Draft animal power: a proper way to lift water in remote villages

Antonio Perrone

Abstract

A prototype has demonstrated that a medium sized draft animal is capable of lifting at least 2500 liters of water per hour up to a six-meter distribution tower. In these situations - frequent in a great number of areas – animal-driven pumps and grain mills are significantly cheaper than pumps and mills powered by fuel engines, and - in certain frequent conditions – also cheaper than photovoltaic devices. This study delves into the case of a farmer, who already uses draft animal power for 120 days a year for transport and land cultivation. This utilization time can be considered the most frequent case in remote villages of areas where the rural economy prevails. The study examines the case in which the farmer has decided to increase his revenues by renting the services of his animals for water-lifting and grain milling. This can be done on the days of the year in which his animals are not engaged in land cultivation and transport. A further result highlighted by the analysis is that if all the work performed today worldwide by animal traction were supplied by fuel engines, the parts of fossil CO2 emitted into the atmosphere - by any kind of engines and for any kind of transport and duties – would increase by roughly 0,5% 0.5%. The energy supplied today by working animals is 1.4% of all the renewable energies produced in the world.

Résumé

Un prototype a démontré qu'un animal de trait de taille moyenne est capable de lever au moins 2 500 litres d'eau par heure jusqu'à une tour de distribution de six mètres. Dans ces situations, fréquentes dans un grand nombre de régions, les pompes et les moulins à grains actionnés par des animaux sont nettement moins coûteux que les pompes et les moulins alimentés par des moteurs à combustible et, dans certaines conditions fréquentes, également moins coûteux que les installations photovoltaïques. Cette étude a examiné en détail le cas d'un agriculteur qui utilise déjà la force animale pendant 120 jours par an pour le transport et la culture des terres. Cette durée d'utilisation peut être considérée comme le cas le plus fréquent dans les villages isolés des régions où l'économie rurale est prédominante. L'étude a examiné le cas où l'agriculteur a décidé d'augmenter ses revenus en louant les services de ses animaux pour le pompage de l'eau et la mouture du grain. Cela peut se produire les jours de l'année où ses animaux ne sont pas utilisés pour le labour et le transport. L'analyse a également révélé que si tout le travail actuellement effectué dans le monde par la traction animale était assuré par des moteurs à combustion, les émissions de CO2 fossile dans l'atmosphère (provenant de tous types de moteurs et pour tous types de transports et de tâches) augmenteraient d'environ 0,5 %. L'énergie fournie aujourd'hui par les animaux de trait représente 1,4 % de toutes les énergies renouvelables produites dans le monde.

Kurzfassung

Ein Prototyp hat gezeigt, dass ein mittelgroßes Zugtier in der Lage ist, mindestens 2500 Liter Wasser pro Stunde auf einen sechs Meter hohen Verteilungsturm zu heben. In solchen Situationen – die in vielen Gebieten häufig vorkommen – sind tierbetriebene Pumpen und Getreidemühlen deutlich kostengünstiger als Pumpen und Mühlen mit Verbrennungsmotor und unter bestimmten häufigen Bedingungen auch kostengünstiger als Photovoltaikanlagen. Diese Studie hat den Fall eines Landwirts untersucht, der bereits 120 Tage im Jahr Zugtiere für Transport und Bodenbearbeitung einsetzt. Diese Nutzungsdauer kann als der häufigste Fall in abgelegenen Dörfern in Gebieten angesehen werden, in denen die ländliche Wirtschaft vorherrscht. Die Studie hat den Fall untersucht, in dem der Landwirt beschlossen hat, seine Einnahmen zu steigern, indem er die Dienste seiner Tiere für das Heben von Wasser und das Mahlen von Getreide vermietet. Dies kann an den Tagen des Jahres geschehen, an denen seine Tiere nicht mit der Bodenbearbeitung und dem Transport beschäftigt sind. Ein weiteres Ergebnis der Analyse ist, dass, wenn alle Arbeiten, die heute weltweit mit Tierkraft durchgeführt werden, durch Verbrennungsmotoren ersetzt würden, der Anteil der fossilen CO2-Emissionen in die Atmosphäre – durch alle Arten von Motoren und für alle Arten von Transporten und Aufgaben – um etwa 0,5 % steigen würde. Die heute von Arbeitstieren gelieferte Energie macht 1,4 % aller weltweit erzeugten erneuerbaren Energien aus.

