

**Working Paper  
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**DYNAMICS OF RURAL WATER SUPPLY IN  
COASTAL KERALA: A SUSTAINABLE  
DEVELOPMENT VIEW**

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June 2008

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This is a revised paper presented on Aug. 9-10, 2007 at the National Seminar on "Crisis in Drinking Water in Coastal India", organized by Centre for Development Alternatives(CFDA), Gandhinagar, Gujarat. We thank Dr. Indira Hirway, Director of CFDA, for inviting us to present the Kerala case on coastal drinking water supply. The comments of the discussant and of Professor Kirit Parikh, Member, Planning Commission, who chaired the session, substantially helped to improve the paper during the revision. We place on record our special thanks to the following persons: (1) Dr. P. K. Thampi for the insightful discussions on the hydro-geological and quality dimensions on sustainability of water supply systems in the region; (2) Personnel of Kerala Rural Water Supply and Sanitation Agency for providing us an opportunity for studying the Sustainability of demand-driven rural water supply systems; and (3) M.P. Pradeep and Sony Paul for excellent computational and research assistance. Needless to say, the usual caveats apply.

## ABSTRACT

This paper examines empirically within sustainable development framework the dynamics of coverage in rural drinking water supply of 180 demand-driven schemes from Malappuram, predominantly a coastal district of Kerala State. The methodology for the analysis comprised (i) multidimensional specification of sustainability in terms of attributes relating to source, technology, quality, finance, institution and hygiene behaviour and (ii) estimation of the degree of sustainability using models of vagueness. Two methods of 'vagueness' viz. 'supervaluationism' and 'fuzzy inference system' were applied to identify systems that are at or below the sustainability line. Results show that sustainability due to source and quality is lower in schemes from non-coastal regions, whereas sustainability in dimensions of finance, institution, and hygiene behaviour is lower in coastal regions. Empirical analysis of 'marginal systems' indicates that gender participation; female education and income have favourable impact on sustainability of schemes in rural areas.

**Key words:** Sustainable development, Vagueness, Supervaluationism, Degree theory, Fuzzy inference, Rural drinking water supply.

**JEL Classification:** Q56.

## Introduction

The 2005 report of Central Statistical Organisation proposes the millennium development goal of Government of India to “...halve, by 2015 proportion of people without sustainable access to safe drinking water and basic Sanitation”<sup>1</sup>. The target for rural drinking water may become unattainable because of the wide spread re-emergence of uncovered habitats/villages as revealed by the data from Department of Drinking Water Supply (GOI, 2007) and National Sample Survey Organisation (NSSO, 1998, 2004). They provide a disturbing picture of covered villages slipping back (habitats/wards) into uncovered ones at an alarming rate in several states<sup>2</sup>. Planners and scientists attribute this dynamics of shrinking to two major factors, viz., falling levels of ground water and quality problems<sup>3</sup>. Despite the fact that this phenomenon has been observed for the last two and a half decades, there is no concerted effort to analyze the problem within a logical framework and understand the nature and causes of it.

A review of development literature indicates that this problem falls within the broad area of sustainable development. The characterization of sustainability by the Brundtland Commission Report (1987) and by Solow (1993, 2000) identify that the essence of sustainable development

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1 See Goal 7, Target 10 in GOI (2005) for details.

2 See for details, GOI (2007).

3 See GOI (2005).

is a steady flow of resources from an asset without any reduction from one generation to the other. Obviously, re-emergence of villages as uncovered in potable water supply violates the condition of sustainability. The flow of water resources is reported to have diminished within a short period of time after commissioning of the water supply schemes. Viewed from this angle, analysis of the dynamics of coverage of rural water supply within the framework of sustainable development becomes significant. The present paper is an attempt in this direction with particular emphasis on coastal region in the state of Kerala.

The concept of sustainable development has been in the rhetoric for nearly a quarter of a century without much empirical content. It was virtually an 'empty box' empirically except in sector-specific analysis such as fisheries and forestry. Water resource professionals even considered that its (sustainability) "usefulness, irrespective of its conceptual attraction and widespread acceptance, can only be marginal, unless it can be used operationally and effectively in the real world"<sup>4</sup>. In this context two aspects of measurement of sustainability are of particular interest to policy makers, sector specialists and development professionals. First, such an attempt provides the framework for 'the development process, which could be planned and implemented in such a way that it could become inherently sustainable'<sup>5</sup>. The second equally important aspect of such an empirical exercise is to identify the parameters that should be monitored and evaluated continuously so that timely intervention reverses the transition of systems from sustainability to non-sustainability. We are more concerned about this 'transition process' of systems towards non-sustainability so that timely public and institutional intervention could reverse the process.

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4 Biswas (2006): p.76.

5 Tortajada (2006): p.15.

Obviously, one faces several hurdles to make the concept of sustainability in the water sector operational. Among them, three issues are particularly important. First is to choose an appropriate definition of sustainability from among the several existing ones. A cursory look at the existing definitions indicate that the concept is complex and multi-dimensional in nature and is spread over diverse disciplines such as hydrogeology, public health engineering, environmental science, sociology, economics and management<sup>6</sup>. This leads us to the second issue, i.e., the identification of the multiple dimensions of sustainability and its measurement. Having identified the empirical measures of attributes that contribute positively or negatively to sustainability, the third and last issue is the choice of quantitative tools for differentiating between the systems as sustainable/non-sustainable. Solow (2000) has convincingly argued that the concept is 'vague'. So the selected tool should be capable of modelling 'vagueness'. Recent advances in the modelling of 'vagueness' identify three methods: (I) epistemic method; (ii) supervaluationism; and (iii) degree theory<sup>7</sup>. According to Qizilbash (2001, 2006), epistemic view treats the dimension within the dichotomous classical logic (true or false) but not in between (degree of truth/falsehood). Therefore it has very little relevance for the present analysis. The remaining two - supervaluationism and degree theory - are both equally appropriate to model vagueness. There is no superiority of one over the other, and both of them have advantages and disadvantages. Since supervaluationism and degree theories have rough borderlines, our approach for the present study is decided after choosing the admissible dimensions in the specification of sustainability.

