On the measurement of sustainability of rural water supply in India: A Supervaluationist–Degree Theory approach

Kesavan, Pushpangadan and Gangadhara, Murugan

Centre for Development Studies, Prasanth Nagar, Ulloor, Trivandrum, Kerala, India

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K. Pushpangadan and G. Murugan
Centre for Development Studies
Trivandrum, India
E-mail: pushpangadan@cds.ac.in

ABSTRACT

The paper proposes an empirical methodology for understanding the nature and behavior of Sustainable Development as a vague and multidimensional concept by a case study of participatory and demand determined Rural Drinking water Supply systems in India. It combines for the first time, two of the most influential models – 'Supervaluationism' and 'Degree Theory'- on the measurement of 'Vagueness', for timely public intervention in reversing the process of Un-sustainability. Analysis clearly brings out the role of institutional, financial and environmental factors that should be part of Public Policy, for ensuring sustainability of potable water supply.

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K. Pushpangadan and G. Murugan
Centre for Development Studies
Trivandrum, India
E-mail: pushpangadan@cds.ac.in;
gangadharamurugan@gmail.com

Introduction

Provision of drinking water to the entire rural population in India is facing a serious challenge due to the inability of existing schemes sustain its supply. This phenomenon known as 'falling back' of covered habitations/villages with drinking water to uncovered ones has been observed for the last two decades[1]. As a result, a major part of investment in rural water supply becomes sunk in nature on a continuing basis. No serious attempt has been made so far to assess the magnitude of this social loss. This is the first objective of the paper. The other major concern of sector specialists and policy makers is the lack of any theoretical framework to analyse the 'falling back' occurrence and its empirical evaluation for policy decisions[2]. The second objective is, therefore, to develop an analytical framework and evolve an empirical methodology for policy formulation. It may be emphasized that all objectives are exploratory in nature in the theory and measurement of sustainable development in rural water supply as is demonstrated in the present paper.

According to the definition of sustainability by the Brundtland Commission Report (1987) and by Solow (1993, 2000), the essence of sustainable development is steady flow of resources from an asset without any reduction from one generation to the other. Obviously, re-emergence of habitations/villages as uncovered in water supply violates the condition of sustainability, the steady flow of resources even during its

[1] Habitation/village is the smallest unit of human settlement used for defining drinking water availability in rural India. A habitation/village is covered, according to government of India norm, with potable water if 40 *lpcd* (liter per capita per day) is provided within a distance of 1.6 Km in the plains and 100 meter in hilly regions.

[2] For such concerns in the water sector, see Biswas and Totojada (ed.) (2006).

lifetime of schemes. Viewed from this angle, one can analyze the falling back event within the framework of sustainable development.

In this context, it may be noted that the concept of sustainable development has been in the rhetoric for nearly a quarter of a century without much empirical content. It is virtually an 'empty box' empirically except in sector-specific analysis of Fisheries and Forestry. Water resource professionals even consider 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"[3]. In this context two aspects of measurement of sustainability are of particular interest to policy makers, sector specialists and development professionals. To the sector specialists and planners, 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'[4]. 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 to non-sustainability. Such an exercise provides a basis for timely public and institutional intervention to reverse the process of 'falling back'.

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 from among the several existing ones. A cursory look at the existing definitions indicate that it is complex and multi-dimensional in nature and spread over diverse disciplines such as Hydro-geology, Public health engineering, Environmental science, Sociology, Economics and Management[5]. This leads us to the second issue, i.e., the identification of the multidimensional nature of sustainability and its measurement. Having identified the empirical measures of attributes that contribute negatively or positively to sustainability, the last issue (third) is the choice of quantitative tool for discriminating the systems as sustainable/non-sustainable one. Since the concept is 'vague', as convincingly argued by Solow (2000), the tool should be capable of

[3] Biswas (2006): p.76.
[4] Tortajada (2006): p.15.
[5] See Bredtland (1987), Worldbank (2000), Solow (2000) and Asian Development Bank (2006), among others.

modeling 'vagueness'[6]. Recent advances in the modeling of 'vagueness' identify three methods: (i) Epistemic method; (ii) Supervaluationism; and (iii) Degree theory[7]. According to Qizilbash (2001, 2006), Epistemic view treats the dimension within the 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 competent to model vagueness. There is no superiority of one over the other since both of them have advantages and disadvantages. Since Degree theory and Supervaluationism have rough borderlines, our approach for the present study is decided after choosing the admissible dimensions in the specification of sustainability.

The outline of the paper is as follows. Section 2 deals with the quantification of the 'falling back' of drinking water and the money value of social loss across states and union territories. Next section, III, summarizes the basic framework used for the analysis. Section IV provides the operational version of the basic frame work including the specification of multidimensional sustainability and models of vagueness in demand-driven rural water supply. The fifth section reports the results based on the operational model and the Socio economic determinants of sustainability. Finally, the last section concludes with implication on public policy.

II

Estimation of falling back of coverage and social loss

In order to estimate the social loss, one needs the magnitude of 'falling back' in coverage and the cost of providing it. On the coverage there are two sources of information; one published by the Department of Drinking Water Supply (DDWS), Government of India; and the other by National Sample Survey Organization (NSSO). Data published in the web page of DDWS do not have uniformity in collection and its reliability is unknown. Moreover it is based on potential supply from capacity created and, hence, does not reflect actual coverage. In the case of National Sample Survey Organization, information

