Developing a Domestic Water Scarcity Index in a Multiple Water Source Situation [1]

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ABSTRACT

Multiple water sources are used by households to fulfill their domestic water requirements. This situation is more apparent in rural areas where availability of a single reliable water source is rare. Rural households that use multiple sources incur a considerable opportunity cost of time.

Domestic Water Scarcity Index (DWSI), an index to express water scarcity to households was developed considering number of water sources, the magnitude of using each water source and distance from household to water source as key determinants. Weights were assigned to water sources to depict increasing water scarcity as using more number of sources. Final index was calculated by weighing different uses according to their volume of water. Developed index was tested using household level data from Kirindi Oya Irrigation and Settlement Project (KOISP) in Southern Sri Lanka. Relationship among DWSI and other socioeconomic and water availability characteristics including the type of water source was evaluated.

DWSI for households with access to a home-based water sources is low. Households without a home-based water source show higher water scarcity when they lack access to a developed public water supply. Households in an area with a dedicated public water supply shows high scarcity in uses that require high volumes of water. This results leads to strengthen the policy implication of increasing investments in domestic water supply schemes in rural areas with an objective to increase the health of households and hence the productivity of available labor. It further identifies the need of providing adequate water for all domestic uses and reducing the time and labor required for collection of water.

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[1] *Paper to be presented at the National Conference on Status and Future Directions of Water Research in Sri Lanka, 4-6 November 1998, Colombo.*

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1.0 Introduction.

Availability of adequate amounts of safe water for drinking and sanitation to households is a key indicator of development. The UN General Assembly declared 1981-90 as the International Water Supply and Sanitation Decade. Domestic uses of water includes drinking, cooking, sanitation, washing of household utensils, laundry and bathing. Per capita consumption of domestic water varies according to a multitude of factors such as availability of water, distance to water source from the household, quality of the water source and geographical factors. Many social, cultural and economic factors including life style also contributes to the pattern of water use within a community.

Evidences of using multiple water sources by rural households have been documented by several researchers (Cosmonesky, 1983, Palmer, 1979) Causes for using multiple sources varies from non availability of a single water source to meet total water requirement for a given purpose to non preference of available sources. Households prefer certain sources for certain purposes mainly due to quality considerations. Using multiple sources for quantitative or qualitative reasons suggests the inability of households to depend on a single source which is situated closer. Supplementary sources are mostly situated away from home and demand more time for water collection.

This paper describes an attempt to construct an index to describe water scarcity faced by rural households living in a multiple water source situation. Part one discusses importance of identifying domestic water scarcity and the need for an index. Part two of the paper is devoted to describing the steps of construction and part three applies the developed index empirically using data from an irrigation and settlement project in southern Sri Lanka. The final part discusses policy implications.

2.0: Conceptual Framework.

2.1 Household decisions regarding using water sources.

Concept of domestic water scarcity is based on the assumption that a rational household prefers to fulfill its total domestic water requirement from a single home-based water source. A household depends on a second source if and only the first water source is unable to provide the total household water requirement. Using a third source represents further scarcity since both first and second sources are not sufficient. Thus domestic water scarcity increases as more and more water sources are used and as dependency on supplementary sources increases.

Figure 1 presents the analytical framework for relationship among environmental, institutional, and economic variables affecting household water scarcity. Factors affecting availability of domestic water for a household are categorized broadly as external or internal. External factors are related to environmental, social and institutional determinants while internal factors include households' ability or willingness to have a home-based water source.

According to the analytical framework presented in figure 1 there are two major determinants of domestic water scarcity: (I) reliability of sources and (ii) spatial distribution of sources. The former contributes to increasing water scarcity as it leads households to use several water sources for a given purpose. Spatial distribution requires households to travel to and from water sources and hence affects household time allocation decisions.

Using more than one source requires the household to commit resources to gain access to supplementary sources. Cost of using multiple water sources is a combination of the cost of three components: time, of maintaining accessibility, and of maintaining utensils and carriages . Households wish to bear this cost only when it is essential.

Households face the constraint of total time available for different household activities. Supplementary water sources are generally situated further away from home and more resources are needed to access them. Increasing time needed for collection and fetching water reduces the time available for productive work or leisure. Time required for fetching water and water scarcity increases as distance from household to water source increases.

Domestic water scarcity and poverty have a mutual relationships. That is to say an increase in water scarcity is associated With an increase in poverty. Need for allocating time for water collection is a loss of potential income. Reduced household health due to lack of water influences household wealth which in turn affects the affordability of a home-based water source (Figure 1).

2.2 Procedure to develop the index.

Domestic Water Scarcity Index (DWSI) is the weighted average of two indexes to describe magnitude of dependency on multiple sources (IMS) and distance from home to water source (IDS). Weights assigned are one third and two thirds respectively, reflecting a subjective judgement that distance is a greater contributer to "scarcity" than source of water.