The study is organized as follows. Section II provides a brief account of the socio economic and demographic profiles of fishermen households in the state. Section III summarizes the basic framework

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6 See Bredtland (1987), World bank (2000), Solow (2000) and Asian Development Bank (2006), among others.

7 Qizilbash (2001, 2006).

used for the analysis. Section IV presents the operational version of the basic framework including the specification of multiple dimensions of sustainability and models of vagueness in demand-driven rural water supply. Section V reports the results based on the operational model. The last section furnishes the conclusion and its implication on public policy.

## II

### **2.1 Socio-economic and Demographic Profiles of Fishermen Households**

India has a long coastline of more than 7500 km, of which approximately 10 percent is the share of Kerala. After Gujarat and Tamilnadu, it has the third largest number of coastal districts. Out of 14 districts in the state, 9 districts comprising 222 villages in 102 panchayats are on the coastal belt. The survey on fisher-folk in Kerala estimates that a population of 8.37 lakh dwell in 1.25 lakh households (GOK, 2004). Average household size is 6.7, which is much higher than the state average of 4.5. The density of population in the coastal villages is 2168 per sq. km., which is also much higher than that of the state average (819 per sq. km). Another interesting feature of these villages is the phenomena of ‘missing females’ in contrast to the ‘surplus’ among the general population in the state, which is the widely acclaimed unique feature of Kerala's high social development indicator among the Indian states<sup>8</sup>. To be more precise, the sex- ratio is 925 female per 1000 males for the fishermen community as against 1058 for the state as a whole. However, this ‘missing females’ cannot be attributed to selective abortion, which is the widely alleged cause in the other parts of India. The indirect evidence is provided by the age-specific sex ratio as reported in Table 1.

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See Kurien (1994), Pushpangadan and Murugan (2000) for a discussion of the same issue.

**Table1: Age-Specific Sex-Ratio of Fishermen Community, 2004.**

Age group	Sex-ratio (Females per 1000 Males)
< 5	1150
5 - 14	1030
15 - 17	878
18 - 24	825
25 - 44	920
45 - 59	930
>60	890
Total	925

Source: GOK (2004)

Table 1 clearly indicates higher mortality rates among females as age increases - showing surplus females up to the age of 14 and missing females after age 14.<sup>9</sup>

Several reasons can be attributed to this peculiar phenomenon, the major one being abject poverty among them as indicated by the percentage of below-poverty level (BPL) households in the survey. It is estimated that 62.4% of households are BPL<sup>10</sup>. In such households, intra-households distribution of resources is likely to be in favour of males since they are the breadwinners. Notwithstanding this abject poverty, females do not have any opportunity for gainful employment, thereby further weakening their bargaining power for a better and equitable share of household resources<sup>11</sup>. This deprivation as evinced in Table 1 is also observed in education as well - another important indicator

9 See Pushpangadan and Murugan (2000), for additional evidence on the same issue from church death records in a fishing village.

10 See GOK (2004) Table 18.

11 See Sen (1990).

of human development. The dropout rate from high school is estimated to be about 41% among females as against 14.5% among males<sup>12</sup>. A major reason for such gender bias in the drop-outs might be the allocation of more time of female children in household chores particularly in fetching drinking water from distant places. The survey result seems to support this hypothesis, since at least 30% of households in the coastal region have to travel longer distances for fetching water needed for their household activities. An indirect effect of this travel time on female children is the deficiency caused by the extra energy requirement for fetching water, which in turn aggravates the poverty gaps among females in the coastal belt.<sup>13</sup> This deficiency in the nutritional level may have negative impact on the performance of females at school level and may increase their dropout rates. Therefore, in order to minimize the dropout rate among females, the coastal regions must be specifically targeted to provide adequate water and sanitation facilities within a shorter distance from their residence. From the socio economic and demographic dimensions, we now examine the sustainability of water supply in the next section.

### III

#### **Theoretical Background**

In this section, we first formulate the basic framework of our analysis disentangling it from the complex nature of sustainable development in the drinking water sector and then, its measurement as a vague predicate.

#### **3.1 Sustainability: definition, nature and concept**

Several definitions on sustainability exist. The Brundtland Commission Report (BCR, 1987) furnished an important landmark in

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12 See GOK, (2004) Table 8.

13 See Pushpanagadan, Murugan and Navaneetham (1996), Pushpanagadan (2006) for further details

this direction. The BCR states: "... Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations". Several attempts are being made to operationalise this concept across different sectors and economies. A step towards this direction in water supply is contained in the project appraisal documents of the World Bank (2000) and Asian Development Bank (2006). According to the Bank documents: "Sustainability implies that the system works throughout its life and beyond, and is able to generate adequate cash flow for future expansion/renewal." In the present analysis, this definition will be followed with some modifications. This steers us to the necessity to deal with the imprecise nature of the definition as is best stated by Solow (2000). To quote him, "14--- sustainability is an essentially vague concept and it would be wrong to think of it as being precise, or even capable of being made precise". The vagueness needs more elaboration since the methodology for empirical analysis depends crucially on it.

### **3.1.1. The 'vagueness' of sustainability**

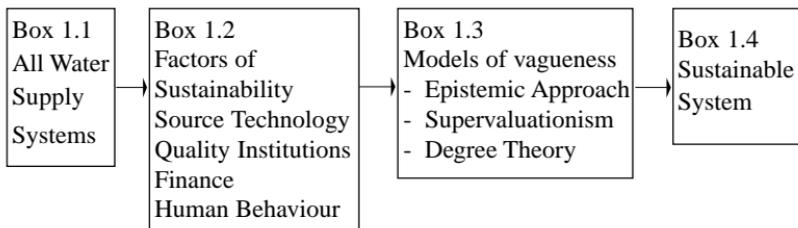
In the literature, 'vagueness' has been distinguished by three non-mutually exclusive characteristics (Qizilbash, 2006). The first is that they 'allow' for borderline cases. In the present instance, this connotes that whether a drinking water system is sustainable or non-sustainable is difficult to judge and hence inconclusive. The second characteristic is that a sharp boundary between cases cannot be drawn. This condition is also appropriate to water supply sector since it is not possible to draw a specific clear cut demarcating line between sustainable and non-

