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Estimating key determinants of household water consumption in Sohra, Meghalaya

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Abstract

This study aims at identifying the key determinants of household water consumption and to determine the factors that are essential in sustainable water management. The study was conducted in Sohra town of East Khasi Hills District of Meghalaya which receives very high-intensity rainfall. Ironically the town is also characterized by water deficiency. The study reveals that the socio-demographic variables play important role in determining household water consumption. Population and water demand projection also showed that by 2041 the water demand will increase to about 23 percent which reveals serious supply-demand gap. Results also demonstrated the need for household water conservation and augmentation of PHED water supply for sustainable water resource management.

Keywords: *household water consumption, population, water demand-supply, sustainable management.*

Introduction

The paper seeks to identify the key determinants for household water management that would contribute to effective domestic water management in Sohra a small tourist township in Meghalaya, India, known to the rest of the world by the name *Cherrapunji*, one of the wettest places in the world characterized by extreme wet monsoons and dry winters. The research used socio-demographic variables such as household income level, household size, level of education and occupation as determinants for household water consumption. Generally, water management issues are undertaken for large cities ignoring problems faced by the small towns such as Sohra. The present study is an attempt to fill this gap.

Sohra is a small town with a population size of 15142 persons (Census of India, 2011) under the East Khasi Hills district of Meghalaya situated at 25.2863°N latitude and 91.7147°E longitude. It falls within the administrative boundary of the Shella-Bholaganj Community and Rural Development Block (Fig.1). Sohra is well known for very high rainfall received in summers driven by southwest monsoon winds while the winters are generally dry.

The town is characterized by severe water deficit at least for about 6 to 7 months every year (Singh & Syiemlieh, 2010). The estimated average household water consumption was 35 litres per day in 2005 and was attributed to four main factors: (i) the effect of seasonality when very less water is available in the streams during dry winters, (ii) the tradition of washing clothes

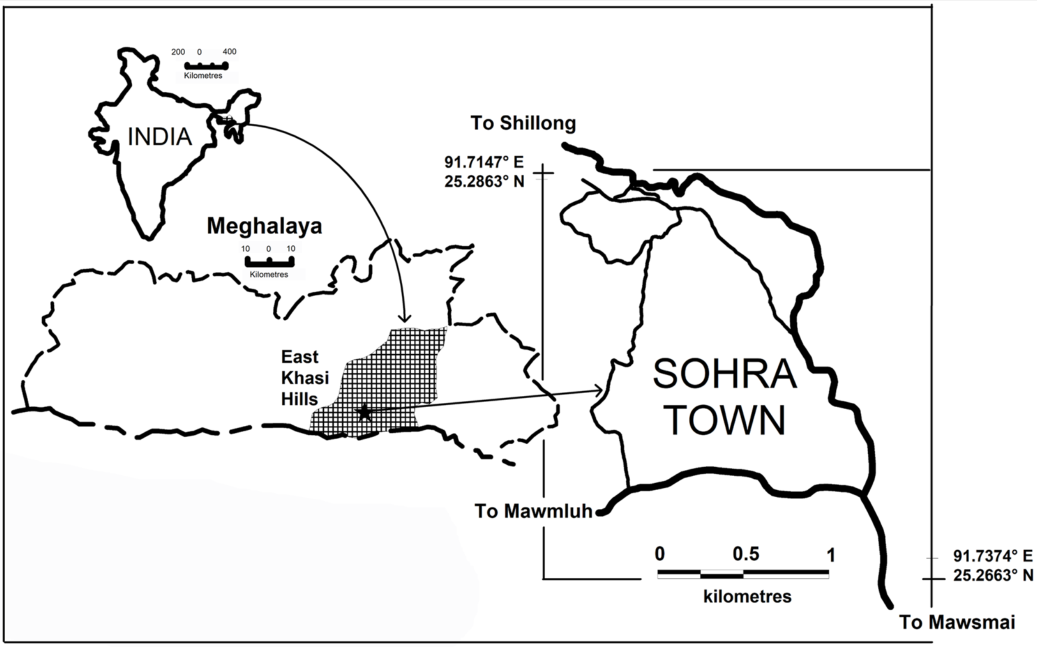

Fig. 1: Location of the study area

and taking bath in the river itself (iii) the low storage capacity of rainwater at home and (iv) the near absence of modern water consuming devices like flushing lavatories, washing machines, shower baths etc. (Singh & Syiemlieh, 2010).