Resumen

Un prototipo ha demostrado que un ganado de tiro de tamaño mediano es capaz de elevar al menos 2500 litros de agua por hora hasta una torre de distribución de seis metros. En estas situaciones, frecuentes en un gran número de zonas, las bombas y molinos de grano accionados por animales son significativamente más baratos que las bombas y molinos accionados por motores de combustible y, en determinadas condiciones frecuentes, también más baratos que las plantas fotovoltaicas. Este estudio ha examinado el caso de un agricultor que ya utiliza la fuerza del ganado de tiro durante 120 días al año para el transporte y el cultivo del terreno. Este duración de la utilización puede considerarse el caso más frecuente en las aldeas remotas de las zonas donde predomina la economía rural. El estudio ha examinado el caso en el que el agricultor ha decidido aumentar sus ingresos alquilando los servicios de sus animales para sacar agua y moler el grano.Esto puede ocurrir en los días del año en los que sus animales no se dedican al cultivo del terreno y al transporte. Otro resultado del análisis es que, si todo el trabajo que hoy en día se realiza en todo el mundo con tracción animal se realizara con motores de combustible, las emisiones de CO2 fósil a la atmósfera —por cualquier tipo de motor y para cualquier tipo de transporte y tarea— aumentarían aproximadamente un 0,5 %. La energía que hoy en día proporcionan los animales de trabajo representa un 1,4 % de todas las energías renovables producidas en el mundo.

Published in: Staatliche Schlösser und Gärten Hessen, Claus Kropp (Eds.), Draft Cattle: their history, value and significance with a global perspective (Heidelberg, Propylaeum 2026), 096-101. DOI: https://doi.org/10.11588/propylaeum.1713.c25096

Introduction

The annual report of the FAO on the state of agriculture SOFA 2022, on page 45, among others says: "For the majority of African small-scale producers, the transition to animal draft power would mean a real progress […] In many cases, advanced manual tools and animal traction are probably the best options for increasing power supply […]."[1]

The interest in the use of draft animal power for the generation of electricity is demonstrated by numerous studies, some of which were performed by public scientific institutions in India, and also by dozens of patents issued in several countries. Several videos are also available on the web[2].

Another study on this matter has been performed in Italy and the main results have been shown, among others, by Perrone, Nasab and La Scala in 2023[3].

The status of the art

With an innovative design, a tested prototype in Italy has solved the main problem of the animal driven electric generators: the high torque of the first shaft of the round multiplier.

The torque is proportional to the resistance to the shaft and inversely proportional to the speed of the shaft. In the systems, as those available on youtube – in which the generator has been put vertically in the center of the round path walked by the animal – the speed is half round per minute so the torque is very high. In the design of the system the circular path, where the animal walks, has considered the first sprocket of the rounds multiplier. Then it has been built a vertical wheel of two meters of diameter as the second sprocket of the rounds multiplier. So the speed of the shaft of the large wheel is higher and then the torque is lower and the system is easy manageable.

This solution has reduced the torque of the slow shaft of the system by several times and has demonstrated how this primary source of energy can be applied safely, affordably and reliably for the production of an electric current. A video of the test is available on the web[4].

In summary, a pump has been powered by an electric generator, which is moved by a rounds multiplier, which in turn is driven by a draft animal walking in circles.

Method

The study here described – devoted to those remote villages where the rural economy is prevailing – has investigated the case of a farmer who already uses the draft animal power for transports and land cultivation 120 days a year. This timespan of work per year can be considered the most frequent case in remote rural villages.

The study has examined the case in which the farmer has decided to increase his revenue, renting the services of its animals for water lifting and grain milling, during the days in which his animals are not engaged in the land cultivation and in transport.

The foundational data has been that of rural villages where the salary of a farmer is approximately 67,93 US$[5], the cost of fuel is approximately 1,43 US$[6], draft animal power is still in use and the demand for energy is less than 1 kW.

The continuous working power of a man does not exceed 100 W, while the drafting power of a medium sized working animal could be considered, as hereafter specified, to be around 400 to 800 W. It can be concluded that animal drafting power can increase the productivity of the farmer by at least three or five times.