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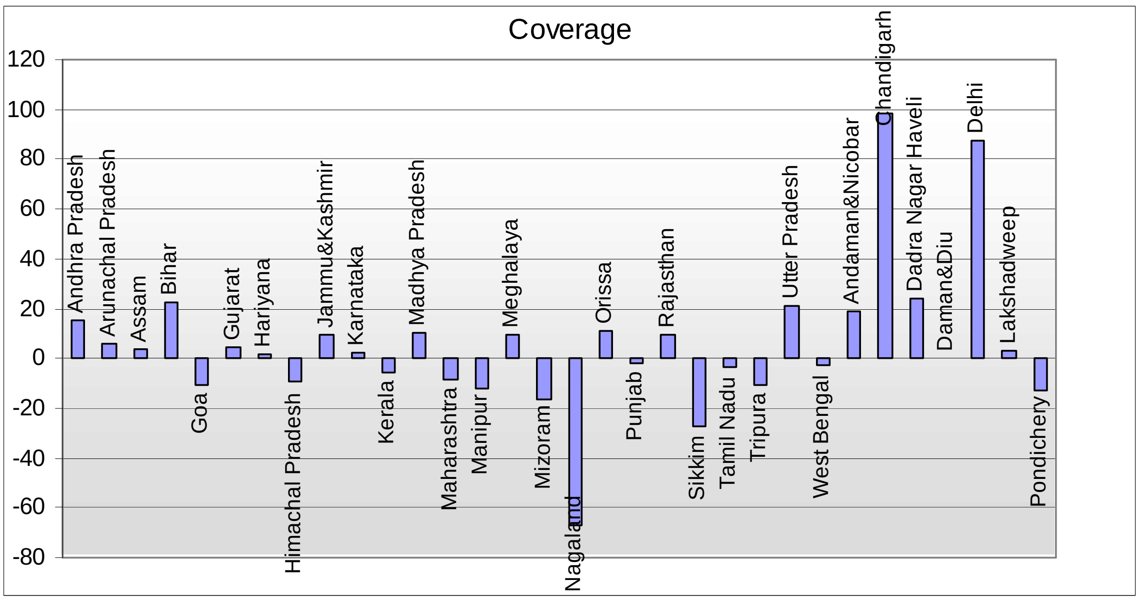
[6] See Hopwood et. al. (2005) for a survey on various definitions on Sustainability

[7] Qizilbash (2001, 2006)

obtained is based on a scientific methodology and implemented uniformly across all states by an independent organization. Moreover it is based on the actual consumption[8]. Therefore we have opted for NSSO surveys in 1993 and 2002 for the coverage estimation.

Figure 1. Change in Coverage of Rural Water Supply by States, 2002 and 1993



Source: NSSO (1993, 2002)

The percentage of population covered with potable water shows a declining trend during the period, 1993-2002, for 12 states and 1 union territory as indicated by Figure 1. The magnitude of this reverse process – popularly known as "falling back" - is the highest in Nagaland followed by Sikkim, Mizoram, Pondicherry and the least in Punjab. It should be noted that this lower coverage during the period is taking place at a time when there is investment to the tune of millions of rupees in the state and central Government. This has to be converted to value terms in order to assess the social loss.

To assess the social cost of falling back, estimate of affected population and the cost of per capita coverage are required. Preliminary investigations show that such data are not readily available. The affected population due to falling back is estimated from the percentage of covered population available in 1993 and 2002 NSSO surveys in the

[8] See for further details, Pushpangadan et. al.(1996)

following way. The 1993 and 2002 rural population is obtained by projecting the Census figures in 1991 and 2001. Applying the ratio of coverage of NSSO to the projected population figures for the respective years, the covered populations have been obtained. The difference between the two covered populations shows the loss/gain in coverage of drinking water during the period (Table 1). The negative coverage of population in Table 1 does not tally with the negative change in coverage from NSSO reports of Fig.1. Loss of coverage is valid in all states except that of West Bengal, Punjab and Tamil Nadu. This might be due to the difference in the population estimated or could also be that the life of many systems might have expired during the decade. The loss estimated need to be converted to value terms by appropriate per capita cost for each state. This information is not readily available and hence the per capita cost of Kerala in 2007 is used for evaluation. The value of social loss for the states and Union Territories are reported in Table 1.

Table 1: Social loss from falling back of coverage by states, 1993 -2002

States/Union Territories	Change in population Coverage (in 000's)	Social Loss (In 2007Prices,in Rs. millions)
Andhra Pradesh	11906	
Arunachal Pradesh	111	
Assam	2033	
Bihar	19196	
Goa	-23	80.5
Gujarat	3529	
Hariyana	1217	
Himachal Pradesh	-168	586.8
Jammu&Kashmir	1210	
Karnataka	2983	
Kerala	-933	3265.8
Madhya Pradesh	5440	
Maharashtra	-1437	5029.0
Manipur	-147	514.5

Meghalaya	255	
Mizoram	-71	247.5
Nagaland	-1557	5448.0
Orissa	4966	
Punjab	1024	
Rajasthan	7052	
Sikkim	-124	432.7
Tamil Nadu	1152	
Tripura	-159	556.5
Utter Pradesh	37453	
West Bengal	2602	
Andaman&Nicobar	61	
Chandigarh	117	
Dadra Nagar Haveli	59	
Daman&Diu	9	
Delhi	740	
Lakshadweep	2	
Pondicherry	-14	50.5
Total		16211.8
Source: NSSO (1993, 2002) and Census (1991, 2001)		

If the population in the Table 1 is positive it implies an increase in coverage and a negative sign denotes the decrease (falling back). Social loss occurs only where the coverage declines. This is evaluated for states with decline in coverage. The total loss is of the order of 16212 Million Indian Rupees (231.60 Million Pounds). In order to cover the population again the cost will be more or less of the same order and hence the total social loss would be double (Rs. 32424 Million) the cost estimated. [9] Social loss is seen to be highest in Nagaland followed by Maharashtra and the least in Pondicherry. This amount is very substantial indeed for a developing country. An understanding of the

[9] Strictly speaking the opportunity cost of this capital should also be added to arrive at the total social loss of falling back.

factors contributing to the falling back problem is required for preventing such social waste in the future. Such an attempt is taken up in the next section.

From the growth literature, this problem belongs to the sustainability of an asset since the yield is not steady during the life of the asset. Therefore a theoretical foundation can be evolved from sustainable development literature. This is being attempted in the following sections.

III

Theoretical Background

In this section, we formulate the basic framework of our analysis emerging from the complex nature of sustainable development and its measurement as a vague predicate.

