
EVALUATION OF TRADITIONAL WATER LIFTING AND MODERN WATER LIFTING TECHNOLOGY: A CASE OF TULA SALLANOF BORANA, SOUTHERN ETHIOPIA

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In developing countries, the technology of lifting water from deep wells installed as groundwater sources to a useful water point of access for domestic and non-domestic consumption is still on a low scale and is threatening to the pastoralist community. In Ethiopia, the pastoralist communities shield above half of the land area, constituting and making the country first in the livestock population in Africa. Regardless of this fact, the study found that pastoralists, particularly in Borana, where the study took place, vary from the central government and were listed among the most marginalised groups in terms of availability and access to public services plus water supply service. Thus, the study took place in an area where water-lifting technology is very rare. The Borana communities traditionally evaluate water lifts to manage their permanent water source, Tula. Traditionally, in the Borana community, the selection of traditional water lifting devices for lifting potable water from Tula comprises enquiry of the Tula end sources, 'Qawaela' depth, nature and types of 'Okole Towa' appearances, daily labour forces on watering day called 'obatu', and sustainability of a traditional water-well ladder called 'Irri' with regular operation and maintenance due to its nature. In this study based on Tula-wells, discharge capacity and accessibility to livestock demand consumption, the available technologies led to a multi-use system of Tula-wells in the Tula-Sallan Borana Cluster of the Borana zone. The small irrigation of vegetables at the back of Tula-wells in the backside of the well fence using water pumps deals with the distribution of water from 'Qawaela' in the Dubluk district of Borana zone at Tula Elwak. The multi-use purposes of Tula-wells and Tula-Sallan Borana cluster with the help of some available technologies have their own advantages and disadvantages. The traditional labour force service on Tula to lift potable water on watering day of livestock and energy or power needed during use of solar or motorised pumps has been compared to evaluate the traditional water lifting and modern water lifting technologies in the study area. The energy required to transport water from the end point of Tula-wells to the drinking trough was one of three Tula had considered

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Water is an absolutely necessary element for life. The availability of water has played a key role in the development of all civilized nations. Indeed, especially in ancient times, water scarcity prevented the development of settlements (Oleson, 1984). Sustained safe drinking water supply and sanitation facilities are essential to improve the living conditions of the rural population. The provision of safe water helps to combat water-borne diseases and improves

community health in general. Thus, it is an essential component of poverty alleviation. In sub-Saharan Africa, information is scarcely available concerning suitable water lifting and management technologies given a particular geographical location and socio-economic conditions (market access, input availability and access, etc.) (Petra Schmitter et al. 2016). During the long dry seasons of 2016, some non-government organizations piloted some water lifting (ladder/irri solar pump and generator) and management technologies (i.e., wetting front detector) or sustainable intensification in different Horn of African countries, including Ethiopia (ATA, 2016). This was to facilitate livestock's demand suitability of the adopted technologies, assess the effect of water lifting on the productivity of livestock in areas like Borana, Afar Regional State, and to save lives and assess potential increases in productivity through traditional and modern livestock's watering guidance.

This study focused on evaluating livestock's demand suitability of the adopted technologies and assessing the effect of water lifting on the productivity of livestock in Tula Sallan Borana. Water demand and supply in the Borana zone are lower than both international and national standards, with households and communities using difficult traditional water lifting methods to extract water from very deep traditional deep-wells (Tula Sallan Borana) (Moti Mosisa et al. 2018). Depending on the water source and availability, the technologies led to a multi-use (agriculture, domestic, and livestock) system in the water scarce area or lowland area of Borana, Southern Ethiopia. The watering day of livestock has used solar pumps or service delivery of water in combination with making generators on some Tula Sallan to produce great potential in Wachille and Dhas Tula.

MATERIALS AND METHODOLOGY

Description of the Study Area

The study was taking place in the Borana zone of the Oromia Regional State of Ethiopia. It is located in the southern part of the state (between 3°36' – 6°38' North latitude and 3°43' - 39°30' East longitude) and borders Kenya. Yabello is the capital town of the Borana zone and lies 570 km south of Addis Ababa. The zone covers 48,360 km² of which 75% consists of lowland; this is frequently exposed to droughts. The zone is inhabited by almost 1 million people (CSA, 2008). The Borana rangelands cover about 1.9 million ha. The area of Tula Sallan has a semi-arid savannah landscape, marked by gently sloping lowlands and flood plains vegetated predominantly with grass and bush land. The geology is composed of a crystalline basement with overlying sedimentary and volcanic deposits. People are predominantly involved in small-scale subsistence agriculture production and mainly in livestock husbandry.