The abovementioned data utilized in this study is shown in ***Table 1***.

It is important to remember that the numbers of animals referred to represent all the animals present in the mentioned countries, but only a part of them is engaged in rural works.

In the same way it shall be remembered that the mentioned countries have been chosen as examples but many other countries and rural areas respond to similar parameters.

The cost of the kWh

Several sources of energy are in use in those remote villages not connected to the electrical grid. These are photovoltaic, wind power, biogas, fuel engines and manual labor.

These sources have been discussed in Perrone, Nasab and La Scala[7] in respect of their efficiency, which will serve as a framework for this analysis: An average output of less than 1 kW. In that study the net present value of different investments in these energy sources was

TABLE 1

	SALARY	FUEL	ASSES	BUFFALOES	CATTLES	HORSES
BANGLADESH	$ 59,76	$ 1,13	=	725.000	23.935.000	=
MADAGASCAR	$ 73,90	$ 1,31	157	=	10.322.680	496
BURUNDI	$ 105,00	$ 1,56	=	=	1.077.539	=
SIERRA LEONE	$ 63,00	$ 1,52	=	=	700.000	438.219
MALAWI	$ 38,00	$ 1,60	5.613	=	3.848.948	87
AVERAGE	$ 67,93	$ 1,43				

1 FAO 2022.
2 Jakhar et. al 2018; Chandrakar et al. 2013; Swain et al. 2015; Perrone 2020.
3 Perrone 2020; Perrone et al. 2023.
4 http://www.wedap.eu/ (last accessed 06-10-25).
5 www.Salaryexplorer.com (last accessed 06-10-25).
6 www.Globalpetrolprices.com (last accessed 06-10-25).
7 Perrone et al. 2023.

TABLE 2			
AVERAGE SALARY	$ 67,93	$ 67,93	$ 67,93
ANNUAL SALARY	$ 815,18	$ 815,18	$ 815,18
COST OF FEED OF 2 ANIMALS (estimed)	$ 163,04	$ 163,04	$ 163,04
YEARLY COST OF THE TEAM	$ 978,22	$ 978,22	$ 978,22
DAYS IN TRANSPORTS AND SOIL CULTIVATION	120	120	120
DAYS IN WATER LIFTING AND GRAIN MILLING	120	180	180
% PERCENTAGE ATTRIBUTABLE TO THE WATER LIFTING ETC.	50	60	30
COSTS ATTRIBUTABLE TO THE WATER LIFTING ETC.	$ 489,11	$ 586,93	$ 293,47
YEARLY COST OF THE EQUIPMENT DEPRECIATED IN 10 YEAR	$ 40,00	$ 40,00	$ 40,00
YEARLY COST TEAM AND EQUIPMENT ON ELECTRICAL TASKS	$ 529,11	$ 626,93	$ 333,47
HOURS PER DAY	6	6	6
kW OUTPUT	0,60	0,60	0,60
kWh OUTPUT: DAYS PER HOURS PER kW	432	648	648
cost per kWh	$ 1,22	$ 0,97	$ 0,51

calculated. Here instead the focus lies on the costs of energy if it is produced in the villages themselves.

The present study is focused on the comparison between the efficiency of fuel engines, draft animal power and photovoltaic as a primary energy source for those remote villages not connected to the electrical grid.

The cost of the kWh produced through draft animal power

Table 2 shows the analysis of the cost of a kWh generated by draft animal power.

The costs of salaries and of fuel are deduced from the sites referred to above. The cost of feed and veterinarians for the two animals has been considered as 1/10 of a person salary multiplied by 2.

For the first column it is assumed that a farmer uses a pair of animals for transport and land cultivation for 120 days a year, and rents out their services for the same amount of time.

For the second column it is assumed that the farmer rents out his two draft animals for 180 days, aside from his own transports and land cultivation.

The third column represents the same situation of the second column. But in this case the farmer considers that 70% of his costs have been compensated by transports and soil cultivation. So only 30% of the yearly cost are attributed to water lifting and grain milling.