3.1 Sustainability: definition, nature and concept

There exist several definitions on sustainability. An important landmark in this direction is the one in Brundtland Commission Report (BCR, 1987). According to BCR, "...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 operationalisation of this concept in water supply is contained in the project appraisal document of the World Bank (2000) and the evaluation report of the Asian Development Bank (2006). According to the Bank documents "Sustainability implies that the system works through out its life and beyond, and is able to generate adequate cash flow for future expansion/renewal." This definition will be followed with some modifications in the present analysis**.** The next issue is to deal with the imprecise nature of the concept. This aspect is best stated by Solow (2000). To quote him,[10] "--- 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.

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[10] See Solow (2000); p.132

3.1.1 The Vagueness of Sustainability

In the literature, three distinguishing features have characterized vagueness though not mutually exclusive[11]. The *first* one is that they 'allow' for borderline cases. In the present case of drinking water, this means that whether a system is sustainable or non-sustainable is difficult to judge. The *second* characteristic is that a sharp boundary between cases cannot be drawn. This condition is also applicable to water supply sector since it is incapable to draw a specific clear cut demarcating line between cases that are sustainable and non sustainable. The *third* is that it is susceptible to '*sorites paradox*'[12] or *paradox of the heap*. Obviously this condition is very well applicable in the measurements of sustainability also. In order to demonstrate that sustainability satisfies *sorites paradox*, consider the case of an aquifer where there exists sufficient quantity of ground water to be made use of by the community for both drinking and irrigation purposes. The community as well as the farmers continuously draws water from the aquifer over and above its recharge level. Such continuous extraction ultimately reaches a stage where the aquifer dries up, wells becoming non sustainable. After certain level, the graduality principle applies and the sustainable system becomes non-sustainable. Therefore it satisfies the third criterion, 'sorites paradox'. Sustainability satisfies all the three features of vague predicate. It may also be noted that all the three conditions are related but not independent. Now we are in a position to depict the basic framework of analysis.

3.2. The Basic Theoretical Framework

Having been identified the concept as a vague predicate; the basic framework for the analysis is summarized in Figure 2.

The first box, 2.1 in Figure 2 contains set of all water supply systems in the region and the last box, 2.4, provides the subset of sustainable systems after eliminating the non-

[11] Qizilbash (2001, 2006)

[12] 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).

sustainable systems using the methods broadly outlined in boxes 2.2 and 2.3 Let us elaborate these boxes. Box 2.2 provides the complexity and the broad areas to which multidimensional nature of the concept belongs. A review of literature, particularly 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 (2.2) points out the broad dimensions for any specification of the concept. Such specifications should include attributes from: (1) Source; (2) Technology; (3) Quality; (4) Institution; (5) Finance; and (6) Human Behaviour. The broad dimensions of sustainability are discussed below.

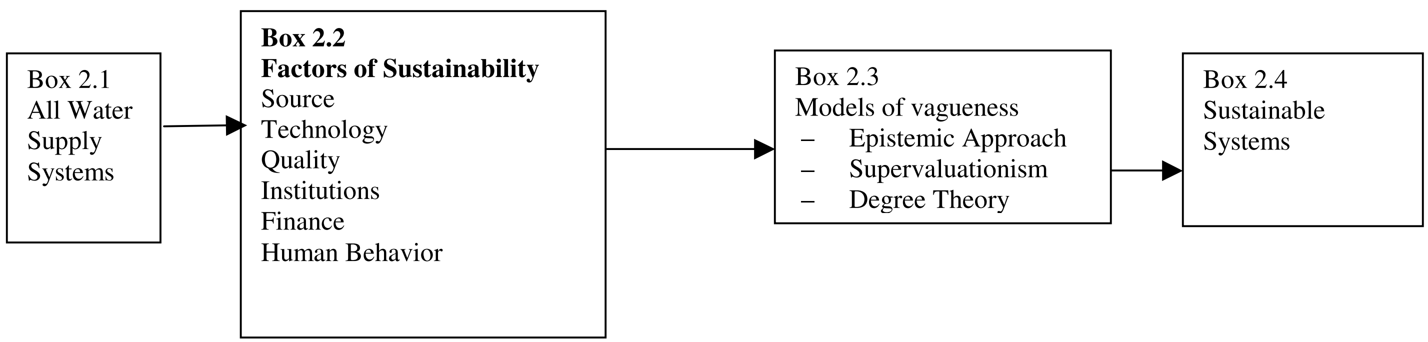
Source: Source refers to a natural water source - surface or sub-surface - from which water is extracted, treated and distributed to the needy community. It may be noted a perennial water source is a prerequisite for sustainability of a system.

Technology: By technology we mean the devices used to extract water from source, process and deliver 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 its interaction with other factors such as water source, quality etc.

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. Water extracted from the source should be amenable for treatment to attain potable standards before delivery. The second one is that even if the quality is good on delivery point the users should also perceive that quality is good. If both dimensions are not met then the system is non sustainable.

Figure 2

Basic Theoretical Framework for Sustainability Analysis



Institution: 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 formulation of rules and regulation 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.

Finance: Sustainability in terms of finance implies that the system generates adequate cash flow for future expansion or renewal. If such adequate cash flow cannot be generated the system cannot sustain.

Human Behaviour: The last pre requisite for sustainability is appropriate Human behaviour. This constitutes personal, domestic and environmental hygiene and awareness, among others.

The next task is to identify the quantitative tool for measuring sustainability as a 'vague predicate'. This requires methods that model 'vagueness'. As indicated in Box 2.3 in Fig.2, 'vagueness' can be modeled in three ways: (i) epistemic approach; (ii) supervaluationism; and (iii) degree theory[13]. The epistemic method treats, vagueness in the classical tradition, only true or false. 'Vagueness' arises because of the ignorance about the border lines. The chief weakness of epistemic approach is "that they assume that it is lack of knowledge which gives rise to vagueness"[14]. The method, does not address two of the three characteristics of a vague concept mentioned above and hence not considered for the present analysis.

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 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 is definitely non sustainable. In the case of core attribute, it is 'core non-sustainable' *(core-*

[13] See Qizilbash (2001, 2006); Martinetti (2006a)
[14] Qizilbash (2001, 2006)

ns). Similarly systems that fall above the highest critical level in all dimensions are sustainable. Systems that are neither core-ns nor sustainable belong to the 'margins of sustainability'. Hereafter such systems are grouped as marginal systems.

