Modeling the Impact of Water Intervention on Household Water Stress.
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ABSTRACT

Kittipong Kumthorncharoen in his PhD thesis- "*Assessing and Modelling household water stress in the Rural tropics: with Application to the to the Mekong Delta Communities*" has developed a water consumption-based index addressing community water stress and has applied it to assessing water stress in Mekong Delta communities in Vietnam. He has also built a computer model (which was strongly influenced by research in the Mekong Delta,) that forecasts household water behaviour (and hence community water stress).

This report describes Akinola's work on this project. It has included the exploration of the implication of the index and its use and the suitability of the model in a rural African (Ghana) community.A proposal for the refinement of Kumthorncharoen's the water-stress function to include water for other uses (namely $WSI = WSI_d + WSIc + WSI_{h)}$ is presented where WSI_d is a Water Stress Index based on water for drinking, WSIc on water for cooking, WSI_h on water for hygiene maintenance. The weightings of the impact of the different water used have been based on the time the human body would survive before threats of death and were in the ratios:- 1: 4: 7

Work on the refinement of the Community Water Behavioural Model based on collected data from Sankpala, Tamale, -rural Ghanaian community has highlighted the need for the inclusion of dirty water in the model. Calibration results suggest the model requires recalibration for use in different regions.

It is suggested that a minimum of 7.5 litres per capita per day will meet the basic health requirements of most people. This is made up from :

- 3.0 water for ingestion (including any via food, if food is in fact eaten in times of high water stress) – highest priority- 1.5 water for cooking (over and above any already assigned to ingestion) – second highest priority- 3.0 water for basic hygiene. – third highest priority

The above proposed water index is based on the introduction of threshold for the three different water uses.

$WSI = WSI_i + 0.25WSIc + 0.14WSI_{h)}$ *

***see Appendix for explanation of Waster Stress Index.**

INRODUCTION

WATER SUPPLY IN AFRICA.

Our main problem in rural communities are the following: walking long distances about 2-3 kilometres daily to public tap; carrying heavy containers on our heads -20 to 25 litres per trip; long queues at the point of taps; should there be contamination at this common point, the whole village is at risk.

-Adult female of South Africa, Water Voice Project 2003

Fig 1.0

Africa is home to more than 27% of the world's population. According to the UN World Water Development Report 2003, only 64% of Africa's population have access to an improved water supply. Africa has the lowest proportional coverage of any region in the world. There is only 50% supply coverage in rural areas and in urban areas half of the 86% urban coverage do not have a house connection or compound tap. Water is a major challenge in the development of Africa.

Efforts to overcome this challenge include the controversial times scale of the United Nations' Millennium Declaration of one of its goals: Halve, by 2015, the proportion who are unable to reach or afford safe drinking water. It is however more practical and executable than the launched International Water Supply and Sanitation Decade in 1981 that stated its goal as : To provide every person with access to water of safe quality and adequate quantity along with basic sanitary facilities, by 1990. Of the world's continents, Africa is the most hit by clean water scarcity and unavailability. Due to the lack of proper, sustainable water supply systems, children especially girls are forced to spend time fetching water therefore depriving them of an education.

The main aim of work on this project is to be able to take a step further towards bridging the gap between developing countries and developed countries but more importantly help bring relief to the African people living in poverty and create improved opportunities for the education of her children.

The purpose of this research is to develop a model that can simply determine the Water Stress of an area/ community and hence give relief organizations clear directions towards the required intervention in the shortest possible time.

The author’s role has been to take Kumthorncharoen’s index and model and examine the feasibility of its usefulness and purpose in an African Community, identify where suitable modifications and improvements can be made.

It is hoped that work on this model- as an extension of Kumthorncharoen’s Model will be able to provide NGOs, local governments, disaster relief organizations with a tool – a reliable resource with which to determine promptly the exact and most beneficial water intervention required in communities (aiding the activities of water agencies).

It provides a simple measure for water stress and a simple prediction of water stress.

METHODOLOGY

Method of Collection of Data Included:

i) Use of available Data resource at local Non-governmental Organisation (New Energy, Tamale) to get obtain data on local climate properties and community properties (demographic).

ii) Use of available data resource at the community (Village WATSAN Member and Village Assembly Man)

iii) Conducting Interviews with Water and Sanitation Officials.

iv) Conducting Interviews with Village Members

v) Carrying Out Informative Sessions with New Energy Staff Members.

Location: SANKPALA

Sankpala is a community located south west of Tamale- West Gonja district in the Northern Region of Ghana. It is about thirteen kilometres from Tamale with a population of about one thousand five hundred people. The people of Sankpala are from the Dagombe tribe, - a prominent tribe in the region and the language spoken is Dagbani. The collected data below reflects behaviour in the middle of the Dry season. (December- Maximum temperature 35 C, relative humidity in the morning- 6am at 54% and at noon).