Figure 1 Location Map of the study area

The Borana zone is mainly characterized by a semi-arid climate. Drought is a common phenomenon in many parts of Borana. The lowland parts have been severely affected by recurrent droughts. The rainfall pattern is highly erratic and often does not occur at the expected time. Thus, the area is characterized by a general scarcity of surface water. The main source of water is a Tula. Annual mean temperatures vary from 19 to 24°C with little seasonal variations. Average annual rainfall varies from 440 to 1100 mm.

Geologically, the area comprises two major litho-stratigraphic units ranging in age from the Precambrian to the Quaternary. Precambrian strata consist of crystalline rocks and associated intrusive, and Tertiary to Quaternary strata consist of volcano-sedimentary rocks. The superficial deposits are all quaternary. Hydrologically, the ephemeral drainage system of the Borana zone is located within the Genale-Dawa River basin. The main source

of water is groundwater. To extract groundwater, the population of Borana use traditional deep wells whose water retention potential varies with rainfall, the so-called “singing wells” or “Tula wells”.

The Borana zone pastoralists are survival livestock producers. Plenteous livestock is the paramount resource of the areas that make Ethiopia the first in Africa and the ninth in the world by cattle population. They mainly live on milk, but this is increasingly supplemented by cereal grain. The annual livestock off-take is very low and directed to finance pastoral household basic requirements. Dry land cultivation has substantially increased in the area over the last two decades. The gross income of a pastoral household is the sum of subsistence plus marketed production, and currently their income is decreasing extremely due to continuous dry climate conditions.

Data Collection

The study to produce this idea collected both primary and secondary data. Interviews with key informants, focus group discussions, an administered questionnaire, and study area observation (SAO) at Tulaa and Adaadii wells and pond sites were used to collect primary data. The collection of data was systematic in such a way to fulfil the requirements under each specific objective. In addition, surveys have been conducted at six of the nine Tulaa well sites (i.e., Wachile, Gorile, Gayo, Dhas, Dubuluk, and Melbana), which had been selected based on reconnaissance and ease of access. The sample wells were physically measured with GPS (and tape in some cases) to determine the coordinates and depth of the groundwater points, well shaft width and their surroundings, along with 32 aquifer points (maddaeelaa). The sample size of the selected six-Tulaa represents nearly 67% coverage out of the total nine. The evaluation of the traditional water lifting methods, livestock demand suitability of some of the adopted technologies, and the effects of water lifting on yield have been considered.

Two of the nine-Tulaa, called Gofa and Laye, are currently under the de facto control of the Somali Region subsequent to the state-orchestrated occupation of the area by the Somali Region in 1991, making them inaccessible for safe visit for physical characterization such as elevation, soil type classification, and vegetation cover. Therefore, information was taken by GPS from Google Earth while data on names, history, and ownership of the wells were gathered through in-depth interviews held in January 2020 at different places with key informants (Hon. Dr.Borbor Bule, 2020).

Under these research objectives, survey data was collected on soil types, variation in water table depth, the structure of Tulaa, and dimensions of Tulaa using a water level meter. Well depth and volume of water lifted by water uplifters (Tootuu) are used to calculate the discharge of well, energy, and waterpower during herd watering days. Interview data covered the traditional instruments used in the excavation of the wells, maintenance and operation, traditional water lifting devices and techniques as the basis for modern engineering standards. With oral historians, questions have been raised regarding "how," "when," and "by whom" the Tulaa were excavated. Furthermore, to answer the research question and fulfil research objectives, issues such as the community's indigenous technical knowledge as to the indicators used in determining areas where ground water may be available within the customary groundwater exploration methods have been raised.

Field observation has been used to understand the present status of the Tulaa, whether they are properly functional, partially functional, or fully dysfunctional. Generally, SAO was applied to determine the number of wells in one cluster and the types of soil, rock, and plants appearing in the environs of the selected Tulaa cluster. For secondary data, various sources relevant to this study were consulted. These include a report by the National Meteorology

Agency, reports from Borana Zone Water, Energy and Minerals Office, books, journals, magazines, the internet, and so forth.

Data Analysis

The collected data was presented and analysed in various forms using different techniques. The field survey data was compared with reports from the zonal administration. The water use calendar, which may vary according to the types of water sources, principal users, and seasonal variation (period of utilization), was determined in a chart form. Approaches to designing this study use both descriptive and explanatory methods to look at groundwater exploration, traditional water lifting, and indigenous water management systems based on the basic principles of the herd watering calendar. Thus, the analysis method details the obtained data with respect to research objectives in the following points.

Evaluation of Traditional Groundwater Supply (Tulaa Sallan)

Application of traditional groundwater supply in the case of Tulaa Sallan Borana focused on the traditional water lifting method and its evaluation in terms of discharge, energy, and waterpower. Their evaluation focused on the depth of Tulaa and water lifting processes, Tulaa geometry, detention time between lifted water level and storage, and the aquifer (qaa'aa/madda) physiognomies. Therefore, in this study, Tulaa traditional structures and dimensions were taken into consideration.

