The valorization of natural resources for irrigation the hilly and terraced surfaces

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Abstract: In the paper is detailed an innovative solution of an equipment used for irrigation for hilly and small terraced surfaces of upland areas, where the water is not available and the electricity grid is missing. The condition to use this solution of irrigation is to have a water source available. This water source can be a spring, an artesian well or a stream that must be near the surfaces on the hillside that need the water. Usually, the level of the water source must be above the site location of the homestead's water needs. If the location of household, garden, or livestock water supply is higher that the water source is necessary to use a solution to pump the water to this location. To pump the water without use electricity in hilly areas it is used a ram pump system which needs a minimum fall of the water. The paper presents an economical solution to irrigate the hilly surfaces where the water source has not a fall to make working properly the ram pump.

Key words: economical solutions, irrigation, water mill design, water resources.

1 Introduction

In country agriculture, water use is of great importance to obtain yields proportionate to the population. Drought is a natural factor very harmful and affects a large agricultural area in total agricultural area of a country. Drought effect is observed mainly in the plains and hills with a moisture deficit and uneven water distribution cultivated area. In Romania, agriculture is one of the major branches of the national economy, with a high agricultural potential. At European level, Romania is among the top countries in terms of agricultural potential of the total agriculture of the country, 2% is affected by large drought every year and on 38% of this surface water requirement is supplemented by irrigation.

Framework Directive 2000/60/EC have introduced the notion of "monitoring" for the use of unconventional water resources and for uses complex quantitative and qualitative control of water resources. The irrigation is intended that soil moisture does not fall below the minimum when it comes to the phenomenon of water deficit is a risk factor in agriculture. High temperatures and winds of summer lead to increased plant transpiration and therefore the amount of water needed is increased and must be applied in best moments by watering cycle.

The paper present a solution to take water from the river and use it on the small and medium sized land holdings, with an area between 0.25 ha to 20 ha. Small land-holdings in this size range are most numerous in many of the developing countries, and extension of the use of irrigation in this small farming sector could bring huge benefits in increased food production and improved economic well-being. It is also hoped that this paper will be useful to those seeking techniques for lifting water for purposes other than irrigation.

Irrigation water more specifically can offer the following important benefits:

- increases land area brought under cultivation
- improves crop yield over rain-fed agriculture three or four-fold
- allows greater cropping intensity
- produces improved economic security for the farmer
- reduced drought risk, which in turn allows:

Studies have shown that small land-holdings are often more productive, in terms of yield per hectare, than larger units [3]. Small family run land-holdings are consistently more productive than larger units, although they are more demanding in terms of labor inputs. Small land-holdings also generally achieve better energy ratios than large ones; i.e. the ratio of energy available in the crop produced, to the energy required to produce it. On the hilly and terraced surfaces due to topographical constraints, an irrigation system is very difficult to make and unavailable because the costs are very high. If it is possible to find a solution to irrigate such lands the productivity of crops can increase by 2 times or higher. Most of the people have to depend on rain water due to the unavailability of irrigation facilities that decreases the productivity for the horticultural crops such as fruits, vegetables, flowers, tuber and rhizomatous crops and species. If they use water pump with electricity or fossil fuel the cost is high and the people from those lands cannot afford to pay and they cannot cultivate their primary means of food in time.

The solution that is proposed in the paper is to utilize kinetic energy of the flowing river to pump water uphill without using any other external sources of energy such as fuel or electricity. The proposed solution consists of a water wheel which raises the water from a river at a height of 4-10 m and from there the water is conducted to a ram pump that will send some amount of water to a higher height uphill, from where it can be used for various crops and households for drinking water purpose.