Socio-demographic determinants

Importance of socio-demographic on household water consumption is well established. Some common factors include characteristics such as household size, household income and level of education (Aitken *et al.*, 1994; Gregory & Leo, 2006; Jorgensen *et al.*, 2009; Jain *et al.*, 2014; Israr *et al.*, 2017). Predictably, households with more members use more water (Aitken *et al.*, 1991; Shan *et al.*, 2015). Households with a higher level of education make greater efforts in water conservation (Geller *et al.*, 1983; Gilg & Barr, 2006). Higher-income households also displayed stronger tendency to use water-saving appliances (Lam, 1999, 2006). Contrastingly, studies also reveal that households with lower education use less water and engage in more water conservation measures than households with higher level of education (Oliver, 1999; Gregory & Leo, 2003). Likewise there are instances which show households with higher income using more water (Harlan, Yabiku, Larsen, & Brazel, 2009). Nevertheless these studies only bring out the importance of household dynamics as an influence on water consumption.

The effects of occupation on water consumption are less clear. Joshua *et al.* (2017) in a study of household water use in Hong local government area of Adamawa state in Nigeria found significant relationship between domestic water stress and income and occupation. However, their water stress measures were limited to household income and occupation. The current study incorporates occupation along with other variables such as household income, household size and level of education in order to assess the household water consumption.

Population growth

Population increase and increasing water demand correspond to each other (Boretti & Rosa, 2019). Among many factors responsible for decreasing per capita water availability, population and growth in economic activities are obvious reasons (Singh and Turkiya, 2013). The rise in population leads to higher household water demand and the future welfare of the population will depend on the ability to understand and manage water demand (Dziegielewski, 2003). The impact of rapid population growth on water resources is more especially in areas with water shortage or arid conditions (Abughleleshal & Lateh, 2013). Along with rapid population growth, poor water supply management and low household water use efficiency have further exacerbated water demand (Jiang *et al.*, 2010). Population growth also results in increased stress on water resources reducing per capita water availability (Sharma, 2003; Keskinen, 2008). The northeastern region of India has rich water resources but increasing human interference and mismanagement has rendered water resources in a fragile state (Sharma, 2003).

Sustainable water resource management

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro (1992) highlighted the importance of water resource management as an integral part of an ecosystem and a natural resource, and a social and economic good, whose quantity and quality determine the nature of its utilization. The main problem in most developing countries has been the demand of water for domestic use (World Bank, 1993). Consequently, a sustainable approach to water management has gained currency as a means to achieve effective decision for water resources use (Galaz, 2007; Westling *et al.* 2009).

The most pressing problem in human society is water scarcity (Jury & Vaux, 2005). Water resources are subject to the effects of history, policy, natural conditions, human activities and science and technology (Cosgrove & Loucks, 2015). Human activities and consumption patterns have been the principal determinants of water resources management (Daily *et al.* 1994). In any case, the issue of sustainability is of paramount importance. One of the most prominent assessments is integrated water resources management where household water demand management has an important role to play in reducing the vulnerability of water supplies for the future (Russell & Fielding, 2010). Demographic and socio-economic factors have been identified to have played a significant role in household water management (Ilic *et al.*, 2013; Gondo & Kolawale, 2019).

Socio-demographic characteristics were found to influence water consumption and conservation intentions (Addo, Thomas & Parsons, 2018). Potentially, household water demand management can be addressed by water-efficient infrastructure to result in substantial savings in household water use (Fielding *et al.*, 2012). A large body of literature has appeared on the development and evaluation of behavioural interventions aimed at promoting sustainable environmental behaviour specifically aimed at water conservation (Aitken et al, 1994; Trumbo & O'Keefe, 2001; Syme *et al.*, 2000, Young, 2000; Addo, Thomas & Parsons, 2019). For example, changing household behaviour through persuasion can be an integral part of providing water demand solutions (Addo, Thomas & Parsons, 2019).

The present study

Sohra, characterised by water deficit during winters, provides evidence of the critical importance of assessment of demand-driven approaches to household water management. Therefore, the present study assessed the key determinants of household water consumption for better water demand management. The research measures the impact of select socio-demographic variables as determinants of household water consumption in small population located in environmentally fragile location in contrast to large cities which receive far greater attention.

Materials and methods

The research is based on descriptive and quantitative analysis of domestic water availability and demand in Sohra. The study involved a household survey carried out during January 2016 to April 2016 (winter season) of a total of 335 sample households. A structured schedule consisting of both open and closed-ended questions on socio-demographic characteristics of the respondents, daily household water consumption and water sources was administered to respondents in a face to face interview. The population (1991, 2001 and 2011) and water supply data of Sohra were collected from the Census of India and Office of the Meghalaya PHED respectively.