Tulaa (Traditional Deep wells) Dimensioning

The dimensioning and designing of Tulaa is based on groundwater flow at end source, discharge potential aquifer and natural hydrological characteristics. The Borana community starts dimensioning Tulaa from the initial point of ready-made water point to the entrance of the well structure, whether it be soft soil or hard rock. In the dimensioning process, each structure in Tulaa was taken into consideration. Each of the wells of Tulaa Sallan Borana is divided into eight structures. These were Ittisa, Gulanta, Baqassa, Dargula, Nanniga, Koloco, Faccana, and Qaa'aeelaa (madda). The Tulaa structures were measured by using a water meter.

Figure 2: Tulaa structures measured at eelaGayo and eelaGorile

Traditional Tulaa structures size are not homogenous. The structures are different from entrance to end structures. They are affected by types of soil, rock, and land cover. According to dimensions, the irri (traditional ladder) has been made both in temporary reservoir (faccana) and aquifer (qaa'aeelaa) structures.

Wells Discharge

The well discharge calculation is based on types of flow (steady and unsteady) and the well aquifer, whether confined or unconfined. The Borana traditional deep wells are connected with an unconfined aquifer. In the case of Tulaa Sallan, the well discharge was calculated by Darcy's constant equation of area and velocity. Hence, discharge is the product of area and velocity.

$$Q = AV, A = LW = \pi r^2 \quad (1)$$

Where: Q = discharge of the wells; A = Area; V = velocity of the up lifted water; r = radius of the qaa'aeelaa (aquifer); L = length/height of the aquifer (h); W = width of the aquifer

$$V = \frac{S}{t} = \frac{h}{t} \quad (2)$$

$$Q = \frac{\pi r^2 h}{t} \quad (3)$$

$$Q = \frac{\pi r^2 dh}{dt} \quad (4)$$

To calculate the Tulaa discharge, researchers measured the static level of water at 'qaa' aeelaa' before 'tootuu' started to lift water to a temporary reservoir, the water level after the first circle of water lifters and the dentation

time of water to reach the indicated level. The qaa'aacelaa (aquifer) depth and water level have been measured by a water level meter. With the help of a stopwatch, the speed that "tootuu" lifted water from the end source (aquifer) at EelaOdicha was 1 m/s with the static depth of 12 m out of a 14 m depth aquifer and seven-pair chains of "tootuu". The radius of the well aquifer was 1 m. As "Tootuu" started to lift water by bucket of ten litres for ten minutes, the water level decreased to 11.838. Then, based on the above formula, the well discharge was calculated as follows.

$$Q = \frac{\pi r^2 dh}{dt} \quad (5)$$

$$Q = 3.14(1m)^2 * \frac{12m - 11.838m}{30min * \frac{60s}{min}} = 0.002826m^3/s = 17L/min \quad (6)$$

Similarly, the discharge of Galanticha of Gorile and Dhibayu of Gayo was calculated. The Galanticha and Dhibayu discharges after the first twenty minutes of filling the temporary reservoir were 15L/min and 17L/min, respectively.

c. Livestock demand calculation

To calculate the livestock water demand, the researcher used the below mentioned procedures:

These were by determining the standard livestock daily consumption in terms of weight equivalent, called Tropical Livestock Unit (TLU) and adding the numbers of herds served on a selected well. The average body weight of one TLU is 250 kg, and an animal consumes one litre of water per day for each 10 kg of body weight on average. Therefore, about 25 liters of water is required daily for each livestock unit. Hence, the daily water demand estimated by calculating the equivalent TLU of the animal multiplied by 25 liters (CLARK, 1997).

In Borana, the livestock's water demand unit per watering day of Tulaa has expanded to the three normal watering days. Thus, the number of livestock's that could serve from a single well in a day, supported by the survey taken and interview data collected at Gorile, Wachille and Irdar detailed in the following table.

Thus, the TLU had calculated by considering the numbers of herds to be watered and average daily consumption. Thus, from the tables (3 and 4) for eelaGalaanticha, on the first watering day, the number of the watered animals was 800 heads. The average LTU was 25. Then the daily water demand for livestock has calculated as follows:

$$TLU \text{ discharge } (Q_{tlu}) = \text{Number of animals} \times \text{average LTU daily consumption} \quad (7)$$

$$Q_{TLU} = 800 * 25 \text{ lpd} = \frac{20,000L}{d} = \frac{20m^3}{day}$$

During the watering days (obaa) of herds, the 'Tootuu' (water up lifters) invest much amount of energy to lift the drop of water from Tulaa aquifer (madda). Hence, energy invested by Tootuu on watering day were calculated based on the numbers of water up lifters, the depth of the maddaeelaa from faccana or afaannaqaa (the first step ladder to enter the madda), the weights of water up lifters and the acceleration due to gravity.

