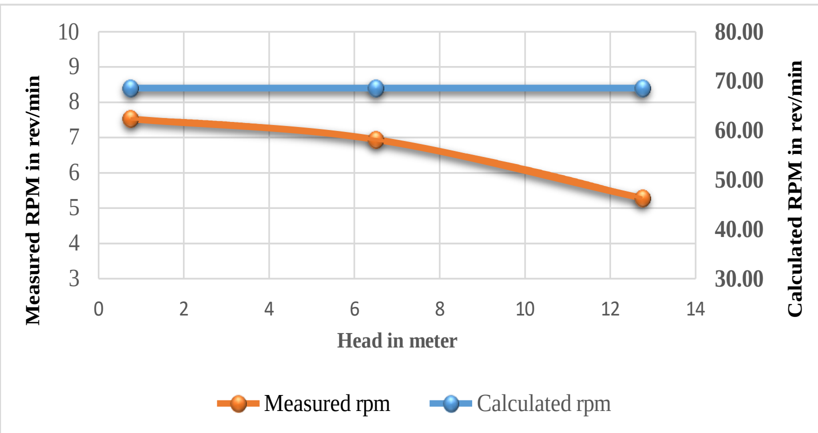

Figure 6. Calculated Discharge, Measured Revolution versus Head in meters

As (Mishra & Verma, 2016), the spiral tube water wheel pump has the potential to pump water for agricultural and domestic purposes as it extracts water above a 50 feet head. Spiral tube water wheel pump is a direct replacement of a small standard piston pump and is just as efficient at pumping a set volume per day.

As shown in Figure 6 the efficiency of the spiral water pump increases as head increases, this is because the amount of water delivered or discharged is changing with respect to the head. The rate of discharge is less than the rate of head.

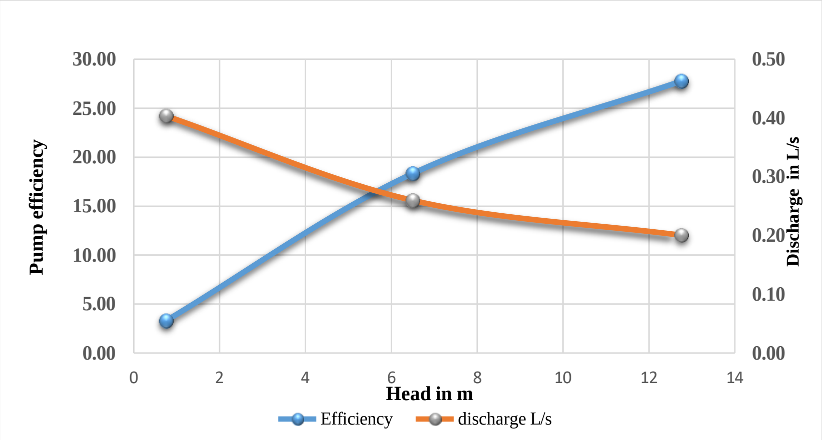

Figure 7. Discharge, Pump efficiency versus Head in meters

In the study of Patil et al. (2013), a hand-operated experimental setup was designed and constructed to analyze the performance of the spiral coil pump under different parameters. The parameters considered are submerged ratios, rotational speed, and layers of coils. For the setup of a 0.8 m wheel diameter with seven coils, the maximum head obtained is between 4.3 m and 5 m, with a maximum discharge of 1200 liters per hour. For a single layer and 2280 lit/hr. For a double layer of the coil with an efficiency range of 20% to 74%.

4. Conclusion and Recommendation

The experiment was conducted at Seka and Karsa wereda of Jimma Zone on Gibe and Bulbul River, respectively. Using a multi-layer coil pump, water inlet from the upper layer gives higher discharge, higher static head, and better pump performance (head and discharge). Increasing the hose diameter leads to better coil pump performance. The pump was proven capable of delivering over 12 L/min of water under pressure heads of up to 12 m.

The pump works without electricity or fuel (powered by the river), hence, it can be used in rural areas for agricultural applications, made from local materials, and easily maintained by the residents. To improve the sustainability and performance of the coil pump, it is recommended to add a floating structure, allowing adjustment to water levels, increasing discharge, and extending its lifespan.

4.1. Future Research Directions

1) Evaluate the durability of locally fabricated materials under long-term use.

2) Making a floating system for variable river flow conditions.

3) Conduct economic feasibility studies comparing with diesel and solar pumps.

4) Evaluate pump performance under different soil moisture management practices.

Declarations

Source of Funding

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare that they have no competing interests related to this work.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Supplementary information is available from the authors upon reasonable request.

Institutional Review Board Statement

Not applicable for this study.

Informed Consent

Not applicable for this study.

Acknowledgments

The authors express their sincere gratitude to the Oromia Agricultural Research Institute, Jimma Agricultural Engineering Research Center, farmers, agricultural experts, and local research collaborators who participated in the Improvement and On-Farm Evaluation of a Locally Fabricated Spiral Water Pump for Small-Scale Irrigation in Jimma Zone, Ethiopia, their valuable insights, field assistance, and continuous engagement played a significant role in the success of this study.

References

Abate, S., & Dibaba, W. (2023). Temperature and precipitation trends using CMIP6 model data: The case of Jimma Zone, Southwestern Ethiopia. International Journal of Weather, Climate Change and Conservation Research, 11(1): 28–46.

Dubey, P. (2016). Performance analysis of four-scoop water wheel spiral pump. International Journal of Engineering Research & Technology, 5(3): 832–834. https://doi.org/10.17577/ijertv5is031269.

Kassab, S.Z., et al. (2006). Tenth International Water Technology Conference (IWTC10), Alexandria, Egypt, Pages 431–440, https://doi.org/10.4028/www.scientific.net/amm.446-447.549.

Mishra, P., & Verma, D. (2016). Spiral tube water wheel pump. International Journal of Innovative Research in Science, Engineering and Technology, 5(4): 137–139. https://doi.org/10.15680/ijirset.2016.0504012.

Mitiku, Y., Ramayya, A.V., & Shunki, G. (2015). CFD simulation and optimization of very low head axial flow turbine runner. International Journal of Renewable Energy Development, 4(3): 181–188. https://doi.org/10.14710/ijred.4.3.

Mitiku, Y., Ramayya, A.V., & Shunki, G. (2016). Turbine driven pump CFD modelling and simulation: A centrifugal pump optimization for irrigation. International Journal of Engineering Science and Research Technology, 5(1): 250–257. https://doi.org/10.5281/zenodo.1133130.

Patil, N.R., Gaikwad, S.R., Navale, R.A., & Sonawane, D.S. (2013). Design, manufacturing, and performance analysis of spiral coil pump. Applied Mechanics and Materials, 446–447: 549–552. https://doi.org/10.4028/www.scientific.net/amm.446-447.549.

Teka, T., Teklawold, D., & Abu, G. (2019). Improvement and on-farm evaluation of the spiral water pump. In Proceedings of review workshop on completed research activities of the Agricultural Engineering Research Directorate, Oromia, Ethiopia, Pages 61–70.