Classification of socio-demographic variables

The socio-demographic variable being categorical data, dummy variables were created for the variables to attain normal distribution and were subjected to multiple regression analysis. The annual income data of the households were classified into five classes such as very low (< ₹ 33000), low (₹33001- ₹55000), moderate (₹55001-₹88800), high (₹88801-₹150000) and very high (>₹150000). The household size was also classified into five categories: very small (<4 members), small (4–5 members), and medium (6–7 members), large (8–9 members) and very large (>9 members). The household income and household size were arbitrarily classified keeping in mind the local realities. The level of education and occupation of the head of the family were recorded as dummy variables.

Estimation of water consumption

The volume of the container or bottles in which the households stored water was measured in litres and the number of buckets used for washing clothes was also ascertained. Based on the information from the respondents, the total quantity of water consumption per day of the sample households was estimated. Assessing quantity of water used for washing clothes was complicated due to the tradition of washing clothes in the rivers. Hence, the households were asked about their approximate estimation of the number of buckets required for washing clothes. Due to extreme variation in the size of the buckets used, the quantity of water for smaller buckets was taken as 10 litres, medium-sized bucket as 15 litres and a large bucket as 20 litres.

Statistical analysis

SPSS software was used to analyse the data for the study. Spearman's Rank Order correlation analysis (two-tailed test of significance) was used to investigate the direction and strength of the association between water consumption and socio-economic factors.

A multiple regression model was used for computing the effect of socio-economic variables on household water consumption. The population of Sohra is projected for 2021, 2031 and 2041 using the arithmetic increase method. Multiple regression analysis combined with the correlation analysis was undertaken to establish relationship between water consumption and the influencing socio-demographic factors. The rate of population increase and water demand of Sohra was calculated. The rate of change in population was calculated using the following formulae:

$dp/dt = C$ i.e. rate of change of population with respect to time is constant.

Where, p represents population, d is the rate of change and t is the time.

The average decadal increase in population was calculated from the last census reports (1991, 2001 and 2011) by integrating

$$P_2 – P_1 = C (t_1 – t_2)$$

Where, P_1 is the population at the time t_1 first census, P_2 is the population at the time t_2 last available census and C represents the constant value.

The average increase is then added to the present population to calculate the population of the next decade. Therefore, the population after the nth decade is determined by the equation below,

$$P_n = P + n. C$$

Where P_n is the population after n decade and P is the present population.

Socio-economic measures

Table No. 1 shows that over 35 percent households were small with 4 to 5 members each. Only about 27 percent households contained 6 to 7 members. A good proportion of households was indeed large or very large. Nearly half of the households earned high income of more than 1.5 lakhs per annum. Respondents' level of education was relatively evenly spread across primary, high school, higher secondary and graduate levels. However, a very significant proportion of the members (44%) were engaged as wage labourers and only 17 percent of the members engaged in government service.

Domestic water consumption

The daily water consumption by the residents of Sohra was estimated at 17026 litres (Table 2). Bulk of the water was consumed by the two high and medium income groups. Contrarily, despite more number of households, the very high income group consumed much less quantity of water. With fewer households included among the low or very low income group, the quantity of water consumption was rather high relative to other income groups.

Per capita water consumption (Table No. 3) is less than the recommended standards of 135 litres per capita per day which is the minimum quantity of water recommended by the Bureau of Indian Standards. The average per household water consumption is about 341 litres per day whereas the per capita water consumption is about 76 litres per day. The analysis reveals significant variations in the household water consumption across income groups. On an average very high income households consumed about 276 litres of water whereas very low income households consumed 219 litres of water per day. However, per capita average water consumption was higher (72 litres) in lowest income group compared to very high income group (66 litres). The average per capita water consumption of all the sample households across income classes in Sohra was less than 100 litres of water per day.

Table 1: The Socio-demographic characteristics

Socio-demographic characteristics	Households (%)	
Household size	> 9 (very large)	8.66
	8 to 9 (large)	15.82
	6 to 7 (medium)	27.16
	4 to 5 (small)	35.22
	< 4 (very small)	13.13
Household income (Rs.)	< 33000 (very low)	2.99
	33001-55000 (low)	4.48
	55001-88800 (medium)	16.42
	88801-150000 (high)	26.87
	> 1.5 lakhs (very high)	49.25
Level of education	Illiterate	7.76
	Primary	36.72
	High School	16.42
	Higher secondary	26.27
	Graduate	11.34
	Technical	1.49
Occupation	Wage labourer	44.48
	Mining	2.69
	Construction	0.90
	Trade	0.30
	Services	4.78
	Midwife	0.60
	Govt. Service	17.01
	Others	29.25

Source: Household Survey, 2016

Water sources

Households use water from diverse sources including tap, spring and stream. Table 4 shows greater diversity in use of water sources with increasing income level. Greater proportion households with more income use tap water for domestic use while the pooer households use combine it with stream water. In fact the poorest section uses far fewer sources compared to the households with better income. Exclusive dependence on stream as a source is confined to relatively richer sections and about 7-10 percent of such households use stream only for their domestic need. Overall, a relatively large number of households use a combination of tap and stream.