sustainable cases. The *third* is that it is susceptible to ‘*sorites paradox*’<sup>15</sup> or *paradox of the heap*. Evidently this condition is very well applicable to the measurements of sustainability also. In order to demonstrate that sustainability satisfies sorites paradox, consider the case of an aquifer at a certain time where sufficient quantity of ground water exists to satisfy the demands of the community for both drinking and irrigation purposes. The community, as well as the farmers, continuously draw water from the aquifer over and above its recharge level for both drinking and irrigation purposes. Such indiscriminate extraction ultimately turns up at a stage where the aquifer dries up, wells becoming non-sustainable. After a certain level, the graduality principle applies and the sustainable system turns into non-sustainable. Therefore it satisfies the third criterion for vagueness: ‘*sorites paradox*’. Hence, sustainability satisfies all the three features of ‘vague predicate’. It may also be noted that all the three conditions above are related, but not independent. With this background, we proceed to the basic framework of analysis.

### 3.2. The basic theoretical framework

The basic framework for the analysis is summarized in Figure 1.

#### Basic Theoretical Framework for Sustainability Analysis



15 Greek paradoxes were usually formulated in terms of a sequence of questions. “Does one grain of wheat make a heap? Do two grains of wheat make a heap? Do three grains of wheat make a heap...Do ten thousand grain of wheat make a heap? It is to be understood that the grains are properly piled up, and that a heap must contain reasonably many grains, If one admit that one grain does not constitute a heap, and are unwilling to make a fuss without the addition of any single grain, you are eventually forced to admit that ten thousand grains do not make a heap.” Williamson quoted in Martinetti (2006b).

The first box, 1.1, in Figure 1 contains a set of all water supply systems in the region. The last box, 1.4, provides the subset of sustainable systems after eliminating the non-sustainable systems using the methods broadly outlined in boxes 1.2 and 1.3. Let us elaborate these boxes. Box 1.2 presents the contours, explicating the complexity of the concept and the broad areas to which multidimensionality belongs. A review of literature, mainly of World Bank (2000) and Asian Development Bank (2006) indicates the broad 'admissible dimensions' in the complex nature of sustainability of potable water supply. Box 1.2 draws attention to the broad dimensions of the factors following the specification of the concept in the literature. Such specifications include attributes from: (1) Source; (2) Technology; (3) Quality; (4) Institution; (5) Finance; and (6) Human Behaviour. These broad dimensions are elaborated below:

(1) **Source:** Source refers to a source of natural water - surface or sub-surface - from which water is extracted, treated and distributed to the needy community. A perennial water source is a prerequisite for sustainability of a system.

(2) **Technology:** Technology in this article refers to the devices used to extract water from source, process and deliver it to the users. Right selection of technology is important in the sustainability of the system. It may be noted that its impact on sustainability can be measured only through its interaction with other factors such as water source, quality etc.

(3) **Quality:** The next broad parameter that affects the potable supply of water is its quality. The relevance of quality to sustainability depends on two aspects. First, water extracted from the source should be amenable for treatment to attain potable standards before delivery to consumers. Second, even if the quality of water is good at delivery point, the users should also perceive that the quality is good. If both dimensions are not met, then the system is non-sustainable.

(4) **Institutions:** According to North (1990), “Institutions are rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction”. He further elaborates that institutions can reduce uncertainty by making available a well-knit structure to every day life. In the present context, institutions signify formulation of rules and regulations for the transparent and efficient functioning of the systems that ensures sustainability. This would mean identification of rules and regulations for the efficient operation, maintenance and management of water supply systems.

(5) **Finance:** Sustainability in terms of finance implies that the system generates adequate cash flow to meet the expenses for current operation and for future expansion or renewal. If such adequate cash flow cannot be generated, the system cannot sustain itself.

(6) **Human Behaviour:** The last prerequisite for sustainability is appropriate human behaviour. This constitutes, among others, personal, domestic and environmental hygiene and awareness.

The next task is to identify the quantitative tool for measuring sustainability as a ‘vague predicate’. This requires selection of methods that could model ‘vagueness’. As indicated in Box 1.3 in Fig.1, ‘vagueness’ can be modelled in three ways: (i) epistemic approach; (ii) supervaluationism; and (iii) degree theory<sup>16</sup>. In the epistemic method, vagueness is treated in the classical tradition, dichotomously as either true or false. ‘Vagueness’ arises because of, lack of adequate knowledge about the borderline - between true and false. The chief weakness of epistemic approach is “that they assume that it is lack of knowledge which gives rise to vagueness” (Qizilbash, 2001, 2006). The method, therefore, does not address two of the three characteristics of a vague concept mentioned above and hence have not been considered for the present analysis.

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16 See Qizilbash (2001, 2006); Martinetti (2006a)

Unlike epistemic view, 'supervaluationism' and 'degree theory' explicitly model 'vagueness'. Yet, there are sharp differences in the two methods in identifying non-sustainable systems. In 'supervaluationism', all dimensions have to be classified into 'core' and 'non core' and a range of critical values are set up for each dimension. It may be noted that a dimension becomes core only if it appears in all admissible specifications of sustainability. Systems that fall at or below the lowest critical level in each dimension are definitely non-sustainable. If the system falls at or below the lowest critical level in the case of core attribute, it is 'core non-sustainable' (core-ns). Similarly systems that fall above the highest critical levels in all dimensions are sustainable. Systems that are neither core-ns nor sustainable belong to the 'margins of sustainability'.

Degree theory drops classical logic, implying that more than two 'truth values' exist, which could be captured in degrees. There are many forms of degree theory. The one which is commonly used recently in economics is the 'fuzzy set' approach that quantifies the degree of truth in 'border line' cases. More specifically, it measures the degree of truth on the  $[0, 1]$  interval with 0 measuring falsehood and 1 indicating truth.

The choice of appropriate tool for the present analysis is conditional upon the operational version of the framework, which is taken up for discussion next.

#### IV

#### **The Operational Version of Basic Framework**

The major concern of this section is the methodology of data collection and the measurement of attributes/dimensions in the specification. It also incorporates an empirical model of the basic framework of vagueness combining the methods of 'supervaluationism' and 'degree theory'.