IMS was designed to depict higher values as households' dependency on supplementary sources increase.. Assuming waiting time at the source as negligible, distance traveled for fetching water is twice the distance from household to water source. An average household is unable to use its time for other productive work if time needed to fetch water exceeds the time available for work (8 hours per day) thus, 6400 m is considered as the maximum allowable distance from household to the water source. A household that reported 6400m as distance to source is considered as depicting the highest burden on productive time. When more than one water source is used, weighted distance according to the importance of the source is considered. Scarcity indexes are separately calculated for different water uses and a composite index (CSWSI) is finally computed using weights to represent the importance of different uses.

(Please refer technical note 1 for comprehensive details of developing the index .)

3 . 0 : Empirical Application.

3.1 Study area and source of data.

Data for the empirical analysis were obtained from Multiple Uses of Water Database developed primarily by Sri Lankan case study on Multiple Uses of Irrigation Water under System Wide Initiative for Water Management (SWIM) Program of the International Irrigation Management Institute.

Kirindi Oya Irrigation and Settlement Project (KOISP) is situated in Southern Sri Lanka. Lunugamvehera reservoir supplies water for two sub areas of the scheme, namely old area and new area. The old area is irrigated through five tanks with a history running back to 300 BC. It was restored in the late eighteenth century. The new area was developed after construction of the reservoir in 1980s. The National Water Supply and Drainage Board provides pipe -borne treated water for domestic use principally in the new area.

Data were collected during March-September 1997 using a structured interview survey schedule. Details on water sources used by households, amount of water obtained from each source expressed as a percentage of total water used for the purpose, and distance from household to the water source were recorded.

3.2: Results and Discussion

Tables 1 -3 show characteristics of using multiple water sources and calculated indicators by three different accessibility groups for different water uses: (I) old area households without a home-based water source (Table 1), (ii) old area households with a home-based water sources, and (iii) new area households without a home-based water source. (Only two households in the new area had a home-based water source – not enough to form a group) The formulas for calculating IMS and IDS are shown in Technical Note 1. In each of the tables, DWSI is a weighted average of IMS = 1/3 and 2/3. CDWSI is a weighted average of drinking = .2, sanitation = .25, washing of utensils = .25 and laundry = .3.

Domestic water uses can be classified in to two categories as light use and heavy use according to quantities of water needed. Uses as drinking and cooking, sanitation and washing of utensils that require relatively smaller quantities of water are included in the first category. Laundry and bathing needs a relatively larger amounts of water are included in the second category.

Multiple sources were more prominent in bathing and least prominent in drinking and cooking. People in the new area use more sources for all purposes than people from the old area. Forty six households in the old area have either a well or tap or both at home.

Thirty two and severity households from old area and new area respectively had no home-based water sources.

Old area households without a home-based water source traveled larger distances to obtain their water supply. New area households without a home-based water source used more number of water sources but their dependency on supplementary sources were low

Old area households with a home-based water source recorded a lower index for all water uses in the light use category and for the composite index. Old area households without a home-based water source recorded the highest domestic water scarcity in all indexes except for laundry. However, Composite index is highest in new area households without a home-based water source due to contribution made by high water scarcity for laundry.

A simple linear regression model was employed to determine CDWSI (dependent variable) as a function of *availability of a home-based water, type of house*(as a proxy for socioeconomic conditions of households) and *area.* (See Technical Note 2 for details). Two categories were identified, permanent houses and non permanent houses, representing a logical upward movement of socioeconomic conditions. The significance of the first two *dummy variables* suggests that domestic water scarcity increases with poverty. The area dummy variable was not significant implying that the differences among households is explained by other two dummy variables.

4.0 Conclusions and Summary

Households in the old area where no extensive water supply schemes are in operation face higher water scarcity home-based higher than new area households for all uses other than laundry suggesting that extension of a public water system will make their livelihoods better.

Households in the old area with access to a home-based water source face the problem of locating water sources for laundry. They typically draw water from deep wells for most domestic purposes but use the irrigation canal as the main source for water for laundry. The DWSI for laundry is even higher in the new area implying that they must use a considerable time for this purpose.

According to the findings of the study, it can be suggested that dedicated domestic water supply systems decreases domestic water scarcity but the importance of increasing quantity of water issued should also be a major concern. The existing public water supply is intended only for drinking. Households must look to other sources to meet other domestic needs.

Acknowledgment

Author is grateful to Dr. Randolph Barker, Senior Advisor to the Director General,

International Irrigation Management Institute, for his invaluable guidance towards improving this paper. Comments made by Dr. M. Samad and Mr. Dharme Bandara are also appreciated.