Average per capita water consumption from different water sources (Table 5) across income groups reveals that maximum per

Table 2: Number of households and their water consumption across income groups

Income range (Rs.)	Households	Total consumption (L)	%
< 33000 (Very low income)	10	2187	12.8
33001 - 55000 (Low income)	15	3105	18.2
55001 - 88800 (Medium income)	55	4293	25.2
88801 - 150000 (High income)	96	4678	27.5
> 150000 (Very high income)	159	2762	16.2
Total	335	17026	100.0

Source: Household Survey, 2016

Table 3: Water consumption per household and per capita across income groups

Income range (Rs.)		Average water consumption (L)	
		Per household	Per capita
< 33000 (Very low income)	218.7	72.0	12.8
33001 - 55000 (Low income)	310.5	71.4	18.2
55001 - 88800 (Medium income)	429.3	90.0	25.2
88801 - 150000 (High income)	467.8	79.8	27.5
> 150000 (Very high income)	276.2	66.3	16.2
Total	340.5	75.9	100.0

Source: Household Survey, 2016

capita water consumption of 72.7 litres per day was found in the category of 'tap, stream' water source, followed by 'spring' as a source category (71.9 litres/capita/day). Moreover, the minimum per capita water consumption was observed for households using 'tap, spring' and 'spring, stream' water source categories with 52.8 litres and 57.5 litres respectively.

Socio-economic variables

As evident in Table 6, socio-demographic variables were significantly correlated with household water consumption. The correlation co-efficient between household water consumption and socio-demographic variables were observed at 0.379 (annual income), 0.403 (household size), 0.147 (level of education) and 0.245 (occupation) at alpha 0.01 respectively. It implies that there is a significant but not very strong correlation between water consumption and socio-demographic variables. However, of the four indicators, household size emerged as the strongest influence as far as water use is concerned.

Predicting household water consumption

The multiple regression analysis (Table 7) reveals that the association of household water consumption and household size was observed to significantly increase the amount of variance for water consumption by 8.6 % ($R = 0.293$; $R^2 = 0.086$; $p = 0.000$). Consistent

Table 4: Household water sources across income groups

Income range (Rs.)	Tap	Tap, spring	Tap, stream	Spring, stream	Spring
< 33000 (Very low income)	4 (40%)	1(10%)	5 (50%)		
33001 - 55000 (Low income)	7 (46.67%)	3 (20%)	4 (26.67%)	1 (6.66%)	
55001 - 88800 (medium income)	28 (50.91%)	4 (7.27%)	21 (38.18%)	1 (1.82%)	1 (1.82%)
88801 - 150000 (high income)	40 (41.67%)	15 (15.63%)	29 (30.2%)	5 (5.2%)	7 (7.3%)
> 150000 (very high income)	86 (54.09%)	25 (15.72%)	27 (16.98%)	5 (3.14%)	16 (10.07%)

**Figures in the parenthesis are household percentage*
Source: Household Survey, 2016

Table 5: Per capita water consumption across income groups and water sources (in litres)

	Average per capita water consumption across income groups and water sources				
Income range (Rs.)	Tap	Tap, spring	Tap, stream	Spring, stream	Spring
< 33000 (Very low income)	91.4	51.0	60.7	-	-
33001 - 55000 (Low income)	52.1	39.6	110.8	36.3	-
55001 - 88800 (medium income)	70.6	58.7	58.0	60.8	43.6
88801 - 150000 (high income)	68.9	45.9	66.6	72.8	85.7
> 150000 (very high income)	62.2	68.9	67.5	60.0	86.3
Average	69.0	52.8	72.7	57.5	71.9

Source: Household Survey, 2016

Table 6: Correlation (Spearman Rho) of water demand and socio-economic variables

	Correlation Coefficient			
	1	2	3	4
Water consumption/HH/day	0.379**	0.403**	0.147**	0.245**
Socio-economic				
Annual household income	-	0.342**	0.051	0.175**
Household size		-	-0.076	0.035
Level of education			-	0.258**
Occupation				-

*** Significant at the 0.01 level (2-tailed).*

with past studies, households with more members emerged as the strongest predictor of household water consumption in the current study. The overall score for household water consumption and household income also showed significance in the adjusted model, explaining 7.5% of the variance ($R=0.274$; $R^2 = 0.075$; $p= .000$) in water consumption.