## 4.1 Data and methodology

The two most commonly found rural water supply systems in Kerala are collectively owned demand-driven systems and publicly owned systems. In demand-driven systems, complete participation of users at all levels of decision-making, operation and maintenance and collection of revenue is detected. These features distinguish them from publicly owned systems. As a result, the demand-driven systems satisfy all dimensions of sustainability as envisaged in the basic framework (Fig. 1). Therefore the selection of samples is restricted to demand driven systems alone.

### 4.1.1. *Sample:*

Demand-driven systems are, a recent phenomenon in the state, started in 1999 on an experimental basis. Initially 4 districts (Trichur, Palakkad, Malappuram and Kozhikode) were selected in the state for implementing the project<sup>17</sup>. From among them, Malappuram is selected for the present study since it has the maximum area under coastal belt. However, both coastal and non-coastal areas in Malappuram are taken up for investigation. Selection of samples involved two stages. In the first stage, a sample of systems was selected at random from the total systems in the district. In the second stage, a sample of households is selected from the beneficiary list maintained by the beneficiary group (BG) of each system. The number of households served by each system varied from 20 to 75. Sample size was limited to 10% of beneficiary households with at least 3 households selected from each system. Samples were selected at random using circular systematic approach. It may be noted that there was only one BG for each system in the sample, except one mega system consisting of 69 BGs with an apex body for inter BG co-ordination. Samples were drawn for the selection of households on the criteria described. The details of the samples are given in Table 2.

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17 See GOK (2007)

**Table 2: Sample Systems and Households by Region, Malappuram**

	No of systems	No of Households
Coastal	66	413
Non Coastal	114	758
Total	180	1171

Information was collected at different levels using different approaches. Participatory Rural Appraisal techniques were used to identify various dimensions of sustainability and its measurement. Such information was then incorporated into a structured questionnaire, pre tested and modified. These questionnaires were then administered at the system level as well as at the household level. The data so collected were verified or supplemented using 'transit walk methods'. Secondary sources of data, if available, were also used for the analysis wherever it was required.

#### 4.2 Measurement of attributes

At this juncture the task was to define the specific attributes from the broad dimensions in Box 1.2 in Figure 1. The measurable dimensions are given in Box 2.3, Figure 2. Eight attributes that influence sustainability were selected on a priori grounds. These were then empirically made sharper and focused as discussed below.

(1) *Source adequacy (S&T)*: Source adequacy is taken as an attribute combining source and technology together. The range of critical values of source adequacy in sustainability is as follows: The upper limit is adequate supply throughout the year. If the source is not able to provide water to all connections for at least 5 or more days in a year, then it is the lower limit of the attribute. The attribute takes the following values:

Source adequacy (SA) = 1, if inadequate supply,

= 0, otherwise.

(2) *Quality (Q)*: It is postulated that if the quality of water is not of potable standards, the users may not participate in the collective management of the systems even when supply is assured. The same is also true if the perceived quality is poor. In both cases, the systems would not be sustainable in the long run. In our survey only perceived quality is measured since laboratory tests are seldom conducted to determine potability standards. In other words, the upper limit is that quality is perceived by all households to be good.<sup>18</sup> However, if 10% households perceive the existence of quality problems then it is the lower limit of the attribute.

$$\begin{aligned} \text{Quality (Q)} &= 1 \text{ if at least 10 \% of the households perceive poor quality,} \\ &= 0 \text{ otherwise} \end{aligned}$$

(3) *Institutions(I)*: Four indicators falling within the label of 'institutions' are taken up for measurement. They are (1) distributional equity (DE), (2) social audit (SA), (3) general body meeting in a year (GB), and (4) record keeping (RK). The first is interactive, whereas the next three are independent attributes. That is because distributional equity arises out of the interaction of the operations of the system with technology. So, for computation, three independent measures and one interaction measure are employed.

Their scale values are determined in the following manner:

(i) *Record Keeping (RK)(I)*: Institutional rules of the system stipulate that five key records are maintained in RK. They are: (a) maintenance of log book in pumping stations; (b) minutes book to record the activities and important decisions in the general body and committee

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18 Demand-driven systems taken for analysis in this study are comparatively small and tiny in size. Hence it is not feasible to carryout regular laboratory check of quality of water in each system. As an alternative, the observations and opinion of the beneficiaries using water from their experience, like the colour of cloth turning reddish on washing, salinity, bad smell emanating from water and the like are taken into account.

meetings; (c) membership register showing the members and their details; (d) receipt book to record transactions; and (e) accounts register showing the inflow and outflow of transactions. If all the above five records are not maintained, or maintained but not up to date, then RK is presumed to be poor and assigned the value 1, otherwise 0. Obviously this implies that if  $RK=1$ , then the system is likely to be non-sustainable.

(ii) *General Body Meeting (GB)(I)*: It is a prerequisite that the General body (GB) of the beneficiaries should meet at least once in a year. If no general body meeting has been convened in a year, GB is assigned value 1; otherwise 0.

(iii) *Social Audit (SA)(I)*: Social audit requires annual verification of all the records held by the system by the elected members from among the beneficiaries themselves. Their report is placed before the general body for discussion and approval. If there is no social audit, SA is assigned a value of 1; otherwise 0.

(iv) *Distributional Equity (DE)(I&T)*: Distributional equity (DE) is measured through household surveys. If a minimum of ten percent of the households surveyed in a system report that they did not get adequate quantity of water, such systems are assigned a value of 1; otherwise 0.

The scale values of the attributes are:

- ▶  $RK = 1$ , if record keeping is poor;
- ▶  $= 0$ , otherwise;
- ▶  $GB = 1$ , if no general body meeting has been convened in a year;
- ▶  $= 0$ , otherwise;
- ▶  $SA = 1$ , if there is no social audit;
- ▶  $= 0$ , otherwise;
- ▶  $DE = 1$  if at least ten percent of households do not get adequate water;
- ▶  $= 0$ , otherwise

(4) *Finance (F)*: Full cost recovery is required for sustainability. Nevertheless, this may not be politically feasible since rural water supply in developing countries is considered a ‘merit good’. Therefore the capital required for replenishment and renewal of the system for use by the succeeding generations is assumed to be a social responsibility of government. For that reason, for schemes falling within the purview of our analysis, it is only required that they should collect the cost of operation and maintenance. Hence there is no range of critical values, but only one value for cost recovery (CR). Accordingly

CR = 1 if the revenue is inadequate to meet the operation and maintenance cost,

= 0 otherwise.