Degree theory drops classical logic, and assumes more than two truth-values, which comes in degrees. There are many forms of degree theory. The one, which is applied in economics, is the Fuzzy set approach that quantifies the degree of truth in borderline cases. More specifically it measures the degree of truth on the [0, 1] interval with 0 measuring falsehood and 1 indicating truth.

The framework for measurement of vagueness in the present analysis is conditional upon the operational version of the framework, which is taken up next.

IV

The Operational Version of Basic Framework

The major concern in this section is the methodology of data collection and the measurement of attributes/dimensions in the specification. It also contains empirical model of the basic framework, which combines supervaluationism and degree theory.

4.1 Data and methodology

Two most common rural water supply systems in Kerala are (i) publicly owned systems and (ii) collectively owned demand driven systems. Unlike publicly owned systems, demand based systems has complete participation of users at all levels of decision making including operation and maintenance and collection of revenue. As a result, the system satisfies all dimensions of sustainability as envisaged in the basic frame work in Fig.2. Therefore the selection of samples is restricted to demand based systems alone.

4.1.1. Sample:

Demand-driven systems, a recent phenomenon in the state, started in 1999 assisted by World bank in the provision of Rural drinking water on an experimental basis. Initially 4 districts[15] (Trichur, Palakkad, Malappuram and Kozhikode) were selected in the state for implementing the project[16].

[15] District is the third tier of administrative unit in India.
[16] See www.jalanidhi.com for details.

Samples were selected from all the four experimental districts. Selection of samples involved two stages. In the first stage, systems were selected at random from the total systems in the district. The second stage of sampling was the selection of beneficiary households from the list maintained by the beneficiary committee[17] of each system. The number of households per system varies from 20 to 75. Sample size was limited to 10% of beneficiary households with a minimum of 3 from each system and selected at random using circular systematic approach. It may be noted that there is only one Beneficiary Group (BG) for every system in the sample except one mega system in Malappuram. Since the system is intended to serve a large area and number of households several BGs have been formed for administering distribution of water equitably and for collection of revenue. Accordingly the mega system has 69 BGs with an apex body for inter BG co-ordination. The details of the samples are given in Table 2.

Table 2. Sample Systems and Households by District

District	No of systems	No of Households
Trichur	143	867
Palakkad	250	1045
Malappuram	179	1175
Kozhikode	217	1031
Total	789	4118

Source: Kerala Rural Water Supply and Sanitation Agency

A combination of the following approaches was used for the collection of data. Participatory Rural Appraisal Techniques were used to identify various dimensions of sustainability and its measurement. Such information was then incorporated into 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 required.

[17] Beneficiary committee is the democratically elected representatives from the beneficiaries to administer maintain and operate the water supply system.

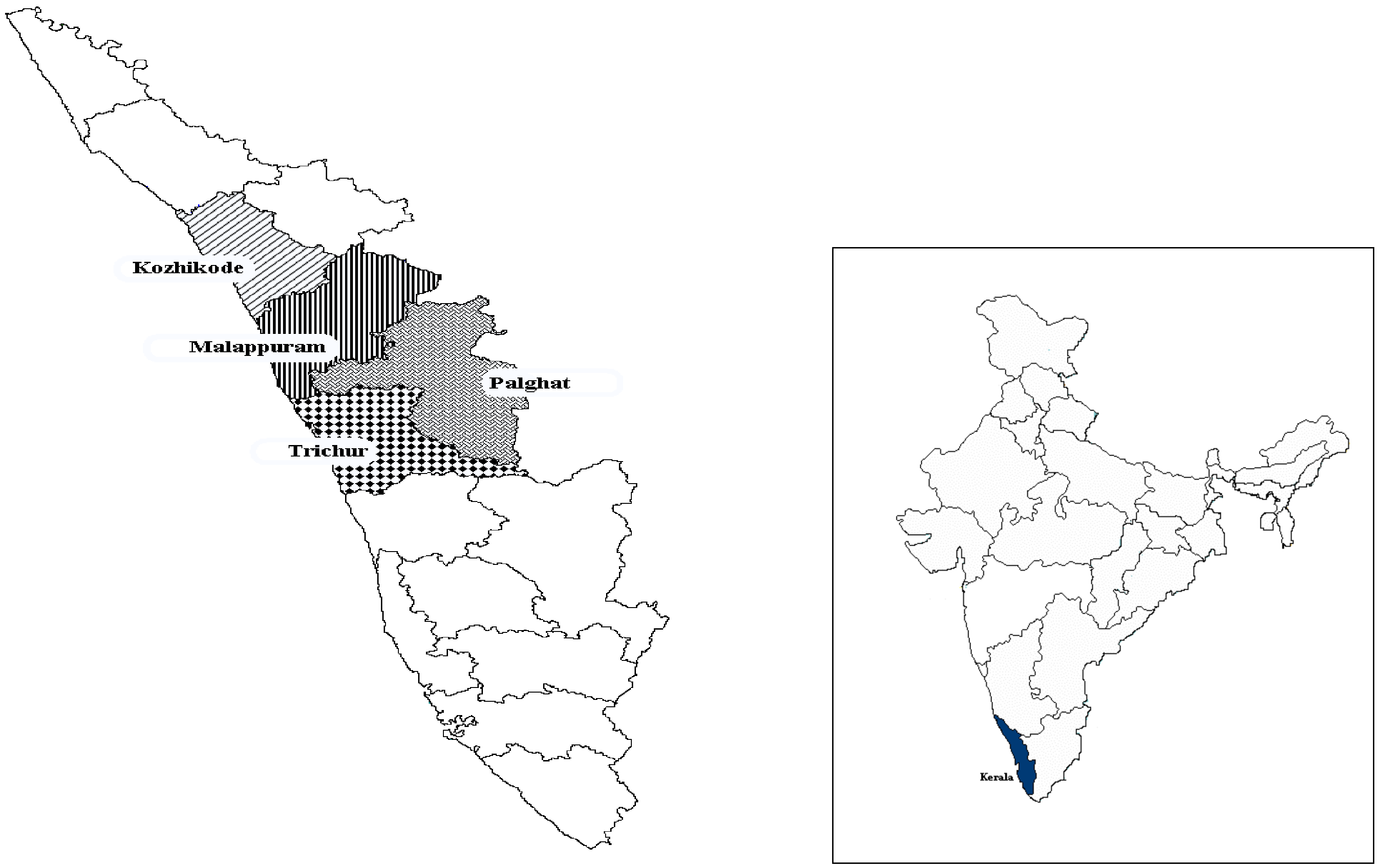


Figure 3. Location Map of Districts

4.2 Measurement of Attributes

Here the task is to define the specific attributes from the broad dimensions in Box 4.2, Figure 4. The measurable dimensions are given in Box 4.3, Figure 4. It may be noted that eight attributes were selected that influence sustainability on a priori grounds. These were then sharpened empirically as discussed below.