d. Energy Calculation

Energy is the ability or capacity to do work. Work is the product of force and distance travelled. In physics, work defined as the amount of energy required to perform a physical task. If force is constant, work can simply calculate using the equation:

$$Work(W) = Force(F) * Distance(S) \quad (8)$$

In water Engineering, lifting water out of the top of a tank or from the deep well requires work because the liquid is moving against gravity. During the calculation of the energy needed to lift up groundwater from Tulaa, researcher was visualized the work required to lift drop of water from aquifer (qaa'aacelaa) to fill the temporary reservoir (faccana). Thus, lifting a series of masses against gravity and allowing the water to trip out from end source.

$$Force(F) = \text{mass}(m) * \text{acceleration due to gravity}(g) \quad (9)$$

$$W = F * S$$

In calculation of the work done due to applied force of Obaatuu (labors group to sustain Tulaa) on specific herds watering day, their total weights and net travelled distances between home and Tulaa should have known.

In this Thesis, to calculate the capacity of work of 'Tootuu' during herds watering day, mass of labors, average height (depth) of Tulaa aquifer (qaa'aaeclaa) and acceleration due to gravity have been considered. Thus, the mass of water up lifters on some wells had identified. Noted that' the weight of 'Tootuu' was taken in default from informants at selected well/Eela on specific watering day. Instead of name the coding, and the mode of the median value has selected for calculation.

Based on the above tables (6 and 7) by selecting the average weight of median value of 'Obatu' the energy possessed by 'Tootuu' during herds watering days was calculated. Thus, by considering the weight and quantity of water up lifters, the depth of the aquifer (qaa'aaeclaa/madda) and acceleration due to gravity the input energy possessed was calculated as follows.

$$\text{Energy input} = \text{mass of water up lifters} * \text{numbers of water uplifters} * \text{average height of tulaa} * \text{acceleartion due to gravity}$$

$$E_{in} = nMgh \quad (10)$$

Where: E in = Energy input by water up lifters

n = Quantity of water up lifters required on the watering day

M = weight water up lifters

g = acceleration due to gravity

h = average depth of Tulaa aquifer

From the table (6); the 15 water up lifters were with average weight of 65kg and 14m average depth of Tulaa aquifer was taken for Energy calculation on first day of herds watering on ElaGalanticha of GorileTulaa.

$$E_{in} = nMgh$$

$$E_{in} = 15 * 65 * 14 * 9.81 = \frac{133,906.5kgm}{s2m} = 133.91KW.$$

From this calculation, 133.91KW was the energy possessed by 'Tootuu' (water up lifters) once a time to fill the faccana (temporary reservoir) at ElaGalanticha of TulaaGorile.

Now, the rate at which energy flow has used per time or the amount of energy used to do work was known. Based on the effort performed by possessed energy during watering day waterpower can be calculated.

e. Waterpower calculation

Energy is the ability or capacity to do work. Power is the rate at which energy flow has used per time or the rate at which work has performed or the amount of energy used to do work or shows how quickly work done. In engineering, the definition of a force has drawn from the second law of Newton and known as a newton unit of measurement. In practice, unit newton is equal to the force generated by the gravity acting on the mass of unit kilogram of matter. In short, it has represented as N. The force on unit kg of mass is ten newtons of load due to the gravitational force 9.81m/s² approximately 10m/s². Moreover, power has given in watt, which is the product of force applied to lift water from the Tulaa and distance of the end source to the watering trough, which is the water-access point for people and their livestock.

Mathematically:

$$1N = \text{unit kg} * \text{ten m/s}^2 \text{ of gravitational force} = 1Kg * 10m/s^2 * 10 = 10N$$

$$\text{Force}(F) = \text{mass}(m) * \text{acceleration}(g)$$

$$F = ma \text{ or } F = mg \quad (11)$$

$$\text{Mass} = \frac{\text{Volume}}{\text{density}}, m = \frac{V}{p}$$

Then;

$$F = \frac{V}{p} * g = \frac{1m^3}{1kg} * \frac{10m}{s^2} = 10N$$

Therefore, the power of water is the product of force invested to lift water from the end source of Tulaa and distance occupied by the chain of 'tootuu'.

$$P = F * S = 1N * 1m = 1NM = 1Watt$$

The yield of waterpower of Tulaa overcome by 'Tootuu' was calculated using the following procedure.

At the first, the depth (height) of the 'qaa'aaeclaa' (aquifer) and volume of lifting device has known. Then, the Power needed to lift water from Tulaa is the product of the force needed to lift water and height or depth of Tulaa aquifer below 'faccana'. Therefore, the waterpower given as:

Power needed to lift water from Tulaa = force needed to lift water * height of Tulaa aquifer

According the above formula the procedure cared out at following Ela.