(5) *Human behaviour(H)*: Influence of human behaviour on sustainability depends on personal, household and environmental hygiene. Several indicators are required for total capture of this dimension. However the practice of open defecation (OD) is a common and expedient indicator, which captures all the three components. This practice is a source of pollution having an impact on perceived quality of water. This dimension is captured in the scale in the following manner:

OD = 1, if there is the prevalence of open defecation in at least one of the beneficiary households surveyed,

= 0, otherwise.

Having brought the attributes of sustainability within a range of scalable measures, let us examine the appropriate model for measuring vagueness.

### 4.3. Methods of modelling vagueness

The present analysis is confined to models of ‘supervaluationism’ and ‘degree theory’. Though both have merits and demerits in modelling vagueness, the former has not been much used in Economics, while the latter has had only a limited application. The need for prior knowledge

on various dimensions for an attribute to be classified as ‘core’ and ‘non-core’ supplies one plausible reason for not utilizing supervaluationism to model vagueness. This also makes a universal application of the methodology not possible. An advantage of the degree theory is that it does not require a distinction between ‘core’ and ‘non core’ among the attributes. A combination of both these methods is not yet applied in the development context. In the present analysis a combination of both the methods is used. Supervaluationism identifies schemes at the margin of sustainability, but does not provide sufficient information for a policy intervention for arresting the transition process of the scheme towards non-sustainability. Policy intervention requires an understanding of the degree of sustainability and its relative dimensions, including the transition process of the scheme towards non-sustainability. This is only possible by the use of ‘degree theory’. Hence we use it for identifying such systems. This combination methodology is an important tool devised for policy makers to detect and reverse the transition of systems towards non-sustainability. Now, we proceed to examine the details of the methodology employed in this study.

### 4.3.1 Supervaluationism

‘Supervaluationism’ requires the binary classification of attributes into ‘core’ and ‘non core’ categories. To illustrate its applicability, the case of multi-dimensional poverty is availed here first. A dimension is core in the case of multi-dimensional poverty only if it is included in all admissible specifications of poverty index. By this definition, nutrition is a core dimension, since multidimensional poverty cannot be specified without this dimension. If a person is at or below the critical level of nutrition, then such a person is ‘core poor’ even if he/she is non-poor in other dimensions such as education or/and housing.<sup>19</sup> In this context,

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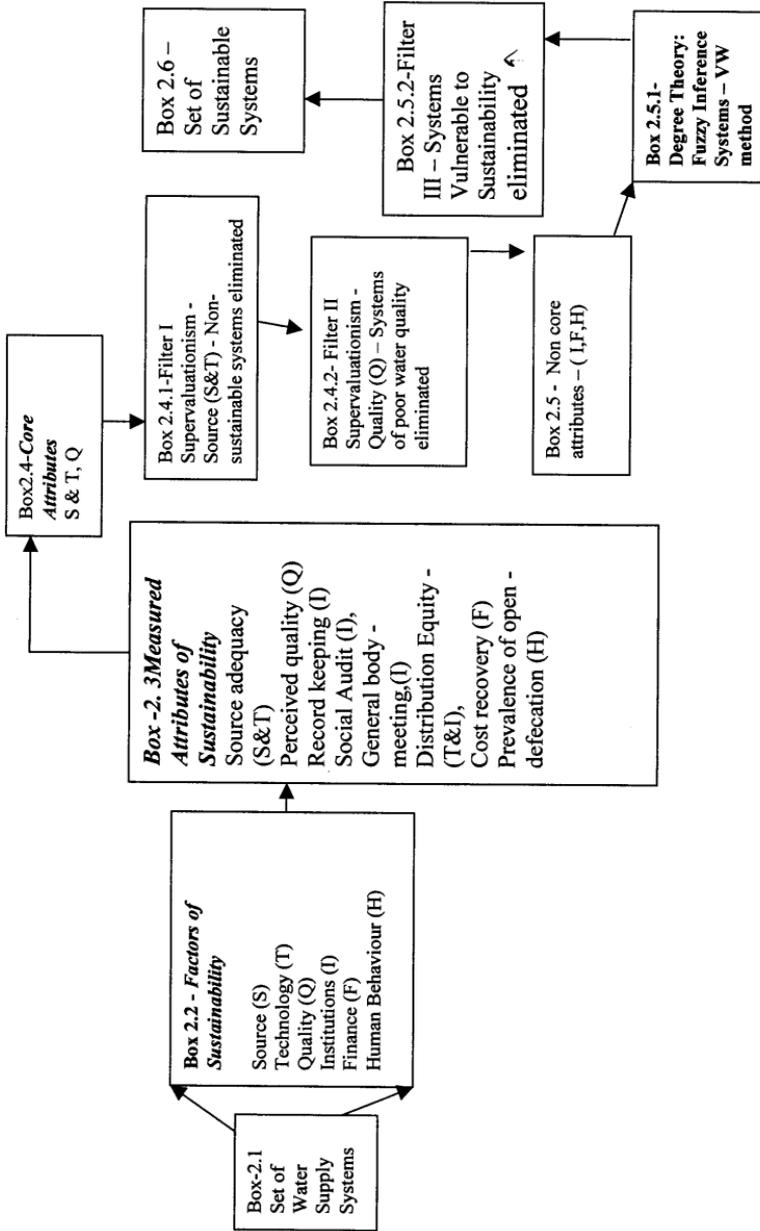
19 Consider the case of three dimensions poverty in nutrition, education and housing. A person is core-poor (nutrition), even if he/she is literate and owns a dwelling place. See Qizilbash (2006: pp. 20-22) for details.

only one dimension (the nutrition level) is essential for classifying a person as poor or non-poor, completely ignoring all other dimensions of poverty. The task for the present analysis is to see whether there are any such core dimensions in the specification of sustainability of drinking water system. Of the eight measured attributes, we detect that two (water source and its quality) are core attributes. If the source is inadequate then the system is non-sustainable irrespective of the nature of sustainability of the other seven dimensions in the specification. Even when the source is adequate, if the quality of water is not of potable standards, then the system is core non-sustainable irrespective of the sustainability of the remaining six attributes. This clearly makes evident that if a system is core non-sustainable, i.e., if the source is inadequate and/or if the water is not potable, then one need not worry about the remaining attributes. The core attributes and its role in the analysis of sustainability of drinking water are given in Box 2.4 in Fig.2.