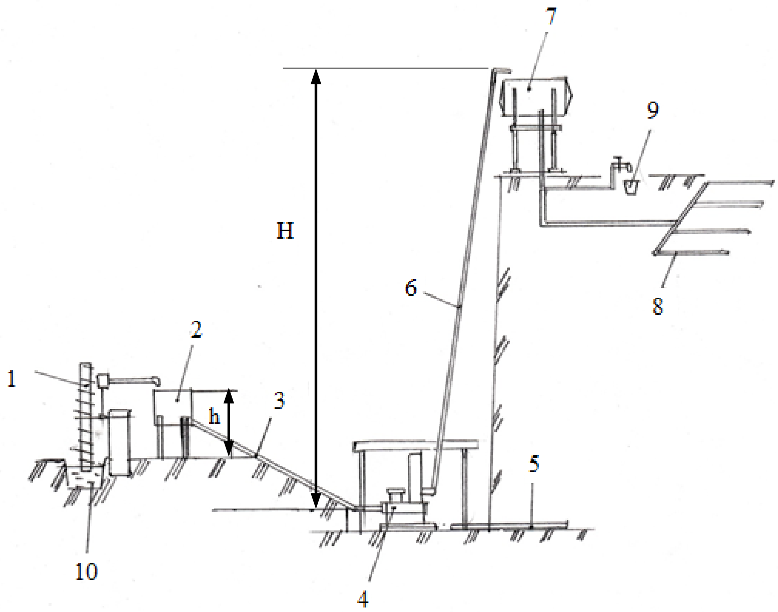

Fig. 1. Layout of the system to irrigate hilly and terraced areas

To irrigate such hilly and terraced areas without the use of any outside source of energy which can supply homestead' water needs, or garden, orchard, was necessary to find a solution with simple construction, easy to install, which does not consume petrol, diesel or electricity, which can operate for 24 hours per day and maintenance free. This solution use the energy of a large amount of water falling a small height to lift a small amount of the water to a much greater height from where it can be used to a village or irrigation scheme on the hillside. When is obtained a fall of water, the ramp pump lift this water with a comparatively cheap and reliable means to a considerable heights.

The solution presented in the paper to use water from a river for the hilly and terraced surfaces is shown in Fig.1. To work the system is necessary to have a pump head or fall *h* needed to start the ram pump function. Because on the plain surfaces where the river is situated, to obtain this pump head is necessary to use a water wheel 1 which lifts the water from the river level to the height *h* that can be around 4-7 m. These values of pump head ensure a delivery head or elevation *H* till 7-10 times more than pump head *h*.

As can be seen in Fig.1, water is taken from a river 10 with a water wheel 1 that transfers the water to a drive tank or intake tank 2 which ensure constant flow water to the ram pump 4, through the drive pipe 3. The ram pump lifts part of the water coming through the drive pipe to the delivery tank 7 on a higher level through the delivery pipe 6. The ram pump is protected by a pump house from accidental damage. From the delivery tank the water is conducted to the distribution system which consists for example of drinking water for the people 9 or for horticultural crops 9. Waste water is delivered out from pump house through the drain tile 5.

The main advantages of using this system of irrigation are:

- Use of a renewable energy source;
- Has a little environment impact by pumping only a small proportion of the available flow;
- Low maintenance requirement by his simplicity and reliability;
- Can be manufactured in the rural villages.

The main limitations of using this system of irrigation are:

- It is limited in hilly areas with a year-round water sources;
- It is pumped only a small fraction of the available flow and therefore require source flows larger than actual water delivered;
- Are limited to small-scale applications.

2 The equipment use for supplying water for irrigation

In Fig.2 is shown a constructive solution of an equipment used to take the water from a river and to send further to a reservoir. The main elements of this equipment are: the primary reservoir (1), the pipe (2) from where the water is conducted to the main reservoir; the rotor axis (3); the screws (4) that permit setting of the water mill in a vertical plan; the counterweight (5); the concrete pillar (6) that supports all the construction; 24 collecting tubes (7); the rotor ring (8) where are mounted the collecting tubes. Water mill has a diameter of 4000 mm which allows lifting water from the river at a height of 3500 mm, where it is stored in a primary reservoir 1. From the primary tank (1), water is passed through the pipe 2 to the main tank located at a distance of 2 m from the concrete pillar (6). Rotor ring (8) is made of two rings of steel sheet of thickness 0.5 mm and is connected to the main shaft (3) by means of profiled spokes. On the two rings of the rotor are fixed 24 tube collectors, made by polypropylene, with a length of 500 mm and diameter of 75 mm. The impeller is submerged in river water at a depth of 200 mm. This allows complete filling tube collector with water from the river.