At a Gorile Tulaa researcher, select elaGalanticha and OdichaBalla for the data sample. The given height of 'Ela/well' for 'qawa-ela' or end source was 14m, Q=10L/s, time to reach 'faccana' 1min of six chain of persons with all have bucket/okole of 10L, means totally 60L

$$\text{Then, } 1L = 1Kg, Q = \frac{V}{t}, V = Qt = \frac{60L}{1min} = \frac{60L}{60s} = 1m^3 = F * S * 1 = 10N * 14m = 140Watts$$

The 140 watts means "140 water watts" in a minute at ElaGalanticha of Gorile. 'Tootuu' were on continuous water lifting task for more than six hours. Similarly, on each watering day based on the worked hours the waterpower was calculated.

RESULTS AND DISCUSSIONS

Evaluation of Borana traditional water lifting and application of available technologies

In order to evaluate traditional water lifting method, the excavation of Tulaa and water lifting process certain primary procedures in the design were considered Tulaa geometry, storage and the aquifer. With regard to geometry, the traditional evaluation of water lifting was taken into account the depth of the well (qaa'aaeclaa) in the geological environment of Tulaa cluster and the aquifer's recharge region of the well structures responsible for water rise at end source. Moreover, dimensioning and designing of Tulaa according to their groundwater flow at end source, discharge potential of the aquifer and wells utilization for maximum productivity were had considered.

The easiest and safest method of dimensioning and designing of a Tulaa by the Borana community has been excavating it from the initial point of ready-made water point to the entrance of the well structure, starting with loose soil and cutting into the hard rock of the end source in the traditional hand-drilling (auguring). The structure of a Tulaa from entrance to end structures is/are not straight cut-ways and has affected by the soil type and rock formation.

Figure 3 Dimensioning of a of Tulaa at eelaGorile

The Borana Oromo community starts dimensioning and designing Tulaa excavation from the initial point of water point to the exit point (i.e. the entrance to the well). Traditional hand-drilling (auguring) considered the nature of the earth materials ranging from a very loose and easily sliding soil known among the indigenous well engineers as 'biyyeeyaattoo', to the hard rock of end aquifers.

In a consolidated ground, including rock formations, the Tulaa stand unlined and unable to resist external loads and thus render structural susceptibility to collapse. However, the indigenous water engineers always reinforce the upper section with bush fences and other local materials. In case of naturally soft soils, a more reinforced stone structure has put in place to avoid or lessen the risk. With development intervention made, nowadays, some structures have improved at several Tulaa with significant reduction in the depth as well as durability of such structures as 'faccana, naanniga' and the steps for instance, plastered with cement concretes.

Another key challenge was in the lay out where runoff enters through 'Baqassaa', resulting, sometimes, in over flooding of the entire structure depending on intensity of rainfall, but most of the time in a mixture of flood water and surface materials (barbaa) transported and deposited around the watering trough. This study depicted that, the

height or depth of a Tulaa from the ground level point to the aquifer ranges between 20m to 40m; 10-20m from faccana to aquifer; while the length or horizontal distance from 'Gulantaa to Daargulaa' varies from 60m to 140m based on the depth of the well (see Table 3). During dimensioning, excavation and water lifting process 'Irrii' has used as a ladder to connect permanent and temporary storage of wells.

'Irrii', is a strong tree trunk (or a bundle of trunks). It has erected or suspended as a ladder to enter the deep 'qaa'aeelaa' down to the aquifer point. It also serves as a stepping point used by the water up-lifters (tootuu) from the aquifer into the temporary reservoir and from the reservoir into the watering trough. 'Irrii' has also used in China and some other parts of the Far East.

The safety of 'irrii' depends on the strength of the material it is made of the strength of the rope used in tying it to the available solid material (nearby-standing tree, log or rock), the art and skill in placing it. With age, loss of friction and slippery surface, irrii may break or fall, exposing the labor force to a great danger. Moreover, some deep structures of the Tulaa are too dark to see due to turn and twist in the Tulaa system and entail more risks.

Figure 4: Borana traditional Tulaa profile and Irrii as core tool in traditional water lifting

In the evaluation of water lifting method, dimensioning and designing of Tulaa (any water wells) used for multipurpose according to their groundwater flow at end source, discharge potential groundwater use for max productivity had required if water-lifting devices had well planned. For details see 'Water lifting devices (Baumann, 2000)

Tulaa discharge estimate from the traditional and various water-lifting technologies

During the fieldwork, the researcher measured the yield of six wells at Gorile, Dhas and Wachille clusters. Tootuu use leather buckets (okoleetoo'aa) to uplift the groundwater, whereas solar radiation pumps and simple diesel motorized pump have also used at Dhas and WachilleTulaa clusters respectively. The discharges estimated from the water-lifting technologies is shown in the below table.