Fig.3.0 Map of the Northern Region, Ghana Fig 3.1 Typical Compund in Sankpala

RESULTS

Community Water Source

As at the time the data was collected, Sankpala had two functional water sources. One is a borehole with a hand pump facility and the other is a dug-out (as shown below). A mechanised borehole facility at the time of the project was near completion and commissioning. There is another dug-out approximately 10km away (used when the closer dugout has dried out during water crisis). An approximate flow rate of the hand pump borehole is 0.125l/s.

Fig. 3.3 Lady at Borehole Source

Fig. 3.4 Dug out water source

Water Quality

Borehole Water satisfies drinking water standards.

The water quality of the dugout out water is not satisfactory as the source is shared with cattle. The water is however filtered (cloth) – an initiative established a few years ago to reduce the number of guinea worm cases

Household Water Consumption

	Total	Male	Female	House	Household
SANKPALA	1,526	739	787	173	194

Village Population Data

The houses are all on one side of the source. The nearest house to the borehole source is approximately 100 metres away while the farthest approximately 1.0km away. Household water behaviour data was compiled to cover the range.

Although houses never stand alone but are in compounds, (number of houses together) for the purpose of calibration, it is assumed that the 173 houses over the distance of 900metres are about 5 metres equidistant of each other.

Fig. 3.5 Typical compounds arrangement

Decision Making

Main water uses are water for drinking and cooking, water for bathing and hygiene maintenance (prayers included).

Daily Amount fetched and consumed is dependent on household number.

From household interview results household numbers stood at 7-10 members.

Water consumption

Clay pots used – 120 litres and 90 litres.

A household of 6- 10 people uses about approximately 2 x120 litres claypots plus 1 x 90 litres claypot, giving a total of 330 litres a day

Water Cost

Cost of filling 30 litre bucket:- 100 cedis ($1 = 10,000 cedis)
Cost of filling 20 litre container:- 50 cedis

Exemptions from payment

- There is a carer at the borehole that monitors the fetching of water and collects payments for the fetched water.

His household is exempted from payments. As compensation for his services.

So too are:

- Farmers on their way to the farm with not more that 10 litre containers.
- Households headed by old women who send kids to the source. The figure above is a picture that shows the yellow containers children use. Since the community is close knit, the carer is familiar with the grandkids that come.

Fetching containers 30litres

Storage clay containers 120/90 litres

As shown above, households keep earthen storage jar that hold 90- 120 litres of water. They are either kept in the open compound or in a hut to keep cool. Keeping the pots outside increases the possibility of dust particles getting into the the water. A bowl is also used to fetch the water from the pots and is not used hygienically. Therefore, contaminating clean borehole water.

	Sampl.1	Sampl. 2	Sampl.3	Sampl.4	Sampl.5	Sampl.6	Sampl.7
No. at borehole	4	6	8	5	6	6	9
No. at dug-out	20	22	18	19	24	20	21

Sampling of numbers at different times during the study at the borehole and dugout.

The figures represent the number of people fetching water however not all for the purpose of household use. Included washing at the source.

From the one – off figure of 11 people (fetching water for use within the household) out of 20 people at the dug-out , it was data in the table above is estimated as

	Sampl.1	Sampl. 2	Sampl.3	Sampl.4	Sampl.5	Sampl.6	Sampl.7
No. at borehole	4	6	8	5	6	6	9
No. at dug-out	20	22	18	19	24	20	21
Fetch for household	11	12	10	10.5	13	11	11.5

Table 3.1 Figures of people fetching for households

	No. of household members	Approx. quantity fetched	Travel time(queue + fetch)	Qty left new fetch	Daily consumed amount	
H.H. 1	<20,7fetch	<10 drums	30 mins	none	<10 buckets	
H.H. 2	Near mosque.4f.	20 drums		None commercial	<20	
H.H. 3	10	10 drums	60mins	none	10	
H.H. 4	8	10, 5f.	90	none	10	
H.H. 5	10	10	105	none	10	
H.H. 6	9	15		none		
H.H. 7	8	10	120	none		
H.H. 8	9	10		none		

In section Two above, we have looked at water stress measures and Kumthornchoren'sBehavioiral Modelling. The author's contribution has been the literature based research of human body water requirements, and investigation of the possibilities of a more specific Water Stress Index. It has been suggested that the water Stress Index is a reflection of the stress from water for ingestion (water drank, water absorbed from food), water for cooking and water for hygiene maintenance, therefore introducing three thresholds. The weightings of the water uses in order mentioned above are in ratio 1: 4: 7. An algorithm has been suggested for the calculation of the stress.

***See Appendix for calculations and comments**

CONCLUSION

i) The research result show that a minimum of 7.5 litres per capita per day will meet the basic health requirements of most people.