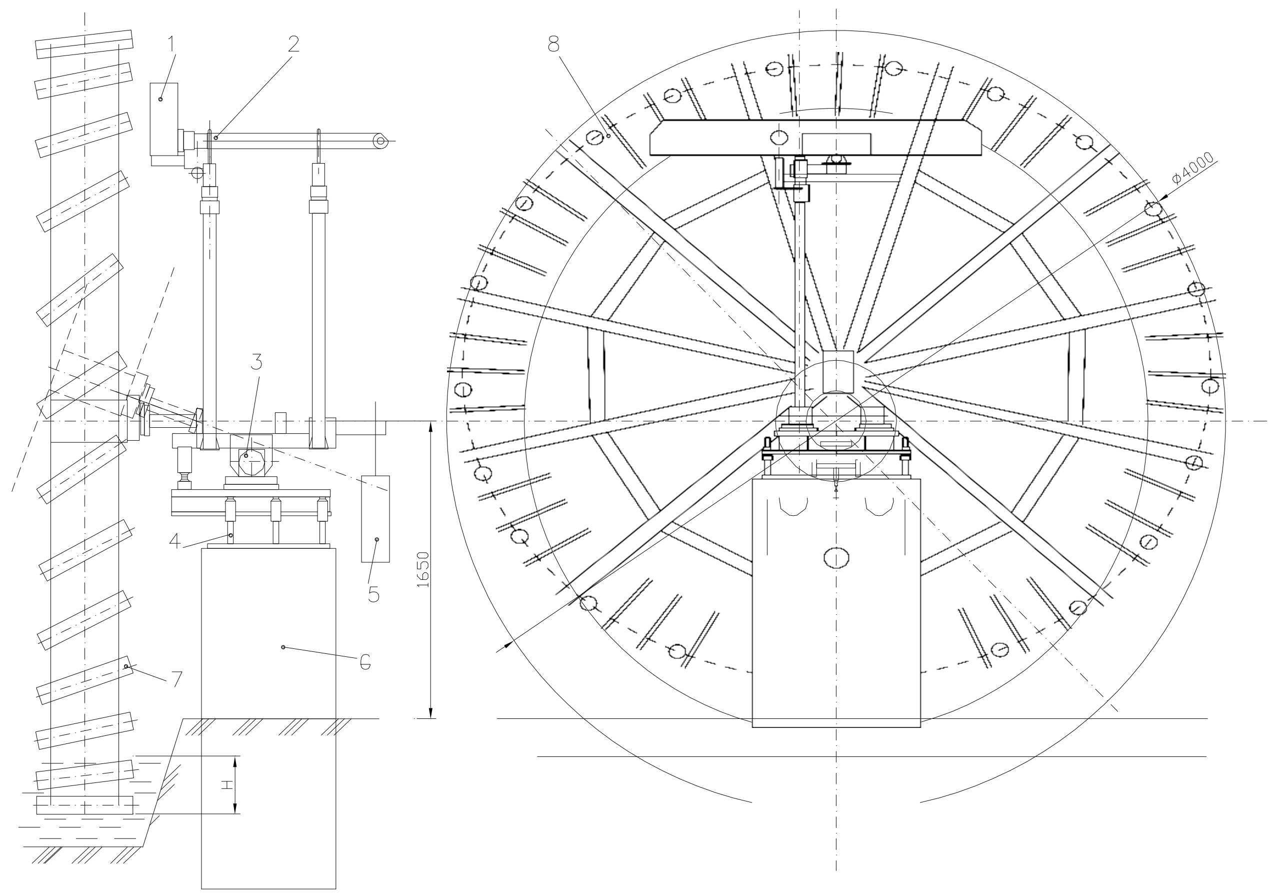

Fig.2 Schematic illustration of an equipment to supply water used for irrigation.

This solution of an equipment used to supply water for irrigation allows adjustment of horizontal and vertical plan to a range of 150 mm which allows being adapted at specific conditions of the installation in the site near to the river. In the period between harvest crops and starting a new season in agriculture, the turbine is decommissioned by tilting it 20 degrees. In this mode extends the life of the plant and reduce costs maintenance. Keeping the turbine in this inclined position is realized by a lock system. It works without interruption throughout the period between the start of the season in farming and till harvesting period ends. During this time water is stored in the main tank, and then distributed through the pipes to areas to be irrigated. Irrigation system is different from one culture to another depending on the terrain where the turbine is installed.