From the above table, evaluation of traditional water lifting method and application of technologies used at selected Tulaashows a small yield difference between these methods. The median yields for tootuu (using okoleetoo'aa), or an equivalent ten-liter jerry-can, with motorized pump and solar radiation pump at Gorile, Wachille and Dhas are 18,17, and 19 L/min respectively, showing a minor yield variation but the power, energy output and efficiency differs. Based on this, attempt was made to calculate the energy and power invested to lift the mentioned amount of water (see section 3.4.2).

Livestock water demand calculation at Tulaa

The available applied technology (motorized pump and solar radiation pump) were not widely used in the Tulaa clusters) except few installations done at limited points. Therefore, only the traditional water lifting method was considered in livestock's water demand calculation. Livestock water demand was calculated established on the standard livestock daily consumptions in terms of weight equivalent called Tropical Livestock Unit (TLU) and adding the numbers of herds served on selected Tulaa. An attempt has made here to determine the number of herds that can serve from a single well in a day. As the herd-watering day, demand unit per watering day has expanded to the three normal watering days the needed water demand based on the quantity of herds watered.

The calculation of livestock demand based on standard LVU and herds watered at Tulaa has revealed that in one watering day, the eela/well called Galaanticha (means 'the well of Galaantuu clan')alone serves 800 heads of animal (see above table). Thus, cantered on the daily consumption of each species, it is possible to calculate the aggregate annual herd size served by the Tulaa in Borana. In addition, one remarkable point is that no matter how the size of the herds brought for watering purpose, it is inconceivable to take the herds back home without watering them due to fatigue on the part of water up-lifters.

According to my informants, if labor shortage has experienced at a particular well, people from the neighboring wells are obliged to fill the gap based on Boorantittii (being Borana/Oromo) beyond the economic principle of reciprocity. Therefore, although the job was physically exhausting, the social obligation and the shame put individually or collectively on the 'Tootuu' of that particular day overcome the physical fatigue. Hence, through the blend of homegrown technical groundwater engineering and social mechanisms, the Borana Oromo have been able to provide water for domestic and livestock consumption from deep inside the subsurface structure for centuries.

From the calculation of ElaGalanticha LVU, daily demand was 20m³/d, and according to water trucking in arid zone BWMO' with unit meter cubic cost twenty-five ETB birr, the financial cost estimation formula of 20*25 Birr, it costs around 500 Birr per 20m³/d. In order to lift this small drop of water, it is conceivable to imagine how much labor force has invested in Tulaa over a few hours' time, which recurs on every watering day. Thus, the energy possessed during watering day and labor force invested in Tulaa over watering day herds were very huge.

Energy possess by 'Totu' from Tulaa during herds watering day

From the field survey at those Tulaa cluster mentioned earlier, the amount of labor required on each watering day was ten to twenty persons of average weight 60-70kg. Thus, 15 men of 65 average kg were had taken to calculate the daily energy needed to lift water from the deep wells. On the three watering days of the selected Tulaa, the average weight of tootuu was 60-70kg. Formerly, based on the obtained data, the average value of certain parameters such as mass, gravity and height were determined. Hence, for eelaGalanticha (m=65Kg the average weight of tootuu, h=14m, the average height of qaa'aeelaathe end source discharge) and acceleration due to gravity, g=9.81kgm/s²). Therefore, for a first moment to fill the 'faccana' 133.91KW energy was been needed. However, based on numbers of herds on specific watering day, the water up lifting activities could continuous about 6 hour's means at least quarter of a day. This indicates how huge amount of labor force has invested at a single Tulaa (deep well) in Borana. The field survey data also shows that in a single Tulaa cluster, there exist now, minimum of 5-30 individual wells. The critical energy of Borana youth invested in fetching one cubic meter of water alone was very huge, and the amount of labor wastage was dismaying.

As a general, with respect to the modern water engineering technology, the manual water lifting was tough and need enormous energy. For details see (Petra Schmitter, 2016). Consequently, the amount of energy water up lifters possessed on a single Tulaa was very huge. This shows how people of Borana lose much energy to lift the little amount of water from Tulaa. Therefore, consideration in advantage and disadvantage of traditional water lifting and supply for livestock and consumptions in terms of input and output energy and comparing it with the water lifted by available technologies in the study area, a few key analytical points have highlighted below as the effect of water up lifters on Tulaa.

Effect of traditional water lifting methods on Totu and application of technologies

In analyzing the effect of water lifting applied per event, no differences are been observed for the water applied throughout the time event of the watering day by totu (both male and female). A men's chain lifted water from the aquifer (madda) while a women group lifted it from the temporary reservoir (faccana). The men's chain was long and therefore high loss of the lifted water was been observed along the chain. Nevertheless, as the water reaches the faccana, the totu from faccana into naanniga delivered water with less wastage. This indicates that despite some variations, the two groups of water up-lifters were having exposed to somewhat similar constraints and opportunities but the effect of 'water power' has taken into consideration.