(i) Source adequacy (S&T): Source adequacy is taken as an attribute of 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.

(ii) 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 if supply is assured. The same is true if the perceived quality is also 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. In other words, the upper limit is that quality is perceived to be good by all households.[18]. Therefore, the lower limit of the attribute is the existence of quality problem if 10 % households perceive quality problems.

Quality = 1 if at least 10 % of the households perceive poor quality

= 0 otherwise

(iii) Institutions: One interaction measure and three independent measures were considered for measurement. They are (1) Record keeping (RK), (2) Social audit (SA), (3) General body meeting in a year (GB), and (4) Distributional equity (DE). Of these,

[18] Demand driven systems taken for analysis are comparatively small and tiny in size. Hence it may not be possible for each system to carryout regular laboratory check. An alternative to is the observations and opinion of the beneficiaries using water from experience, like cloth get reddish colour on washing, salinity, bad smell etc.

distributional equity is the interaction of the operations of the system with the technology. Theses attributes were sharpened in the following way.

Institutional rule of the system stipulates that RK has five key records. It involves: (i) maintenance of log book in pumping stations; (ii) minutes book to record the activities and important decisions in the general body and committee meetings; (iii) membership register showing the members and their details; (iv) receipt book to record transactions; and (v) 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 poor and assigned the value 1, otherwise 0. Obviously this implies the possibility of non sustainability of the system. It is a prerequisite that the General body (GB) of the beneficiaries should meet at least once in a year. GB is assigned value 1 if no general body meeting has been convened in year; otherwise 0. Social audit implies 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 1; otherwise 0. Distributional equity (DE) is measured through household surveys. If at least ten percent of the households surveyed in a system report that they don't get adequate quantity of water such systems are assigned '1', otherwise '0'. The sharpening of the attributes is:

(1) RK = 1, if record keeping is poor,
= 0, otherwise;
(2)GB = 1, if no general body meeting have been convened in a year,
= 0, otherwise;
(3) SA = 1, if there is no social audit,
= 0, otherwise;
(4) DE = 1 if at least ten percent of households do not get adequate water
= 0, otherwise

(iv) Finance: Full cost recovery is required for sustainability, which may not be politically feasible considering the merit good nature of the commodity - rural water supply - in developing countries. Therefore the capital required for replenishment and renewal of the system for the next generation is assumed to be a social responsibility of Government. Schemes under analysis; it is only required to collect the cost of operation and maintenance, hence there is no range of critical values but there is only one value for cost recovery (CR). Accordingly

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

= 0 otherwise.

(v) Human behaviour: Influence of human behaviour on sustainability depends on personal, household and environmental hygiene. Several indicators are required for capturing this dimension. However a common indicator which captures the three components is the practice of open defecation (OD). It also has impact on quality of water owing to source pollution and perceived nature of quality. This dimension is sharpened according to the following way. If, there is the prevalence of open defecation in at least one of the beneficiary households surveyed. Then,

OD = 1, if open defecation is prevalent in at least one household surveyed,

= 0, otherwise.

Having sharpened all the attributes of sustainability, let us examine the appropriate model for measuring vagueness.

4.3. Methods of Modeling Vagueness

As mentioned earlier the present analysis confines to models of supervaluationism and Degree theory. Even though Supervaluationism and degree theory have both merits and demerits in modeling vagueness, the former has not been much used in Economics, while the latter had limited application[19]. One plausible reason for not using supervaluationism is the need for prior knowledge on various dimensions; to be classified as 'core' and 'non-core'. Hence a universal application of the methodology is not possible. In this case, degree theory has an advantage since it does not require a distinction between 'core' and 'non core' among the attributes. A combined use of the methods is not yet applied in the development context. In the present analysis both the methods are used for the following reasons. Supervaluationism identifies schemes at the margin of sustainability but do not provide sufficient information for a policy intervention for arresting the transition process towards non sustainability. Policy intervention requires an understanding of the degree of sustainability and its relative

[19] Quizilbash (2001)

dimensions. This is only possible by the use of 'degree theory' and hence we use it for identifying such systems. Such a methodology is an important tool for policy makers, to detect and reverse the transition of systems towards non sustainability. Now, let us examine the details of the combined methodology of supervaluationism and degree theory.

4.3.1 Supervaluationism

Supervaluationism as mentioned earlier requires the classification of attributes into core and non core categories. This dual classification of dimensions is illustrated clearly in the case of multi-dimensional poverty before it is applied to sustainability. A dimension is defined to be core if it is included in all admissible specifications of poverty. By this definition nutrition is a core dimension, without which multi dimensional poverty cannot be specified. 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[20] in other dimensions in the specification say, education, housing, etc. In this context, only one dimension (the nutrition level) is needed for classifying a person as poor or non poor. The task for the present analysis is to see whether there are any core dimensions in the specification of sustainability of drinking water system. Of the eight measured attributes, two of them (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 remaining seven dimensions in the specification. The second core is the quality of water. If 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 brings out the point that, if a system is core non-sustainable, then one does not worry about the remaining attributes. The core attributes and its role in the analysis of sustainability of drinking water are given in Box 4.4 in Fig.4.