2.1 Calculation of turbine parameters

To calculate the equipment parameters it is used Fig.3. This figure shows schematically the position of the collector tube fixed on the rotor in the time when its upper end comes out from the water,
Note: in the following it is presented only the final equations.
Equation (1) shows the relationship between the tube collector mounting angle (γ) and rotor construction elements (Fig.1).

$$\delta = 2\arcsin\frac{l\cdot\sin\gamma}{2} \quad (1),$$

where *l* is the rotor width.

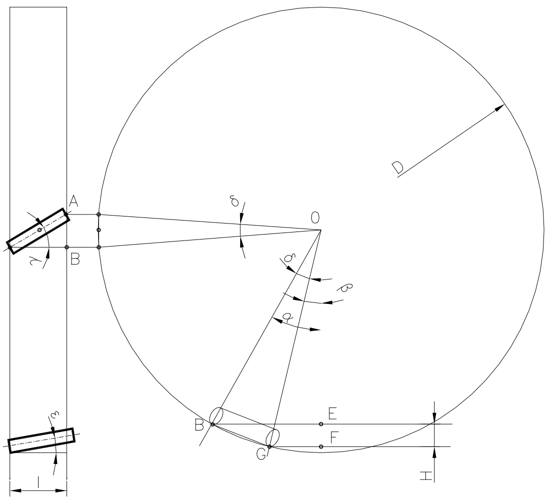

Fig.3 Calculation of the rotor parameters.

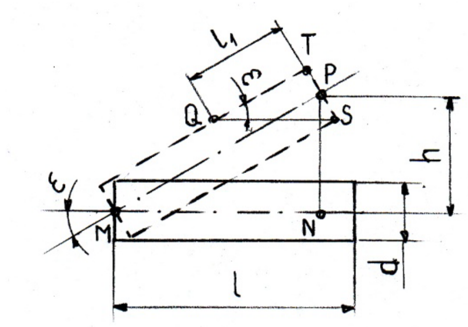

Fig.4 Calculation of the amount of water carried by the tube collector.

Using equation (2) is calculated the relationship between the constructive elements of the rotor and the exit angle of the tube collector from the water.

$$\alpha = \arccos\left(1 - \frac{2H}{D}\right) \quad (2),$$

where, H is the depth of immersion of the rotor in river water.
Due to tube collector mounting angle, water can never fill its entire cavity. To calculate the amount of water that is transported by one collector tube it is used Fig.3.
Mounting angle of the rotor tube collector on the circumference (ε) is calculated by formula (3).

$$\varepsilon = \arcsin\frac{D[\cos(\alpha-\delta)-1]+2H}{2l} \quad (3),$$

where D is the rotor diameter.

The volume V_2 of the water that is taken from the river by one collector tube at one rotation of the rotor, can be calculated with relation (4).

$$V_2 = \frac{\pi d^2}{4}\left(l - \frac{d\sqrt{4l^2-\{D[\cos(\alpha-\delta)-1]+2H\}^2}}{2\{D[\cos(\alpha-\delta)-1]+2H\}}\right) \quad (4),$$

where *d* is the diameter of tube collector.
Since the rotor has 24 tube collectors, this value from equation (4) must be multiplied by 24 to determine the amount of water taken from the river at one rotation of the rotor.
An important factor for plant efficiency is the speed of the water of the river (v_w). As the speed of the water is higher the amount of water extracted by the rotor will be higher and therefore higher plant efficiency. Volume of water extracted from the river in one minute V_{min} is given by equation (5).

$$V_{min} = C \cdot v_w \quad (5),$$

where C is a coefficient depending on the angle γ of the collector tubes on the rotor circumference and the water volume V_2 (Table 1).

Table 1. Coefficient C depending on the angle γ and the water volume *V2*.

γ	**15⁰**	**20⁰**	**25⁰**	**30⁰**	**45⁰**	**60⁰**
V_2	14,64	24,20	27,12	36,24	37,68	40,08
C	1,196	1,979	2,215	2,959	3,077	3,273

3 The ram pump

As is shown by Gregory (1996), the second main component of this irrigation system is the ram pump. Ramp pump is useful where the water source flows constantly and the usable fall from the water source to the pump location is at least 2 m. In our case this distance is 3.5 m. The operational principle of ram pump is based on water hammer, effect in the ram to transmit water from lower elevation to a much higher elevation. It has only two moving parts that dictates the whole operation. These are waste valve *B* and the check or discharge valve *C*.