Table 1 : Pattern of multiple uses and calculated indexes for Old Area Households without a home-based water source (n = 32)

	Average number of Water Sources	Weighted distance traveled (m)	(% of Water) from the main Source	Indicator of multiple sources (IMS)	Indicator of distance traveled (IDS)	Domestic Water Scarcity index (DWSI)
Drinking	1.16	386	common tap (67)	3.13	6.04	5.06
Sanitation	1.21	216	common tap (37)	6.25	3.38	4.34
Washing of Utensils	1.25	246	common tap (53)	5.31	3.86	4.34
Laundry	1.62	477	irrigation canal (82)	17.50	6.46	10.14
CDWSI						6.22

Table 2 : Pattern of multiple uses and calculated indexes for Old Area Households with a home-based water source (n = 46)

	Average number of Water Sources	Weighted distance traveled (m)	(% of Water) from the main Source	Indicator of multiple sources (IMS)	Indicator of distance traveled (IDS)	Domestic Water Scarcity index (DWSI)
Drinking	1.07	44	home garden well (50)	1.09	0.52	0.70
Sanitation	1.10	16	home garden well (56)	2.83	0.22	1.09
Washing of Utensils	1.08	14	home garden well (67)	2.17	0.19	0.85
Laundry	1.97	180	irrigation canal (43)	26.74	2.52	10.59
CDWSI						3.80

Table 3 : Pattern of multiple uses and calculated indexes for New Area Households without a home-based water source (n = 70)

	Average number of Water Sources	Weighted distance traveled (m)	(% of Water) from the main source	Indicator of multiple sources (IMS)	Indicator of distance traveled (IDS)	Domestic Water Scarcity index (DWSI)
Drinking	1.23	115	common tap (96)	2.29	1.80	1.96
Sanitation	1.44	102	common tap (64)	8.00	1.59	3.72
Washing of Utensils	1.42	114	common tap (96)	7.14	1.78	3.56
Laundry	2.38	380	common tap (53)	42.29	4.70	17.22

CDWSI						7.38

5.0: References.

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TECHNICAL NOTE 1

CALCULATING DOMESTIC WATER SCARCITY INDEX

$DWSI_{(basic)}$ are calculated for each water use identified in the community. Final index (CDWSI is calculated as the weighted average of all $DWSI_{(basic)}$ s Weights assigned according to volume of water used by an individual for different uses are as follows,

0.2 for drinking and cooking
0.25 for washing of utensils
0.25 for sanitation
0.3 for laundry

Two components named as (a) IMS (Indicator of multiple sources) and (b) IDS (Indicator of distance to source I is used in calculating $DWSI_{(basic)}$ for each water use.

(a) IMS = Indicator of multiple sources is calculated using

$$IMS = \sum_{i=1}^{n} \frac{PWDOMUi \times 1/n - (i-1)}{100/n} - 1 \quad \text{-------(1)}$$

Where.

PWDOMU i Amount of water from i th source as a percentage of water used by the household for the considered purpose.

i : Rank assigned by the household to the water source according to magnitude of use. (reverse ranking i.e . lower the use higher the rank)

n : Total number of water sources used by the household to satisfy total water requirement for the purpose.

Handling Ties

When two or more sources provide equal amounts of water for the household the ranking method described above does not hold valid. Mid rank method will then be used similar to handling the ties in rank data analysis in statistics. assuming maximum IMS as 2

IMS ~ 0 - 1

these values are converted into index values using the general formulae

$$Index = \frac{Actualindexvalue - Minimuindexvalue}{Maximumndexvalue - Minimuinndexvalue} \quad \text{----------(2)}$$

such that

$$IMS = \frac{IMS_{obs} - IMS_{min}}{IMS_{max} - IMS_{min}}$$

since

IMS ~ 1-2 IMS = IMS_{obs}

(b) IDS (INDICATOR OF DISTANCE FROM HOUSEHOLD TO THE WATER SOURCE)

$$IDS = \frac{DSDOMU(m)}{6400(m)} \quad \text{----------(2)}$$

IDS ~ 0 - 1

converting into index form using equation (3)

$$IDS = \frac{IDS_{obs} - IDS_{min}}{IDS_{max} - IDS_{min}}$$

since

IDS ~ 0 -1 IDS = IDS_{obs}

combining two components and presenting in percentage form we get

DWSI = {(IMS + 2*IDS.)/3}*100

TECHNICAL NOTE 2

Details of regression analysis

Simple linear regression model

CDWSI = a + b1 hmbwrsd + b2areadum + b3permhsd -------- (1)

Table TII-1 : Variable Description and results.

variable name	variable description	parameter estimate t ratios in parenthesis
CDWSI (dependent variable)	Composite domestic water scarcity index	
AREADUM	area dummy variable old area = 0 new area = 1	0.532 (0.687) n.s.
HMBWRSD	Home-based water source dummy household WITHOUT a home-based water source =1 otherwise = 0	2.702 (3.364) **
PERMHSD	socioeconomic dummy variable - NO permanent house = 1 otherwise =0	1.858 (2.659) **
Constant		3.438 6.421) **
R^2		19.60
F ratio		11.867

** estimate significant at; p = 0.05.

n.s : estimate not significant at; p = 0.05

Figure 01 : Relationships between Domestic Water Availability and Poverty