As far as the cost of the equipment is concerned, it shall be referred that in the aforementioned Perrone, Nasab and La Scala the cost of the equipment has been calculated to around 1.000,00 US$ with retail parts purchased in Italy, with sprockets made of steel and worked on a lathe. For this study it is assumed that similar sprockets made with pressed metal sheet will be easy to find on the market. While calculating the cost of mechanics in certain markets, let's remember that through e-commerce web sites it is quite easy to find motorcycles which cost significantly less than 800,00 US$. So the proposed yearly cost of the equipment (400 US$ for the equipment depreciated over fifteen years) here assumed seems to be reasonable.

All the costs have been calculated for an equipment driven by two middle sized working animals so the output of 600 W can be considered quite reasonable[8].

Dividing the yearly cost of the system for the kWh output offers the following results - shown in Table 2: 1,22, 0,97 and 0,51 US$ per kWh with an average cost of 0,90 US$.

The cost of the kWh produced with fuel engines

The cost of the kWh produced with fuel engines has been calculated analysing the technical sheets of equipment easily available on the market and with an output of around 1 kW.

In this table the depreciation cost of the engine and the manual labour cost haven't been added. So the real cost should be considered greater than that shown in ***table 3***.

8 Goe/McDowell 1980.

TABLE 3				
MODEL	HONDA EU 10i	PRAMAC Pmi 1000	EINHELL TC-PG 10/E5	EINHELL TC-IG 1100
POWER kW	1,0	1,0	0,68	1,0
OPERATION POWER kW	0,9	0,425	0,45	0,7
TANK LITERS OIL	0,25			
TANK LITERS GASOLINE	2,1			
TANKS LITERS TOTAL	2,35	2,1	4	6,5
AUTONOMY HOURS	3,3	3,2	6,6	5,4
POWER OUTPUT WITHIN THE AUTONOMY kWh	2,97	1,36	2,99	3,60
FUEL CONSUMPTION PER HOUR	0,71	0,66	0,61	1,20
FUEL CONSUMPTION PER Kwh	0,79	1,54	1,34	1,81
COST OF FUEL PER LITER	$ 1,43	$ 1,43	$ 1,43	$ 1,43
COST OF FUEL PER kWh	$ 1,13	$ 2,20	$ 1,91	$ 2,57
AVERAGE COST OF kWh				**$ 1,95**

TABLE 4		
OUTPUT FROM A 2 ANIMALS DRIVEN ELECTRIC GENERATOR		
Watts of power from a 2 animals driven generator	W	600
Operation hours per day	h	6
Wh/d output from the animal driven electric generator	Wh/d	3.600
DIMENSIONING OF A PHOTOVOLTAIC PLANT WITH THE SAME CAPACITIES		
Terms of comparison from the animal driven daily output	Wh/d	3.600
Sun irradiation as for well insolated areas		4
Basic Wp required (Wh per day/ sun irradiation)	Wp	900
Oversizing for no peak sun hours, Figure 12 of WB mentioned document		1,8
Oversized plant, as per Figure 12 of WB mentioned document	Wp	1.620
For 2 days storage, see paragraph 5.3.of WB mentioned document	d	2
Wp	Wp	3.240
Overall efficiency of the plant, see paragraph 5.1 of WB said document		0,774
Wp to have the same pumping services of an animal driven pump	Wp	4.186
Modules costs for Wp (ex-factory- China)		$ 0,20
Increase of cost from the factory to the assembler in the village		1,5
Cost of Wp delivered in the village		$ 0,30
number of Wp required		4.186
Ex works photovoltaic modules cost		$ 1.255,81
Masonry for the fundations		$ 200,00
Frame and fences		$ 400,00
Construction, assembly, installation and testing		$ 400,00
Cables and fittings		$ 100,00
Electrical components		$ 250,00
Gran Total		$ 2.605,81
YEARLY RATE FOR 15 YEARS DEPRECIATION RATE		$ 212,53
MAINTENANCE AND INSURANCES		$ 200,00
YEARLY COST		**$ 412,53**

The data presented in ***Table 3*** for tank capacity, autonomy and power output, have been deducted from technical sheet shown by the manufacturer on their websites.

The power output along the hours of autonomy has been obtained multiplying the operation power in W per the said hours.

The fuel consumption per hour has been obtained dividing the capacity of the tank by the hours of autonomy of the engine.