The instant energy of the acting forces by 'tootuu(totu)' to lift water from the Tulaa relative to the axis of turning 'okoleetoo'aa' from qaa'aeelaato faccana. In using the solar radiation and motorized pump these forces or labor

forces were optimized. However, they were rare in Tulaa cluster and profoundly were not adopted. Thus, the effect of traditional water lifting methods on Totu likely to the moments of acting forces relative to the axis of rotation is determined by the law of rotational motion in hydroelectric and water pumping machine (Dilshod Kodirov and Obid Tursunov, January 2019).

Waterpower during the water lifting exercise

In relation to the traditional water lifting methods and some available water lifting technologies, an attempt has made to explain the meaning of waterpower, which in turn needs a 'drawdown' of Tulaa' definition of force. In engineering, the definition of a force has drawn from the second law of Newton and known as a newton unit of measurement. Force to lift water from the Tulaa aquifer is the product of the chain of persons and acceleration due to gravity that apply from the top to bottom of the borehole called 'qaa'aeclaa' (aquifer). In addition, mass is a volume of water lifted from Tulaa per density of the water.

The unit watt of power used to lift water from the Tulaa is/are equal to the unit newton of force applied to lift unit meter within one second; or, equivalently, unit watt is equal to unit newton every second's water has lifted through unit meter of the length of 'irrii'.

Using the traditional water-lifting device, the chain of 'Tootuu' lifts the water unit meter and 10 liters of water raised from the end source each minute with movements of water up-lifters. Then, the yield of the lifted water is unit liter/seconds. In water engineering application, a unit liter is equivalent of unit kilogram weights in physics, and the general engineering tender force on unit kg is ten Newton. Therefore, the unit liter per second lifted yield of Tulaa has comparable to ten Newton/second.

In an economic calculation, the efficiency of water lifting has given in water watt per vested amount of money such as Watt per USD, watt per ETB etc. Note that in water engineering and water-lifting technologies, the old term "horsepower" (HP) should avoid when computing the waterpower; as water horsepower is the minimum power required to move water. Generally, from Tulaa waterpower calculation noted that the power wasted by a chain of persons on each herd-watering day has very huge and implies marginalization in terms of development planning. How energy or power wasted in manual water lifting has pointed in the next section.

How water up-lifters loss energy or power

The lax of nature for traditional and modern water-lifting devices was that water could have lifted higher than the theoretically determined water head. For example, if the vertical height of a well is 15m and the water lifted to 16 m, the excessive lift is 1m or that paralleling to only 5 percent of the lifted water. In the same way, in view of this study, from the illustration taken at eelaGorile, the water head was 4m and the water has lifted 5m, in each movement of uplifting 'tootuu' exchanges 'okoleetoo'aa' among the chain's members, then 50% of the waterpower was wasted. In Borana traditional water lifting method, people draw water into the temporary reservoir that increases water and waterpower loses because they lift water at least half a meter.

Figure 5: Madda or qaa'aeclaa (the borhole), Faccana and Koloco structures of Tulaawell atGorile (eelaOdicha), showing that how water lose by traditional lifting method.

The smallest power invested in water lifting at Gorile was the yield taken from a single 'okoleetoo'aa' and that was 15 water watts. Actually, there was no limit of waterpower for any watering day as the herd size and the households served have not automatically fixed, but for a watering day with small herd size and small number of households, the invested power was about 5000 water watts at OdichaBallaa and Galaantichawells atGorile. The figure below from Dhas indicates that by a solar radiation pump, the well yields about 250 watts, but if manual labor was preferred instead, 30 chains of men had needed.

Figure 6: Solar radiation pump installed at the Gaadulticha well in Dhas

According to the finding of this study, a single motorized diesel pump can replace up to three hundred-labor force. On the other hand, solar radiation pumps installed at Tulaa sites often yield small amount of water due to power fluctuation with changes in the weather and season of the year.

In order to adjust the waterpower, the devices used for water lifting from Tulaa should have selected in accordance with the available power source. For example, an adult person should not work with a tool intended for a child and donkeys should not draw camel-powered devices for lifting water or for any other purposes. In addition, women should not carry 25L of water on their back, but in pastoralist communities, women sometimes carry more than 25L of water, which has numerous effects on their health.

Emerging issues about Tulaa

A number of processes with both positive and negative results are unfolding around the Tulaa. Below is the outline.