Two 'core' attributes source of water (S&T) and its Quality (Q), as is evident from Box 4.4 in Figure 4 exist in water supply. Now the question is whether they function simultaneously or in sequence. Only if the source sustains on a perennial basis the next attribute, quality arises. Therefore source has to be analyzed first followed by

[20] Consider the case of three dimension 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.

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). To be more specific the SS methodology is necessitated because quality of water of potable standards arises only if source has adequate quantity to be distributed among the beneficiaries.

Supervaluationism classifies 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 sustainable systems[21] (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 margins of sustainability, which we call as marginal systems[22]. In other words they are neither core non-sustainable nor sustainable. It may be noted that the marginal systems gradually fall either to sustainable group or to core non sustainable. 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.

There are three methods in fuzzy inference system that can be used for the present analysis. They are (i) Totally fuzzy and absolute approach of Cerioli and Zani; (ii) Totally fuzzy and relative approach by Chelli and Lemmi; and (iii) the approach suggested by Vero and Werquin.[23] Among them Vero-Werquin (VW) approach is the only method that avoids "….excessive importance being assigned to correlated indicators and redundant variables." [24]

In the estimation of VW model, two stages are involved. In the first stage an indicator 'f_i' (frequency) is calculated. In the second stage, a two step estimation is used

[21] Super true according to Fine See Qizilbash (2001, 2006).
[22] See Qizilbash (2001, 2006) for more details.
[23] See for details Deutsch and Silber (2006) p.156.
[24] See Vero (2006) p.218.

involving the transformation of 'f_i' to the membership 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 and six systems.

Let 'K' (=3) be the number of attributes and 'n' (=6) be the number of systems and 'f_i' (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 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=1then the system follows a very poor record keeping that eventually leads to a non sustainable situation. If RK= 0 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 sustainabe and 0 sustainable in that dimension.

Illustration of the Computation of 'f_i' and Membership Function					
Systems	RK	DE	CR	f_i	$m_s(i)$
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

Consider cases of extreme systems first. System 2, where values of all attributes are 1, shows that they are at or below the lower limit of all attributes. Since this is on the bottom line no other system can be classified to be below; though there can have systems at par. This would mean that this is a system in the worst position, hence cannot have any one else below this. As there is no other member in the system at par or below that of system 2 since it is deprived in all dimensions (RK, DE, and CR) and has the highest chance of becoming a non sustainable one. Hence the proportion of systems as sustainable as f2 is 1/6, implying a very high chance of transition to non sustainability. Consider again the case of system 4, the other extreme of system 2. Here since the values of all attributes considered are satisfied and all other systems are either at par or below system 4 the relative frequency is 6/6, the lowest chance of transition to non sustainability. There are cases intermediary to the two extremes cited. Consider the case of system 1. This system is sustainable on two of the attributes (RK and CR) but does not so in DE. In order to compute 'f1', one has to consider number of systems that are, at most, in the same position as system 1 according to all the indicators. This implies that systems that are found to be non sustainable on other attributes along with DE will also be considered, while computing 'f1'. Systems at par are first counted. That is to say, one has to count number of systems with same elements in the vector. There is one more system with same value i.e. system3. Now 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 'f1' is 4/6. Similarly fi can be calculated for all the remaining three systems.

Having obtained the frequencies (f_i), we use a two step procedure for the computation of membership function. The first level membership function for sustainability is measured using the formula given in equation (1) below.

$$m_S(i) \approx \frac{\ln(1/fi)}{\sum_{i=1}^{n} \ln(1/fi)} \text{..........} \qquad \text{...}(1)$$

$$if \quad 0 < fi \leq 1$$

There is always at least one system that has exactly the same level of sustainability as system 'i', i.e. system 'i' itself. Therefore, 'f_i' 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 is estimated using equation (2).

$$\mu_S(i) \approx \frac{m_S(i) - Min[m_S(i)]}{Max[m_S(i)] - Min[m_S(i)]} \text{.......... ..(2)}$$

In Eqn (2), $\mu_s(i)$ is defined as the ratio of the difference between one's own value of $m_s(i)$ and the minimum in the range to the difference between the minimum and maximum of $m_s(i)$. This is made clearer by looking at the membership value calculated for our example given above. The range of degrees of membership 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 value equal to 0 is sustainable in all dimensions. System 2 in the example is non sustainable since it has 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 sustainablility. 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 μ_s (i) is taken as the line of sustainability, which is 0.44 in our example. This means that systems with membership value 0.44 or above are in transition towards non sustainability of varying degrees. This would mean that approximately three schemes whose membership value close to 1 are non sustainable. The remaining is sustainable. By this criteria systems 2, 5 and 6 are non sustainable and systems 1, 3 and 4 are sustainable.

Now we generalize the above empirical model to a large number of systems and attributes.[25]

[25] The frequency table is calculated using a computer program

V
Empirical analysis

In this section empirical application of the sequential supervaluationism is applied to 789 samples for the classification of the systems into core-non sustainable and marginal systems. The marginal systems were then analyzed for the estimation of degree of truth using VW method of fuzzy inference. The marginal systems are then examined for establishing the relation between socio-economic factors and sustainability.

5.1 Supervaluationism - Results

In the sequential supervaluationism as shown in Fig.4 -filter 1 and 2 is applied to 789 samples by taking source as the first core. The results are shown in Table 3.

Table 3. Core - Non-Sustainable Systems by District (Core : Source)

District	No of systems		
	Sustainable	Non Sustainable	Total
Trichur	128 (90)	15 (10)	143 (100)
Palakkad	230 (92)	20 (8)	250 (100)
Malappuram	168 (93.9)	11 (6.1)	179 (100)
Kozhikode	184 (84.7)	33 (15.3)	217 (100)
Total	710 (90)	79 (10)	789 (100)

Source: Primary survey. Note: numbers in parenthesis are percentages

On an average 10% (79) of the systems are core non-sustainable in source: the highest in Kozhikode (15.3%) and the least in Malappuram (8%). Reasons for such inter district variation could be the hydro-geological conditions in the districts, which require further probing. Now let us examine the core-sustainability of the remaining 710 (789-79) systems taking quality of water as the second core. The results are summarized in
Table 4.