The fuel consumption per kWh has been determined dividing the fuel consumption per hour by the operation output.

The cost of fuel per kWh has been determined by multiplying the fuel consumption per kWh by the average cost of fuel as per ***Table 1***.

As a result the average cost of the kWh in the mentioned rural area, produced with a small fuel engine, has an average cost of 1,95 $.

Let's remember that the costs of the equipment, the cost of transport of the fuel to the village and that of the manual labour for refuelling and maintenance haven't been considered. So the cost of the fuel engines should be considered somewhat higher.

The cost of the kWh produced with a photovoltaic plant

The cost of a kWh produced by a photovoltaic plant in a village with an output comparable with that of draft animals, has been calculated using, as well as possible, the methodology shown in the World Bank document *Solar Pumping: The Basics*.

Figures and paragraphs mentioned in ***Table 4*** refer to that document[9].

In ***Table 4*** the referred "Oversizing for no peak sun hours" refers to the fact that a pumping station will receive sufficient power only in the very sunny hours of the day: At sunrise and sunset the power won't be sufficient to drive the pumps or other equipment. Similarly, a high increase is needed for a "two day storage", necessary for continuous power availability in case of cloudy days. The "Overall efficiency" factor has been taken from the aforementioned World Bank document and refers, among others, to manufacturing tolerance, temperature, controls, cables and their connections.

In the analysis of costs none of the classical components, such as the inverter, have been inserted, so the real cost of a plant is greater than which is deduced here.

After determining the purchase cost, the yearly depreciation rate has been calculated following the method presented by the Depreciation Calculator site and ammortamento.com[10].

The result of these calculations shows that the purchase costs of the photovoltaic plant are around 2.605,00 US$ and the yearly costs around 412,00 US$.

These costs are greater than those in the third column of ***Table 3*** referred to the annual cost of the draft animal power while the animals were engaged in water pumping and milling, i.e. 333,47 US$.

Some consideration on the method

For the selection of a source of energy to implement, technical literature suggests, as is commonly known, the so called 'LCOE' method i.e. the Levelized Cost of Energy[11]. The procedure here utilized is a simplified method because the starting data was simpler than those of big investments in the energy field.

The technological assessment

The technological assessment of draft animal power for water lifting and grain milling has been discussed in the afore mentioned Perrone, Nasab and La Scala Paper[12].

The use of draft animal power as referred to in said paper has shown the following strengths and weaknesses.

Due to the difficulty to always impose the same gait onto the draft animal, it is difficult to always achieve the same voltage, which makes it difficult to use draft animal power for lighting and for battery charging.

The DC pumps and the DC motors have demonstrated their capacity, within a certain range, to be driven with any voltage and any amperage so the irregular gait of the animals doesn't present a limit in their utilization for electricity production.

The test described in "http://www.wedap.eu/fl/videofl.html" has demonstrated that a medium sized working animal is capable of lifting at least 2500 liters of water to a height of 6m per hour.

The test has been certified by an independent engineer and, from the animal welfare point of view, by an independent veterinarian, "http://www.wedap.eu/fl/or/ingsardellarep.pdf" and "http://www.wedap.eu/fl/or/allavoro.pdf".

It is important to remember that the electric motors here discussed can be utilized not only for pumping and milling but also for powering other rural equipment such as threshers, winnowers, milking machines, fruit sorters and squeezers. This equipment, now moved by farmers by cranks and pedals, are easily available via e-commerce on the web. The substitution of their cranks and pedals with sprockets and a belt thus would be very easy.

The potential of the system

The potential of the system is enormous. The prudential estimated number of working animals in the world is, today, around 200,000,000.

If all the work performed today worldwide by animal traction would be taken over by fuel engines, the parts of fossil CO_2 emitted into the atmosphere - by any kind of engines and for any kind of transports and duties – would increase by roughly 0,5%. The energy supplied today by working animals makes up 1.4% of all the renewable energy produced in the world[13].

The recognized international standards for animal welfare recognize that the here described kind of job is not stressful for the animals. Therefore there is no contraindication to using animals for this type of work.

9 World Bank 2018.

10 Depreciation Calculator; www.ammortamento.com (last accessed 06-10-25).

11 www.Nrel.gov (last accessed 06-10-25).