Now the question is whether these two core attributes function simultaneously or in sequence. Only if the source sustains on a perennial basis would the need for analysing the next attribute - quality - arises. Therefore source has to be analyzed first, followed by quality in a sequential way, as both are important for the existence of the system. Since the method needs to be applied in sequence, we call it as 'sequential supervaluationism' (SS). If quantity of water supplied is found to be inadequate or sources are drying up either partly or fully, the beneficiaries may become reluctant to pay the user fees and to participate in the management of the system. To be more specific, the SS methodology is necessitated because priority of adequacy of source over quality of water of potable standard is inherent for the issue of sustainability.

Application of supervaluationism results in the classification of the systems into three categories, on the basis of the range of critical values of all the dimensions in the specification. They are (i) 'core non-

Figure 2. Operational version of Basic Framework



sustainable systems<sup>20</sup> (ii) 'sustainable systems' and (iii) 'marginal systems' (systems falling on the margins of sustainability). Sustainable systems are those systems at or above the upper limit of all eight admissible dimensions. The systems that are at or below the lower limit of critical values of core dimensions belong to the 'core non-sustainable' group. The residual systems are on the margins of sustainability, which we call as marginal systems<sup>21</sup>. In other words they are system on transition to either core non-sustainable or sustainable. It may be noted that the marginal systems gradually move towards either sustainable group or core non-sustainable group. From the policy perspective our interest is more towards systems that fall at or below the lower limit on non-core attributes so that immediate policy intervention can reverse the process. Now the challenging task is how to identify the marginal systems that require immediate policy intervention for reversing the process. One way of identification of the group is the use of fuzzy inference system in 'degree theory'.

#### **4.3. 2. Fuzzy inference system**

Fuzzy inference system has been used in three ways to model vagueness. First is the totally fuzzy and absolute approach of Cerioli and Zani; Second is the totally fuzzy and relative approach by Chelli and Lemmi; and the third is the approach suggested by Vero and Werquin<sup>22</sup>. Among the three approaches, the present analysis applies the third suggested by Vero and Werquin (VW) in view of the fact that it is the only method that avoids "...excessive importance being assigned to correlated indicators and redundant variables."<sup>23</sup>

Two stages are involved in the estimation of VW model. In the first stage, an indicator 'f<sub>i</sub>' (frequency) is calculated. In the second stage, two-step estimation is used for transforming 'f<sub>i</sub>' to the membership

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20 Super true according to Fine, See Qizilbash (2001, 2006).

21 See Qizilbash (2001, 2006) for more details.

22 See for details Deutsch and Silber (2006) p.156.

23 See Vero (2006) p.218.

function (the details of which is given later in eq. (1) and eq. (2). The membership function provides an estimate of the degree of sustainability among the marginal systems. Before we undertake a detailed analysis of such an estimation technique, the methodology is illustrated in the case of three attributes (RK, DE and CR) and six systems to have a better understanding while one proceed further.

Let 'K' (=3) be the number of attributes and 'n' (=6) be the number of systems and 'fi' (i=1,2,...6) proportion of systems that are at least as sustainable as system 'i' considering all the indicators and systems. The three attributes considered are record keeping (RK), distributional equity (DE) and cost recovery (CR). It may be noted that a value of 1 for an attribute denotes that the value is at or below the lower limit of that attribute and '0' otherwise. For example: if RK=1, then the system follows a very poor record keeping that eventually leads to a non-sustainable situation. If RK= 0, then record keeping is perfect, there is every chance that the system will be sustainable in that dimension. Coming to the second dimension i.e. DE =1, if inequity exists in the distribution and 0 for perfect equity. CR =1 if revenue is insufficient for meeting O&M expenditures, other wise '0'. Obviously '1' indicates non-sustainability in that dimension, and '0' sustainability.

**Table 3. Illustration of the Computation of 'fi' and Membership Function**

Systems	RK	DE	CR	fi	ms(i)
1	0	1	0	4/6	0.23
2	1	1	1	1/6	1
3	0	1	0	4/6	0.23
4	0	0	0	6/6	0
5	0	1	1	2/6	0.61
6	1	0	1	2/6	0.61

Source: Primary survey, Note: RK = Record Keeping, DE = Distributional Equity, CR = Cost Recovery, fi = indicator frequency, ms(i) = first level membership function.

Let us consider the extreme cases of the systems first. For system 2, the values of all attributes are 1. This confirms that the system is at or underneath the lower limit in all attributes. This system is on the bottom line. So no other system can be classified to fall below this; however, there can be systems at par. This would mean that this is a system in the worst position, hence cannot have any other system below this. There is no other member among the systems, which are at par or below that of system 2. System 2 is deprived in all dimensions (RK, DE, and CR). So it has the highest possibility of becoming non-sustainable. Hence the proportion of systems as sustainable as  $f_2$  is  $1/6$ , so that it has the highest value in the membership function. This is a relative frequency of the attributes, which obviously should have the lowest weight.

Consider the case of system 4, which is the other extreme of system 2. Here, the values of all attributes considered are satisfied. All other systems are either at par or below system 4. The relative frequency of the system is  $6/6$ , which has the lowest value in the membership function.