This is made up from :

- 3.0 water for ingestion (including any via food, if food is in fact eaten in times of high water stress) – highest priority
- 1.5 water for cooking (over and above any already assigned to ingestion) – second highest priority
- 3.0 water for basic hygiene. – third highest priority

ii) It is recommended that in the model, the algorithm for household water storage (which is currently developed for 3 day storage) requires modifications. In Sankpala, the author during the household surveys discovered that fetching water for daily use is the normality in the area. Household members only fetch was for '1-day storage' i.e one day usage. In Sanpkala, homes usually have two 150 litres clay pots and one 90 litre pot.

iii) The author concluded that the Model required recalibration for use in different regions. The calibration calculations in section 4 have demonstrated the applicability of Kumthorncharoen's algorithm on unit water cost and calibration constants. It confirms its use in the African context. As the parameter required to calculate the unit cost and calibration constant differ from continent to continent and region to region, the author recommends that in the instruction manual, it is stated that model is to be recalibrated for use in different regions (i.e of countries dependent on the weather, live style etc).

iv) Work on the model is required. Modifying the model in Visual Basic and improving the user interface. Recommendations for improvement include an improved data entering process for the rainfall data.

v) The author's general belief is that that the Model can be used in it current state to assess water Stress and forecast water consumption in the African context. It offers crude, 'rough and ready' results. However, as a requirement for refined data results, an improved reliability and better user friendliness, work is required, with reference to the comments and recommendation included in the appendix.

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APPENDICES

Calibrating the CommunityWaterBehavioural Model with Data from Sankpala, Ghana

Representation of 'cost'(in minutes)

For simplicity and a common measure (i.e throughout countries and regions) it has been proposed that cost is represented in terms of time (minutes). The CWBM has also been refined so that 'a travel time' can be computed, which will be added to the cost of obtaining water. Kumthorncharoen's model states that :

$$T = N \times 2xD\frac{1}{S} \, where N = \frac{F}{C}$$

Notations

T = is the total travelling time (minutes)

F = is total quantity fetched from source (litres)

C= is capacity per trip (litres per trip)

N = is the no. of trips (1,2,3….) rounded number of F/C.

D = is distance to source metres

S= is the mean travelling speed to and from the source (metres per minute)

Weighted unit Water cost.

Kumthorncharoen's arithmetic formula:- To compute a 'weighted' unit water cost for a mix of the present day's (today's) fetched water and collected water (for a particular day and household) is

$$U_w = \frac{(U_s x F_s) + (U_R x R)}{(F_s + R)}$$

U_w = weighted unit water cost.

U_s = today's unit cost for water fetch from source (minutes per litre).

F_s = water actually fetched from the sources (litres).

U_R = todays's unit cost for harvested roof water is free i.e. $U_R = 0$.

R = Amount of rainwater harvested (in litres).

Unit Water Cost

$$U_s = \left(\frac{T_Q + T_R + T_P}{F_s} \right) + T_I + T_M$$

Equation Unit Water Cost of Obtaining Water

Notations

U_S Unit water cost of source *s* (minutes per litre)

T_Q Queuing time cost (minutes)

T_P Pumping-water time (minutes)

F_s Water fetched from source s (litres)

T_R Travelling time (round trip, minutes)

T_I Water treatment cost (minutes per litre)

T_M Money paid at source (minutes per litre)

The equation above expresses the unit cost of water in time units. It was decided to express costs in this way so that they can be directly compared regardless of monetary currency and living standards. T_M and probably T_I can be expressed in time units by interpolating a wage rate.

It is also noted that the opportunity cost of collecting water also has an effect on economic and social wellbeing. If the responsibility of water collection falls on children (as seen in Sankpala) education is lost. Carrying heavy buckets is not safe for the health and growth of the children.

Using data from Ghana to test the applicability of the equation in Kumthorncharoen's model.*

Based on similar travelling time figures as with the Mekong Delta (flat land terrain)

Walking /travelling speed 4km /hr (67m/min)

From the data collected in Sanpkala

We know that it takes a resident 300 metres away from the borehole source 30mins to fetch water.

Therefore,

$$T = 1 \text{ x } \frac{2x300}{67} = 8.9 \text{ approx. 9 minutes}$$

Pumping time: At pumpting rate of 0.125 ls, a 30 litre bucket would be full in 4minutes. **Resting period** between pumping sessions can be estimated as another 2 minutes. **Queuing Time:** With 3-5 people at the borehole, the fetcher is comfortable prepared to wait in the queue. Assuming there are 4 people in the queue at the borehole the fetcher (fetcher 5) would have to wait approximately 24 ((=4+2)4) minutes to fetch water. Interpretation of the monetary cost in terms of minutes requires the daily wage of a local labourer. From a source (Project manager of a construction site in Accra, labourers daily wages range from 50,000 cedis to 80,000 cedis. We shall assume the daily wage as 50,000 cedis and daily wages are expected to be less in the rural areas.