There is an optimum configuration for the ram pump set up. It is a 5 to 1 ratio, where the drive pipe length is five times longer than the vertical fall from the water source to the ram pump. Ideally the drive pipe should have a length of at least 100 times its own diameter. The drive pipe *A* must generally be straight; any bends will not only cause losses of efficiency, but will result in strong fluctuating sideways forces on the pipe which can cause it to break loose. The length of the delivery pipe *E* is not considered in the equation because friction less are normally small due to low flow rates.

The ram pump body requires to be firmly bolted to a concrete foundation, as the beats of its action apply a significant shock load. The ram pump (Figure 5) should be located so that the waste valve is always located above flood water level, as device will cease to function if the waste valve becomes submerged.

Its operation is based on converting the velocity energy in flowing water into elevation lift. Water flows from the source through the drive pipe which is the drive tank (Fig.1) and escapes through the waste valve until it builds enough pressure to suddenly close the waste valve. Water then surges through the interior check valve inside the pump body into the air chamber *D*, compressing air trapped in the chamber. When the pressurized water reaches equilibrium with the trapped air, it rebounds, causing the check valve to close. Pressurized water then escapes from the air chamber through a check valve and up the delivery pipe *E* to its destination. The closing of the check valve causes a slight vacuum, allowing the waste valve to open again, initiating a new cycle.

Fig.5 The ram pump used for tests.

4 Results and discussions

Coefficient *C* was calculated for the following angles *γ* of mounting tube collectors on the rotor circumference, and volume of water V_2 extracted from the river water at one rotation (Fig.6).

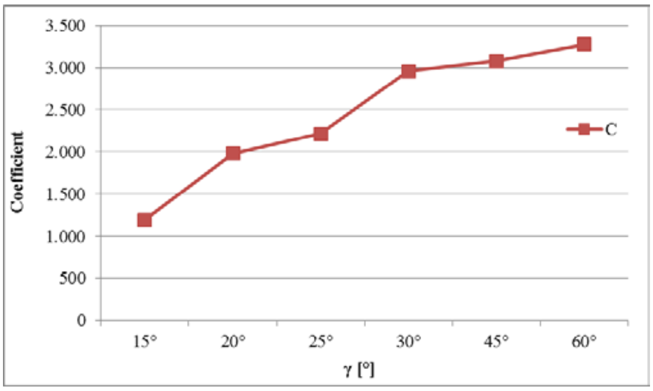

Fig.6 Coefficient C depending on the angle γ and the water volume V_2.

Using C coefficient values, we can calculate the volume of water extracted from the river in one minute V_{min} depending on the speed of river v_w for different mounting angles γ of the collector tubes on the rotor circumference (Figure 7).

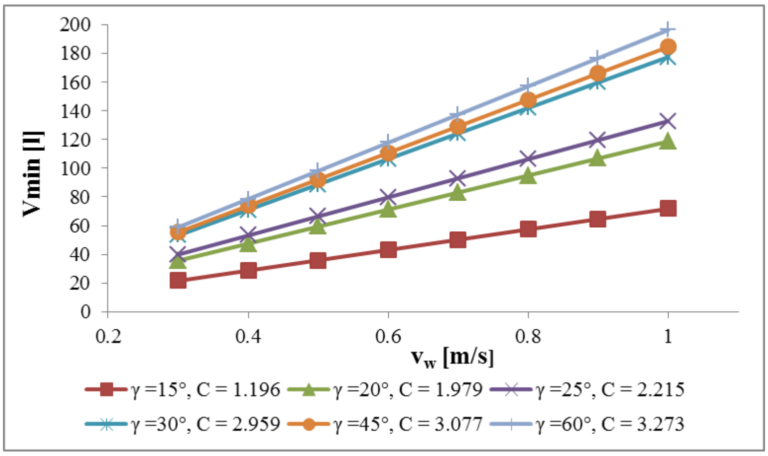

Fig.7 The volume of water extracted from the river for different parameters

Fig.8 The water mill installed in the position to work.

In Figure 8 is shown the water mill after it was installed in position of working near the river. It is a small river 2 m width and 0.3 m deep.