Table 7: Multiple regression analysis of socio-economic variables on water consumption

	β	t	Sig.
Predicted annual household income overall score(R=0.274; R2 = .075; p= 0.000)			
Low income (dummy)	0.042	0.511	0.609
Moderate income (dummy)	0.128	1.036	0.301
High income (dummy)	0.151	1.039	0.300
Very high income (dummy)	0.42	2.665	0.008
Predicted household size overall score(R = 0.293; R2 = 0.086; p = 0.000)			
Small household (dummy)	0.187	2.995	0.003
Medium household (dummy)	0.233	3.664	0.000
Big household (dummy)	0.227	3.73	0.000
Very big household (dummy)	0.279	4.826	0.000
Predicted level of education overall score(R = 0.281; R2 = 0.079; p = 0.000)			
Primary (dummy)	0.029	0.292	0.771
High school (dummy)	0.147	1.718	0.087
Higher secondary (dummy)	0.031	0.327	0.744
Graduate (dummy)	0.254	3.249	0.001
Technical (dummy)	0.15	2.696	0.007
Predicted occupation overall score(R = 0.269; R2 = 0.072; p= 0.001)			
Wage labourer (dummy)	0.018	0.053	0.958
Mining (dummy)	0.078	0.61	0.543
Trade (dummy)	0.044	0.522	0.602
Services (dummy)	0.041	0.254	0.800
Midwife (dummy)	0.024	0.288	0.774
Govt. service (dummy)	0.189	0.723	0.47
Others (dummy)	0.288	0.913	0.362

Here baseline or reference category in annual household income is the 'very low' income level group, in household size is the 'very small' household group, in the level of education is the 'illiterate' group, and in occupation is the 'construction' group

Overall, level of education explained 7.9% of the variance (R = 0.281; R^2 = 0.079; p = 0.000) while, occupation accounted for 7.2% of variance in household water consumption (R = 0.269; R^2 = 0.072; p= 0.001).

Projected population

As seen in Table 8 the rate of population growth between 1991 and 2001 was 23.87 percent which declined in the subsequent decade to 17.20 percent indicating deceleration in the rate at which the population was growing. However, despite decline in the rate, population size continues to increase albeit at a slower pace with increasing demand for water on account of demographic size alone besides other contributing factors. According to the projected growth, there is going to be a

Table 8: Projected population growth rate and domestic water demand (1991-2041)

Year	Population	Decadal Population variation		Water demand (in litres)
		Absolute	Percentage	
1991	10430			688380
2001	12920	2490	23.87	852720
2011	15142	2222	17.2	999372
2021	17498	2356	15.56	1154868
2031	19854	2356	13.46	1310364
2041	22210	2356	11.87	1465860

Table 9: Projected population and domestic water supply-demand gap

Year	Total water supplied by PHED (in litres)	Total water demand (in litres)	Shortfall (in litres)
2011	832810	999372	-166562
2021	832810	1154868	-322058
2031	832810	1310364	-477554
2041	832810	1465860	-633050

Projection carried out considering the PHED water supply constant for the following decades

significant increase in water demand over the next two decades. However, Table 9 shows the Public Health Engineering Department (PHED) water supply remains constant for Sohra from the year 2008 onwards till date (2016). The estimated water demand was 999372 litres per day in the year 2011 when PHED water supply was 832810 litres resulting in supply-demand gap of 166562 litres per day. The supply of water was only 55 litres per capita per day when the estimated average water consumption from the survey was estimated at 76 litres per capita per day. The amount of PHED water supplied to the residents is grossly inadequate is expected to exasperate in years to come.

Discussion and conclusion

The study finds household size as the key variable in household water consumption. Moreover, the level of education and income too had significant influence on water consumption. Though the influence of occupation on household water consumption was the least among the predictors, it was observed to affect household water consumption to some extent. These findings along with the evidence from the field survey suggest the importance of strategies for efficient PHED water supply. This may be achieved through augmentation of PHED water source to ensure sufficient water supply to households in Sohra. Simultaneously, promoting a culture of water conservation at the level of the households is essential in all seasons especially during the dry spell. This may be achieved through community awareness programmes.

The study showed that socio-demographic variables coupled with population growth will play decisive role in determining household water consumption in small towns which are generally neglected in considering their water needs. In such towns, water efficiency measures can comprehensively reduce water demand. One way of promoting sustainable water management is through water conservation (rainwater harvesting) in households. Promoting sustainable water management at households in Sohra may be through developing a culture of water conservation during wet seasons.

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