Table 4. Core – Non Sustainable Systems by District (Core : Quality)			
District	No of systems		
	Sustainable	Non Sustainable	Total
Trichur	69(54)	59(46)	128(100)
Palakkad	159 (69)	71 (31)	230 (100)
Malappuram	108 (67.7)	60 (33.3)	168 (100)
Kozhikode	128(69.4)	56(30.6)	184(100)
Total	464(65.35)	246 (34.65)	710 (100)

Source: Primary survey. Note: numbers in parenthesis are percentages

Average core non sustainability due to quality is 35% (246) of 710 systems considered. Quality problem is found to be severe in Trichur district, but more or less the same among the remaining three districts. Our findings based on the perceptions of the households are also supported by other scientific analysis undertaken recently by the scientists of Indian Institute of Science and water quality monitoring carried out in the open wells in the state by the Socio Economic Unit Foundation. Reasons for non sustainability in quality vary from place to place. Observations from the field show that in some of the locations it is because of nature itself (hydro-geological conditions etc.) where as it is man made in certain others (Agricultural and industrial pollution). Reasons for variations in quality can be assessed only through detailed laboratory check followed by investigation on the perceptions among the households.

From the supervaluationist analysis it is evident that almost 41% of the systems in the state are found to be non sustainable by core attributes, source and quality. Further it varies from 36.4% in Palakkad to 52% in Trichur. Non sustainability of systems ranging from 1/3rd to half due to the two core factors, alone requires an immediate policy intervention for correction.

According to supervaluationist theory the remaining 464 systems are either 'super sustainable' or in the 'margins of sustainability'[26]. In order to identify the 'super sustainable'[27] systems one needs to have upper limits for all core and non core factors. However one of the non core factors, 'cost recovery', allows only for recovery of operation and maintenance cost. An upper limit of this dimension should include a recovery component on capital cost of the project, for intergenerational equity. As major portion of the capital cost is subsidized by the state and the tariff system does not envisage any recovery of capital cost, super true category cannot be identified. Hence we assume that the remaining systems belong to the margins of sustainability and are treated as marginal systems.

From the policy point of view this group needs to be prioritized so that public intervention can reverse the process. Policy intervention depends crucially on a methodology, which enables such identification. As mentioned earlier this is possible through Fuzzy inference system (VW method) in the degree theory.

5.2 Fuzzy Inference System - Results

In this analysis our effort is to locate the systems with higher possibility of falling back to non sustainability. This has to be estimated from the 453 marginal systems identified earlier[28]. As mentioned above systems that are in transition are identified by applying the two step membership function outlined above and the results are given in Table 6.

Table 6 shows that a little more than one third of the marginal systems are in transition to non sustainable status. Percentage of systems below the line of sustainability is maximum in Trichur and minimum in Palakkad. This would mean that all together 151 systems require immediate public intervention for correcting the 'reversing' process in the 'non core' attributes. This suggests that public policy should be reoriented in order to strengthen the institutions that limit the 'reversing' process. The above findings point to the need for a restructuring of the present institutional set up of providing rural water supply system through public provision for sustainable drinking water supply.

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[26] Marginal system=Total system -Core non sustainable systems by source and quality.

[27] Each of the core attributes do have a lower and upper limits within which Super sustainable are systems whose values attribute all above upper limit of all attributes.

[28] Though 464 systems are in the marginal category only 453 have been found suitable for analysis.

Table 5: Distribution of non sustainable systems by districts				
District	Total Number of marginal systems	Average member ship value	Marginal Systems	
			Non sustainable	Sustainable
Trichur	64*	39.3	25	39
Palakkad	153*	29.1	44	109
Malappuram	108	31.2	34	74
Kozhikode	128	37.2	48	80
Total	453	34.2	151	302
Source: Computed from primary survey * excludes systems in public institutions				

Source: Same as Table 4

On an average 34% of the marginal systems have a higher possibility of falling back to the non sustainability. The maximum that are likely to fall under the unsustainable category is in Trichur and minimum in Palakkad. However this process can be reversed if suitable public policy intervention is made specifically targeting to this group.

Other socio-economic dimensions that may influence sustainability have not been considered because it is very difficult to hypothesize a direct relationship of these variables to sustainability. This shortcoming is resolved by cross tabulating such variables with sustainable/non-sustainable group as discussed below.

5.3. Socio-economic Factors and Sustainability

Among the socio-economic factors that affect sustainability, we examine gender participation, female education and income levels of households. Gender participation is measured through the presence of females elected in the executive committee of the respective beneficiary group. Although female education is examined at all levels, only primary education shows any systematic relationship with sustainability. The third important variable considered is the income of households. Although several proxies exist, land possessed by the household is used. The results are reported in Table 7.

Table 6: Socio-economic factors and Sustainability by Districts				
Distrct	Nature of Systems	Total number of Marginal Systems	No Gender Participation	Female education
Trichur	Sustainable	39	24.4	1.6
	Non sustainable	25	34.8	4.4
Palakkad	Sustainable	109	15.5	2.3
	Non Sustainable	44	27.9	6.2
Malappuram	Sustainable	74	14.7	10.8
	Non Sustainable	34	26.4	6.2
Kozhikode	Sustainable	80	7.3	2.7
	Non Sustainable	48	12.8	1.1

Source: Same as Table 5

It is interesting to note that higher the gender participation higher the degree of sustainability in all the districts. In the case of female education, the degree of sustainability and education are positively related only in Trichur and Palakkad but not in Malappuram and Kozhikode. For income, average land possessed per household does not show any systematic relationship and hence not reported[29]. However, firm conclusions require further multi level statistical analysis.

VI
Summary and Conclusions

Falling back of covered habitations/villages to uncover has been observed in rural water supply for the last two and a half decades. This has far reaching consequences both for the community as well as to the government. As regards the community the beneficiaries of such systems are forced to draw water from non-potable sources thereby affecting their health and livelihood. The second is the loss of resources to the exchequer and social loss. However, only the latter has been examined in this study. The former could not be

[29] However the income proxy is found to have a positive relationship with sustainability in the case of coastal and non coastal regions. See Pushpangadan and Murugan, (2007) for details.

addressed due to unavailability of data. The estimated loss for the period 1993 - 2002 is estimated to be 32422 Million Indian Rupee. This resource waste can be avoided if it is analyzed in the framework of Sustainable Development. Sustainable development literature shows that it is a concept in multidimensional and vague in nature. This is operationalised using the multidimensional specification implied in World Bank documents and supervaluationism and degree theory models of measuring vagueness for a sample of 789 demand driven participatory rural water supply systems in rural Kerala.