There are intermediary cases falling between the two extremes cited. Consider the case of system 1. This system is sustainable on two of the attributes (RK and CR), but not on DE. In order to compute 'fi', one has to work out the number of systems that are according to all the indicators, at most, in the same position as system 1. This implies that while computing 'fi', systems that are found to be non-sustainable on other attributes will also be considered. Systems at par are first counted. That is to say, one has to count number of systems with the same elements in the vector. There is one more system with same value i.e. system 3. After this one has to look for cases of lower dimensions in the first and third elements and their combinations. There are two cases (0,1,1) and (1,1,1) i.e., system 2 and system 5. Thus there are 4 systems that are at par or below of system 1, accordingly 'fi' is  $4/6$ . Similarly (fi) can be calculated for all the remaining three systems. Having obtained the frequencies (fi), we use a two-step procedure for the computation of

membership function. The first level membership function for sustainability,  $m_s(i)$ , is measured using the formula given in equation (1) below.

$$m_s(i) \approx \frac{\ln(1/f_i)}{\sum_{i=1}^n \ln(1/f_i)} \dots \dots \dots (1)$$

*if*  $0 < f_i \leq 1$

There is always at least one system that has exactly the same level of sustainability as system 'i', i.e. system 'i' itself. Therefore, 'fi' can never take value '0'. It should also be noted that a higher value of 'fi' is given a lower weight and vice versa in the membership function. The second level measure,  $\mu_s(i)$ , is estimated using equation (2).

$$\mu_s(i) \approx \frac{m_s(i) - \text{Min}[m_s(i)]}{\text{Max}[m_s(i)] - \text{Min}[m_s(i)]} \dots \dots \dots (2)$$

In Eqn (2),  $\mu_s(i)$  is defined as the ratio of the difference between one's own value of  $m_s(i)$  and its minimum to the difference between the minimum and maximum of  $m_s(i)$ ,  $i = 1, \dots, n$ . This is made clearer by looking at the membership value calculated for our example given above. The range of degrees of membership values varies from 0 to 1. A system, which has a truth-value of 1 is non-sustainable. At the other end if a system has a truth-value equal to 0, it is sustainable in all dimensions. System 2 in the example is non-sustainable since it has a truth-value 1 in the membership function. By definition system 4 gets '0' in the membership function implying that it is sustainable in all dimensions. By this logic any system nearing 0 is becoming sustainable. On the contrary, systems approaching 1 is in transition to non-sustainability. Thus systems, 1 and 3, are close to 0 and hence satisfying most of the dimensions. Whereas systems, 5 and 6, are close to membership value 1 and hence are having a higher degree of non-sustainability. It is necessary

to have a demarcation between the non-sustainable and sustainable systems. Average value of  $m_s(i)$  is taken as the line of sustainability, which in our example is 0.44. This means that systems with membership value 0.44 or above are in transition towards non-sustainability of varying degrees. This would connote that approximately three schemes whose membership value is close to 1 are non-sustainable. The remaining schemes are sustainable. By this criterion, systems 1, 3 and 4 are sustainable and systems 2, 5 and 6 are non-sustainable.

Now we generalise the above empirical model in the next section<sup>24</sup>.

## V

### 5.1 The Empirical Results

In this section sequential supervaluationism method is applied to identify core non-sustainable and marginal systems.<sup>25</sup> Marginal systems are subjected to analysis of Vero and Werquin fuzzy inference (VW) method, in order to identify the sensitivity of institutions to sustainability. Both the groups were then examined for the influence of their regional dimension, coastal and non-coastal. Finally an attempt is also made to relate the effects of gender, education and income to the sustainability of systems.

#### 5.1.1. Sequential Supervaluationism

We filter the systems that do not provide steady water supply due to source inadequacy, and follow it by filtering for quality of water. The result of filtering the entire sample first for sustainability of source (Box 2.4.1, Fig.2) is reported in the first row of Table 4. The estimate shows

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24 The frequency table is calculated using a computer programme.

25 Strictly speaking the systems that are above the upper limit of all attributes should be eliminated from the marginal systems since they are by definition sustainable. Such a group cannot be identified in our data set due to lack of sufficient data.

that 6.1% of the systems are core non-sustainable (source). The remaining 169 schemes are then filtered for core II, (Box 2. 4.2, Fig. 2) i.e. quality sustainability. Analysis shows that 60 of them (33.3%) are core non-sustainable. Application of sequential supervaluationism facilitates identification of 71 systems as core non-sustainable, the regional distribution of which is given in Table 5.

**Table 4. Distribution of sustainable and non-sustainable systems by sequential supervaluationist method**

Sequence/ Method	Core attributes	No of systems		Total
		Sustainable	Non- Sustainable	
I	Source	169 (93.9)	11 (6.1)	180 (100)
II	Quality	109 (67.7)	60 (33.3)	169 (100)
Total	--	109 (60.6)	71 (39.4)	180 (100)

Source: Same as in Table 2. Note: Figures in parenthesis are percentages.

Among the 71 schemes identified to be non-sustainable, 21 - almost 30% - are in the coastal regions. It is clear from Table 4 that source and quality related sustainability are lower in the coastal regions. The higher incidence of non-sustainability in the non-coastal region can be attributed to the differing hydro geological conditions.

**Table 5: Distribution of non-sustainable systems by core attributes and by region**

Core attribute	Non-sustainable systems		
	Coastal	Non-Coastal	Total
Source	3(27.2)	8(72.8)	11(100)
Quality	18(30.0)	42(70.0)	60(100)
Total	21(29.5)	50(70.5)	71(100)

Source: Same as in Table 2. Note: Figures in parenthesis are percentages.

The remaining 109 schemes by definition belong to the marginal group, which are in transition to, or already in, non-sustainable status (Box 2.5, Fig.2). From the policy point of view, this group needs to be prioritised so that public intervention can reverse the transition process. The identification depends crucially on a methodology, which enables such detection. As mentioned earlier, this is possible through the use of fuzzy inference system in the degree theory. Such systems are identified, applying the two-step membership function outlined above to the 109 marginal systems (Box 2.5.1 and 2.5.2, Fig.2). The results, with its regional distribution, are reported in Table 6.