12 Perrone et.al. 2023.

13 Perrone 2020.

Conclusion

Draft animal power is the cheapest primary source of energy in those remote villages where the rural economy is prevailing, where the demand for energy is less than 1 kW and where working animals are still in use.

This is true in those large areas where the average monthly salary of farmers is approximately 67,93 US$ and where the cost of fuel is approximately 1,43 US$ per liter.

This source of energy can power, among others, pumps, mills, threshers, winnowers, milking machines, fruit sorters and squeezers.

A comparison with different sources of energy has given the following results:

Wind energy and photovoltaic plants are not transportable and in some cases more expensive than draft animal power.

The average cost of draft animal power, as a primary source of energy, has been calculated to approximately 0,90 US$ per kWh with a minimum percentage of the said money spent outside the village. In some cases this cost can drop down to 0.51 US$ per kWh.

The use of fuel engines as a source of energy was labeled with an average cost of approximately 1,95 US$, all of which spent outside the village.

For an analogous amount of energy the yearly cost as well as that of the kilowatt, of a photovoltaic plant seems to be in certain cases greater than that of a draft animal power generator i.e. 412,53 versus 333,47 US$.

A photovoltaic plant isn't capable of supplying similar services as draft animal power because it is non transportable and incapable to always supply energy when required, but only in sunny hours. All the money for its utilization would also be spent outside the villages. The purchase cost of one photovoltaic plant is approximately five times greater than that of a draft animal power generator.

SOFA 2022, the annual report of the FAO on the state of agriculture states: "In many cases, advanced manual tools and animal traction are probably the best options for increasing power supply."

Today there are at least 200.000.000 working animal, distributed throughout millions of villages in the world.

While the average, continuous power output of a human exceeds not more than 100 W, that of a draft animal can reach between 700 or 800 W, which means the use of draft animals can increase the productivity of farmers – in the aforementioned tasks - by several times.

This increase of productivity is incomparable in case of water pumping. Let's imagine the case of a farmer who has to lift several liters of water from a well and then has to carry this water to his home with buckets and bins.

Instead the draft animal powered electric pump can lift a lot of water to a distribution tower and then the pipes can distribute this water to hundreds of taps in hundreds of households.

Bibliography

Chandrakar et al. 2013 S. K. Chandrakar/D. L. Soni/D. K. Yadav/L. K. Sahu, Experimental study on animal powered mechanical device for home lighting system. International Journal of Environmental Engineering and Management 4, 2013, 471–482.

Depreciation Calculator Depreciation Calculator at calculator.net, URL: https://www.calculator.net/depreciation-calculator.html [Date of Website access: March 2024].

FAO 2022 FAO, The State of Food and Agriculture 2022. Leveraging automation in agriculture for transforming agrifood systems (Rome 2022). URL: https://doi.org/10.4060/cb9479en [Date of Website access: March 2023].

Goe/McDowell 1980 M.R. Goe/R.E. McDowell, Animal traction Guidelines for Utilization, Department of Animal Science, Cornell University (ed.) (Ithaca/New York 1980).

Jakhar et al. 2018 O. Jakhar/R. R. Choudhary/M. Budaniya/A. Kumar, Experimental study of camel powered electricity generation unit. In: AIP Conference Proceedings 1953, 1 (2018), Online Edition. URL: https://doi.org/10.1063/1.5033175 [Date of Website access: March 2024).

Perrone 2020 A. Perrone, Sustainable energies for remote villages. A new target for the corporate social responsibility. In: 2020 AEIT International Annual Conference (AEIT). IEEE (2020) 1–6.

Perrone et al. 2023 A. Perrone/Nasab/M. La Scala, Draft Animal Power Versus Photovoltaic. A Benchmark. Presentation at 2023 AEIT International Annual Conference in Rome.

Swain et al. 2015 S. Swain/A. Dash/A. Mohapatra/D. Behera/B. Behera et al., Utilization of animal energy for postharvest operations in rotary mode, Journal Crop and Weed 11, 1, 2015, 75–79.

World Bank 2018 World Bank, Solar Pumping. The Basics (World Bank, Washington, DC, 2018).

Author info
Antonio Perrone
WEDAP, Grottaglie I
E-Mail: aperrone@wedap.eu