For the application of 'supervaluationism', 'core' attributes have to be identified. They are adequacy of water supply (source) and perceived quality of water. Since source is of first priority of any sustainable system, it is taken up first. If the system is sustainable in source then quality attribute becomes the second core for measurement of sustainability. Therefore the analysis becomes 'sequential supervaluationism' in nature. The first core analysis shows that about 10% of 789 systems are non sustainable in source, highest in Kozhikode and the least in Malappuram. The remaining sustainable systems in core 1, is further analysed for core 2 i.e. quality. The results show that 35% of 710 systems are found to be core non sustainable in quality, the highest in Palakkad and the lowest in Kozhikode. Sequantial supervaluationism suggests that about 41% of the systems are non sustainable in core attributes (source and quality). It varies from 36.4% in Palakkad to 52% in Trichur. According to supervaluationist theory the remaining 464 systems are either super sustainable or in the margins of sustainability. However lack of information limits the estimation of super sustainable systems. Hence all the 464 systems are treated as systems belonging to margins of sustainability for policy prescriptions. But for the estimation data limitations restrict the number to 453.

For policy purposes one needs to identify systems in the marginal group for immediate intervention. This group for immediate policy intervention is obtained by applying fuzzy inference system (VW method) in degree theory. Fuzzy inference analysis shows that 151 schemes are in transition towards non-sustainability. This is highest in Trichur and lowest in Palakkad.

A preliminary investigation of relating other socio-economic variables to sustainability indirectly indicates that gender has an important role in the sustainability of systems and female education a partial role. Income of the households does not show any systematic relation ship to sustainability, which may be due to the survival nature of the commodity for life.

The study clearly shows the immediate intervention of policy makers by introducing institutional innovations and appropriate governance structure.

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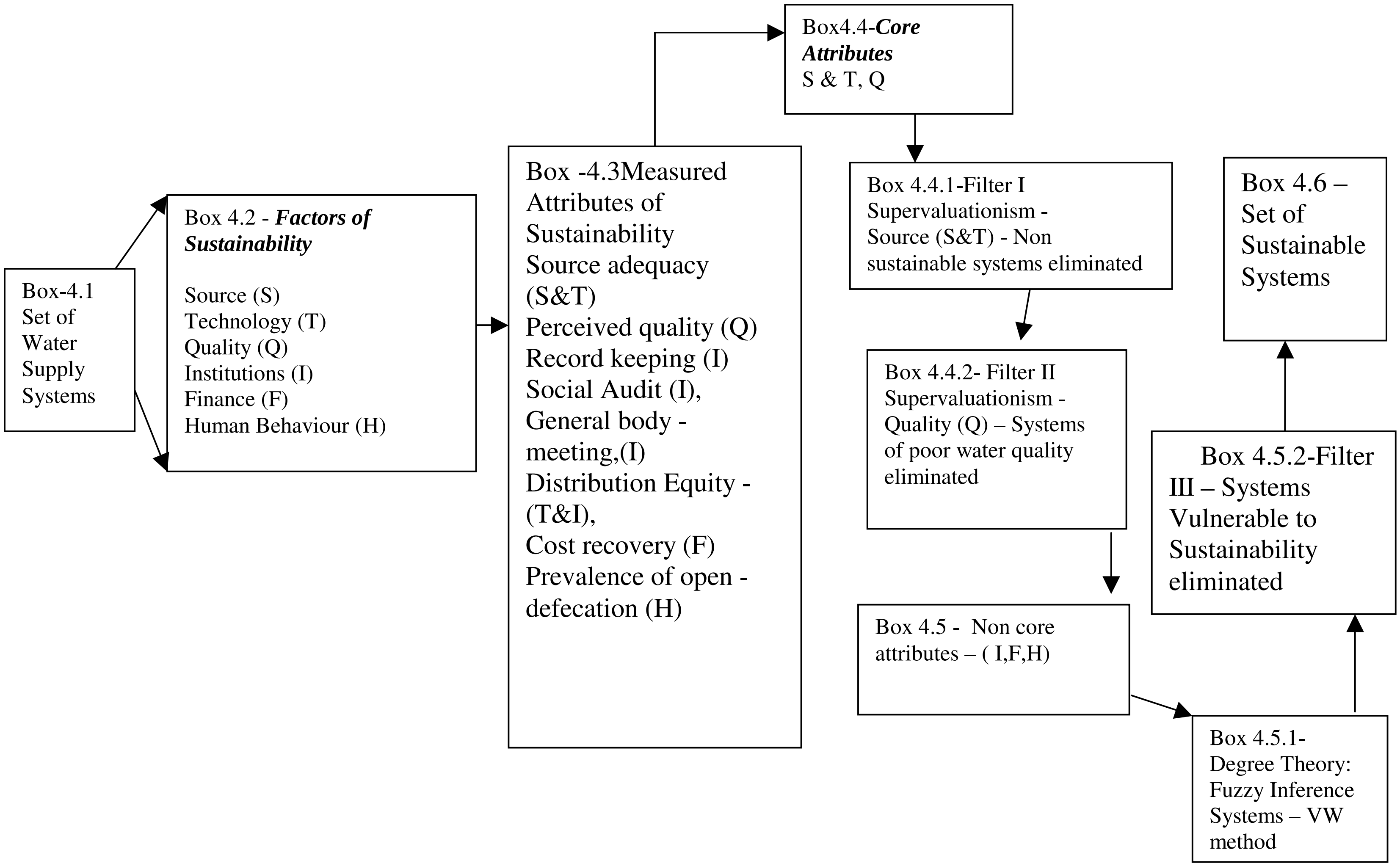
Figure 4. *Operational version of Basic Framework*



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