Table 6 shows that 31.2% of systems (i.e., 34 out of 109 systems) in the marginal group are likely to descend to the category of non-sustainability. This would indicate that they are prone to have problems on organizational, institutional and financial aspects, which may lead to non-sustainability in the long run. Disaggregate analysis shows that 17 marginal systems in the coastal areas (38%) are non-sustainable. However in 17 marginal systems (27%) in the non-coastal region are non-sustainable. So relative deficiency is higher in the coastal regions. This signifies that public policy should be reoriented to strengthen the institutions that enhance coverage in coastal areas. It also indicates that the present institutional set up for providing rural water supply through public provision requires a through restructuring in order to create sustainable water systems.

**Table 6: Distribution of non-sustainable marginal systems by region - fuzzy inference system - VW method**

	Non-sustainable systems		
	Coastal	Non coastal	Total
(a) Non-sustainable systems	17	17	34
(b) Total marginal systems	45	64	109
a / b (%)	37.7	26.5	31.2

Source: Same as Table 2

In this analysis only the demand-driven systems are considered. Such households opting for demand-driven systems are likely to be better endowed with resources, since a part of the capital cost is borne by the beneficiaries. Even such better-endowed households in the coastal region are able to obtain only a poor service. In that case, the service for the rest is likely to be much worse. Therefore specific targeting and public policy intervention is required to make complete coverage in the coastal region, as envisaged in the millennium development goal. The socio-economic dimensions that affect sustainability have not been considered for analysis so far, because it is very challenging to establish a firm relationship between these variables and sustainability. Nonetheless, we select a few socio-economic variables and attempt to relate them to the degrees of sustainability.

## **5.2. Socio-economic Factors and Sustainability**

Among the many socio-economic factors that affect sustainability, we examine here only gender participation, female education and income levels of households. The percentage of females who got elected to the executive committee of the respective beneficiary groups of the systems is used as a proxy to measure gender participation. Systems that do not contain at least 33% females in the executive committee are classified as having low gender participation. Although female education is examined at all levels for its impact on sustainability, only in the case of education up to primary level has any effect on sustainability across regions. Three indicators were considered from the survey for testing the effect of income levels of households on sustainability. They are: occupation of the households, nature of housing and land possessed by the household. When all the 180 systems are considered, all the three indicators do not show any systematic relationship. However, when the 109 marginally sustainable systems alone are considered, a systematic relationship emerges for the regions and across degrees of sustainability. The results are reported in Table 7. It is interesting to note that higher the gender

participation, higher is the degree of sustainability in all the regions. This relationship is stronger in the coastal belt. The degree of sustainability and female education are positively related in both coastal and non-coastal regions. The difference is sharp in the non-coastal region, which might be due to cultural taboos. Among the indicators of the level of income, average land possessed per household has a positive relationship with sustainability, that is to say, higher the land possessed higher the degree of sustainability.

**Table 7: Gender, Education, and Land Ownership in marginal systems (%)**

Region	Nature of Systems	Gender Participation Below 33%	Average Land Owned	Female education
Coastal	Sustainable	18.2	15.4	7.9
	Non-sustainable	38.2	10.5	4.7
Non Coastal	Sustainable	24.7	43.1	13.6
	Non-sustainable	29.9	35.1	7.7

Source: Primary survey

## VI

### Summary and conclusions

The socio-economic and demographic aspects of fishermen community in the coastal belt of Kerala state stand in contrast with the rest of the population in the state. Poverty is found to be rampant and is almost three to four times that of the state's average. The widely acclaimed favourable sex ratio of the state (surplus females) does not hold well in respect of coastal villages. Missing females are more in the age group 15 to 24, compared with the rest of the population in the state, indicating their age-specific vulnerability in the life-cycle.

Dynamics of coverage of rural water supply has been examined within the framework of sustainable development. A scrutiny of the

framework reveals that the concept is multidimensional, and yet is vague in nature. Consequently, empirical application requires a specification of measurable attributes and a technique for modelling vagueness. World Bank documents suggest that specification of sustainability of water supply systems should include attributes such as source, technology, finance, institution and human behaviour. The multidimensional specification is operationalised for a sample of 180 demand-driven rural water supply systems from Malappuram, a predominantly coastal district in Kerala. A sample of 10% households was selected from the beneficiaries of the above systems for measuring attributes and for gathering information on quality. The six measured attributes out of eight are: (1) adequacy of supply from source, (2) quality, (3) cost recovery for operation and maintenance and three indicators of institutions (4) record keeping, (5) annual general body meeting and (6) social audit. The seventh and eighth indicators are (7) distributional equity (interaction of source and technology and (8) practice of open defecation (human behaviour) respectively. These specifications are used for modelling vagueness using 'supervaluationism' and 'degree theory'.

For the application of 'supervaluationism', identification of 'core' attributes is required. They are identified as adequacy of water supply and perceived quality of water. Since source is of first priority of any sustainable system, it is analysed first. If the system is sustainable in source adequacy, then quality attribute becomes relevant for sustainability. Therefore the analysis becomes sequential supervaluationism in nature. The first stage of 'supervaluationism' shows that 11 systems out of 180 are source non-sustainable. These were excluded from the subsequent analysis. Applying quality as the second core to the 169 systems 60 more systems are found to be non-sustainable. The remaining 109 systems are at the margins of sustainability. Marginal systems are in various stages of sustainability, some are non-sustainable, some are nearing non-sustainability and some are sustainable. The identification of these different degrees of non-sustainability is important for timely policy

intervention for reversing the transition process. The classification is achieved through the application of fuzzy inference system - VW method - in degree theory. The estimated membership function shows that about 34 of the 109 systems (31%) are non-sustainable.

To sum up, the major findings of the regional (coastal and non coastal) analyses are:

- (i) Core non-sustainability (source and quality) is more in the non-coastal region;
- (ii) Non-sustainability among the marginal systems is more in the coastal belt;
- (iii) Socio-economic and gender dimensions indicate that (a) higher the gender representation in the governance of the system higher is the chance of sustainability, particularly in the coastal region; (b) higher the female primary education higher the chance for sustainability; (c) higher the income (land owned) higher the sustainability.

To conclude, the study provides evidence for holding that the institutional factors are just as important as technical factors - source and quality - for the successful working of a sustainable demand-driven rural water supply system. This indeed provides a benchmark for analysing the observed phenomenon of the regress in rural water supply in India - popularly known as falling back, from 'covered to uncovered villages'!

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