Daily wage= 50,000 cedis = 7hours

C500,000 = 420mins

Cost of 30 litres bucket = c 100

Therefore, $\frac{50000}{100} = \frac{420}{x}$

500x=420

x= 0.84minutes

Unit water cost = $\left[\frac{9+4+2+24}{30}\right] + 0.84 + 0$ =**2.14 mins/litre**

The above water cost is relatively high and confirms Kumthorncharoen's results and comments on analysis of data from the Mekong Delta, shown below.

i) The research result show that a minimum of 7.5 litres per capita per day will meet the basic health requirements of most people.

This is made up from :

- 3.0 water for ingestion (including any via food, if food is in fact eaten in times of high water stress) – highest priority
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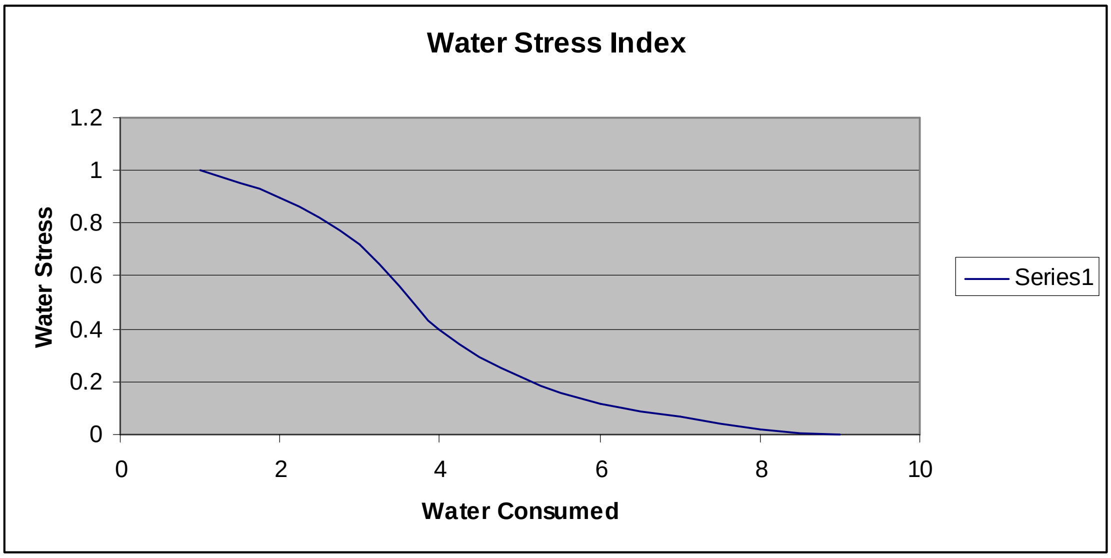

The Above above proposed water index is based on the introduction of threshold for the three different water uses.

WSI = WSI_i + 0.25WSIc + 0.14WSIh)

Where,

$$WSI_i = \left(\frac{D}{T}\right)^n \qquad D_i = T_i - C_i$$

$$WSI_c = \left(\frac{D_c}{T_c}\right)^n \qquad D_c = T_c - C_c$$

$$WSI_h = \left(\frac{D_h}{T_h}\right)^n \qquad D_h = T_h - C_h$$

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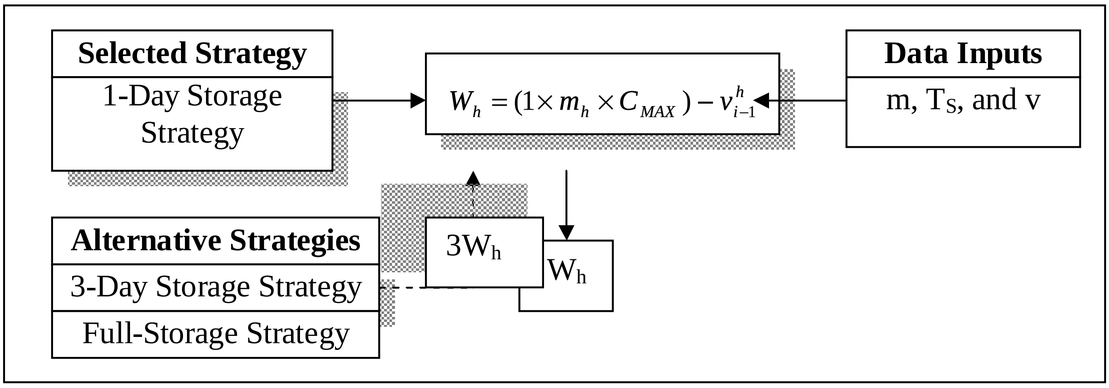
It is suggested that the changes as are in the Figure below.



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