The ram pumps can cycle anywhere from 25 to 300 times per minute. The frequency of the cycle is adjustable by changing the length of the stroke of the waste valve. A longer stroke produces a lower frequency. This means more of the supply flows to and through the pump and more is pumped up the delivery pipe. The stroke is adjusted to restrict the amount of water used to the amount available, or if supply is unlimited, to regulate the amount delivered to match the amount needed.

The ram pump utilizes the inertial energy to pump water to a height greater than the source of the water. It runs all the time, requires no fuel, and needs only minor adjustment and cleaning for maintenance after the initial setup. The ram pump uses much more water than it pumps; it uses the energy of a lot of water to move a portion of it, about 10-15%. Because it is somewhat more involved to set up than a powered pump, a ram pump is generally used only where electricity is too expensive or not available.

The cycle repeats between 20 and 100 times per minute, depending upon the flow rate. If properly installed, a ram pump will operate continuously with a minimum of attention as long as the flowing water supply is continuous and excess water is drained away from the pump.

The location of the water source in relation to the desired point of water use determines how the ram pump will be installed. The length of drive pipe should be at least 5 times the vertical fall to ensure proper operation. The length of delivery pipe is not usually considered important because friction losses in the delivery pipe are normally small due to low flow rates. For very long delivery pipes or high flow rates, friction losses will have an impact on the performance of the hydraulic ram pump.

The relationship between vertical fall (F) and length of drive pipe is given in Table 2.

Table 2. Relation between vertical fall and length of drive pipe.

Vertical fall [m]	Length of drive pipe [m]
0.9-4.5	5.4-27
4.8-7.5	19.2-30
7.8-15	23.4-45

A ram pump system is designed to deliver the desired pumping flow rate for a given elevation lift. The range of available flow rates and elevation lifts is related to the flow quantity and velocity from the water source through the drive pipe. The mathematical relationship for pumping flow rate is based upon the flow rate through the drive pipe, the vertical fall from the source through the drive pipe, and the vertical elevation lift from the pump to the point of use.

To calculate water delivered by ram pump *D* [l/day] to the delivery pipe is used equation 5, [4]

$$D = (S \cdot F \cdot E)/L, \qquad (5)$$

where: *S* is the quantity of water supplied in liters per minute, F is the vertical fall [m], *E* is the efficiency of the ram pump installation (usually 0.6), L is the delivery head [m].

More water can be obtained by installing two or more ram pumps in parallel in tandem if is needed. Each ram pump must have its own drive pipe, but all can pump through a common delivery pipe.

In Figure 9 and Figure 10 are presented the delivery liters per day for different working fall and different delivery head (vertical elevation) during one day.

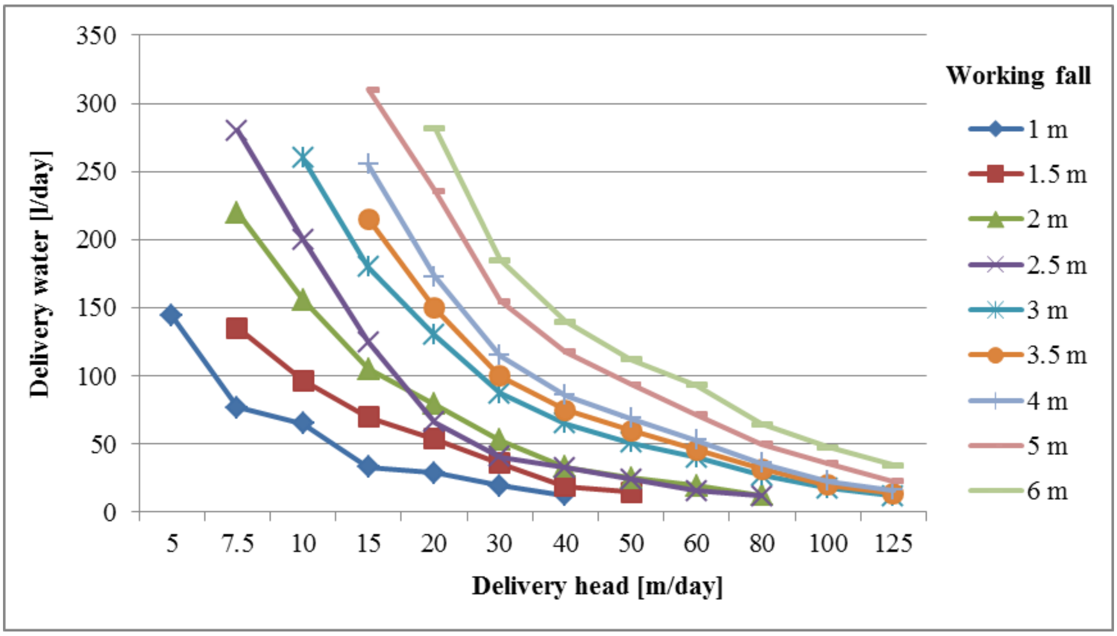

Fig.9 Ram pump performance data for working fall between 1 m and 6 m.