As it is a case in some Tulaa clusters, some water owner families are obtaining solar radiation pumps or a diesel motor to draw more water than required for the regular services. They are engaging in some instances in small irrigation behind the wells, using the 'surplus' water to grow food crops. Whereas food production is a positive venture, tilling the land in vicinity of the Tulaa exposes the latter to siltation and over flooding risks.

Tulaa have attracted emergence of small towns with consequences for sustainability of the wells and water hygiene.

As a Tulaa has a limited depth due to labor requirements, it may thus face slowdown of discharge.

Modern techniques, solar panels and motorized schemes for example, are replacing the traditional water lifting devices around the wells. The community seems happy about the lessened burden and improved efficiency in watering their herds. However, they often raised concern about the schemes affecting the aquifer and the imminent risk in service sustainability related to technical failures in these schemes and shortage in diesel/petrol.

CONCLUSION AND RECOMMENDATION

The Borana Oromo community has been able to pursue successful pastoral production in the semi-arid environment through application of indigenous groundwater engineering skills developed over centuries, and sophisticated institutional arrangements in managing water scarcity. The Tulaa are great manifestation of ancient human civilization, which demonstrated pastoralist innovation in overcoming environmental and technological constraints. Specialized knowledge in water exploration, profound engineering skill in designing and executing structural works has been applied to enable supply of water for human, livestock and wild life consumption from deep aquifers accessed via amazingly difficult cuttings into soft and hard rocks.

The job of lifting water from the sub-surface structure was risky, arduous, monotonous, time consuming, and involves the use of locally available instruments and materials which are 'backward' in the light of the present technological advancement but have been the back bone to the subsistence economy of the pastoralists for long time. This means that the practice was successful when considered in social, economic, technological and demographic contexts of the time.

With technological improvement in the water uplifting method, however, the huge amount of energy and the time invested in watering the herds could have saved and used to addressing the emerging demands of the day. For example, the need for saving labor is becoming crucial day by day in the present economic context of Borana where participation in other non-pastoral activities is becoming crucial to supplement household income. Moreover, with improved method in water up lifting, the aggregate number of herd units served by the Tulaa could increase while herd-watering frequency could reduce depending on the yield at individual wells.

Technical solutions are required to resolve the existing human burden inherent in manual uplifting of water from the deep aquifers (both in shallow and Tulaa) and the materials used to fetch water. It is equally important,



however, to set any intervention endeavor (externally driven intervention in particular) in the institutional context of the society in consideration for sustainability, equity and internal societal harmony.

Based on the key findings of this study, the following suggestions had forwarded:

The rich indigenous engineering tradition of Borana demonstrated by the Tulaa could be recognized as tangible heritage, which if protected and promoted well can inform how human societies made life possible by overcoming environmental difficulties through labor and other resource mobilizations to develop and manage scarce resources. Similar practices may exist in different parts of Ethiopia that should have been assessed, documented, recognized and applied in integration with scientific knowledge to develop water lifting technique in rural parts of Ethiopia in particular.

This study dealt with the technical engineering and social aspects of Borana Tulaa. The researcher's initial intention to run laboratory test to determine the quality and hygiene of Tulaa water lifted through human chains could not have materialized due to security and time constraints in the field. It has hereby recommended that future research endeavors should pay attention to this matter and bridge the information gap created in the present study.

REFERENCES

- ATA. (2016). National Smallholder Irrigation and Drainage Strategy. p. 138.
- CLARK. (1997). <http://www.clarktanks.com.au/>. Retrieved from www.clarktanks.com.au/knowledge-base/how-to-calculate-water-storage-needs-for-livestock/: www.clarktanks.com.au/knowledge-base
- Dilshod Kodirov and Obid Tursunov. (January 2019). Calculation of Water Wheel Design Parameters for Micro Hydroelectric Power. <https://www.researchgate.net/publication/333459987>, 5.
- e.g. Hon. Dr. Borbor Bule, B. G. (2020, January). Traditional Groundwater exploration method, Indicators, history of Tulaa and water management system. (J. Bonaya, Interviewer)
- Marshall, K. C. (2007). An Evaluation of the Water Lifting Limit of a Manually Operated Suction Pump: Model Estimation and Laboratory Assessment, University of South Florida.
- Moti Mosisa et al. (2018). Rural Water Supply and Sanitation in Pastoral Community of Ethiopia: Status, Challenges and Prospects: (The Case of Borena Zone, Oromia Regional State).
- Oleson, J. (1984). Greek and Roman Mechanical Water-Lifting Devices: The History of a Technology; University of Toronto Press: Toronto, Canada.
- Petra Schmitter et al. (2016). Evaluation of suitable water lifting and on-farm water management technologies for the irrigation of vegetables and fodder in Lemo district, Ethiopia. International Livestock Research Institute.
- Petra Schmitter, D. T. (2016). Evaluation of suitable water lifting and on-farm water management. <https://www.researchgate.net/publication/328963669>.