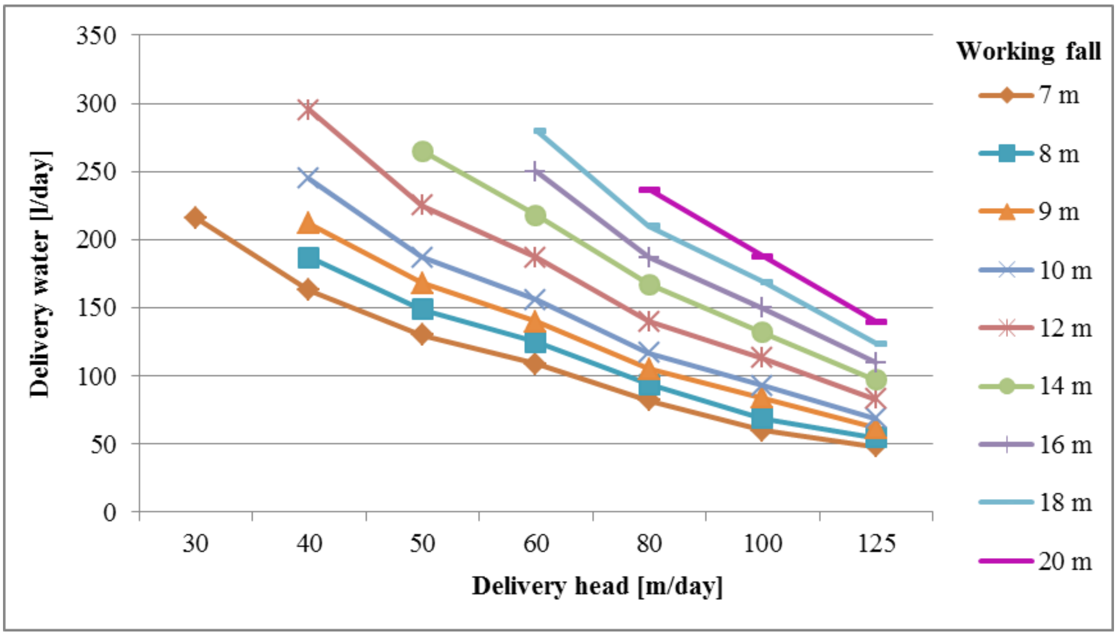

Fig.10 Ram pump performance data for working fall between 7 m and 20 m.

5 Conclusions

The present paper is centered towards the design and execution of water mill that would conveniently alleviate the problem of water supply to the mass populace. Ideally, different combinations of the supply and delivery heads and flows, stroke length and weight of the impulse valve, length to diameter ratio of the drive pipe, volume of the air chamber and size of the snifter valve, were tried to come up with an optimum size of a ram pump presented in the paper.

This solution presented in the paper can save hours of back-breaking work carrying water and cash where expensive water pumps are replaced. As long as is free water and we have or can create at least two meters drop, the installation is best suited option compared to fuel, wind or solar operated pumps.

The benefits of working with this installation are:

- It puts an end to children and women carrying heavy water jugs to and from the spring;
- Its time saving;
- It improves general health of the villages;
- It males laundry washing near the houses possible;
- Fishponds become possible, as well as vegetable growing, and animal husbandry.

Some of the advantages of installing this system of obtaining water are listed below:

- Zero pollution;
- Operates 24 hours a day, 7 days a week without supervision;
- Pumps 20+ more its own fall, with the record of 200 meters up without a motor;
- No fuel or electricity cost;
- Low maintenance and repair cost;
- Repairs are done locally;
- Installation is up to 80% cheaper than other water system models;
- Local manufacturing and training generates employment.

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