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ASSESSMENT OF GROUNDWATER QUALITY FOR IRRIGATION PURPOSE IN VELLORE DISTRICT, TAMIL NADU, INDIA: A SPATIAL APPROACH USING GIS

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Abstract

The quality of groundwater always plays a major role in the regions where the agriculture activities depend directly on them. With this point, the study area - Vellore District has been chosen to assess its groundwater quality for agriculture purpose. For this investigation, eighty-two observation wells have been considered and the groundwater quality data for the period from 1989-2007 have been procured from the Water Resources Organisation, Public Works Department, Chennai. The field samples are collected from the same locations for analysis during the year 2008. The major cations and anions with few general parameters are processed and considered for the analysis. With these results, various mathematical formulas and diagrams such as USSL's diagram, Wilcox's diagram, Doneen's classification, Residual Sodium Carbonate method, Kelley's ratio, Magnesium Ratio, Non-Carbonate Hardness method etc. are employed to identify the exact status of groundwater quality in the study area. Further, the diagrams and results obtained through many ratios and indices are converted into spatial outputs using Geographic Information System (GIS) concepts, particularly ArcGIS software. At last, the groundwater quality in post-monsoon season is concluded as better quality than pre-monsoon season's in most of the locations. The suitable quality of groundwater for irrigation purpose is identified in Jolarpet, Natrampalli, Pernambattu, Gudiyatham, Katpadi, Arcot, Kaveripakkam and Sholinghur blocks. The unsuitable quality of groundwater is found in Kandhili, Jolarpet, Tiruppathur, Alangayam, Madhanur, K.V.Kuppam and Vellore blocks.

Keywords: Groundwater quality, GIS, Pre-monsoon, Post-monsoon, Vellore District

Introduction

The quality of groundwater plays an important role in promoting agricultural production. The overexploitation of groundwater has destructively affected the groundwater in terms of its quality and quantity standards. In India, many large towns and new megacities derive a major component of their domestic, irrigation and industrial water supply from groundwater, both from municipal well fields and from large numbers of private boreholes (Raju *et al*., 2009). Besides this, the groundwater accounts for about 88% of safe drinking water in rural areas, where the population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist. Groundwater also plays an important role in agriculture, for both watering of crops and for irrigation of dry season crops. It is estimated that about 45% of irrigation water requirement is met from groundwater sources (Jain *et al*., 2010). In recent years, the dependence on groundwater has increased tremendously in many parts of India, especially in the arid and semi-arid regions, due to the scarcity of surface water and the erratic action of monsoon.

Generally, groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and subsurface geochemical processes (Twarakavi and Kaluarachchi, 2006). Through rapid increase in population and growth of industrialisation, groundwater quality is being increasingly vulnerable to contamination by agricultural chemicals and disposal of urban and industrial wastes. The evaluation of groundwater suitability for different purposes needs the basic understanding about chemical composition of groundwater. Further, it is possible to understand the change in quality due to rock-water interaction (weathering) or any type of anthropogenic influence (Kelley, 1940; Todd, 1980). By keeping all these facts in mind, an attempt has been made to examine the quality of groundwater for irrigation purpose in the selected area. However, various water quality diagrams, indices and methods are used to evaluate the current status of groundwater quality for irrigation purpose during pre- and post-monsoon seasons.

Vellore District is the area chosen for this study, located between 12°15' - 13°15' N latitudes and 78°20' - 79°50' E longitudes. The areal extent of the District is 6,077 sq.km; however, hills and reserved forests alone occupies 2,000 sq.km of area in the total study area and the remaining 4,077 sq.km of area falls under plain region, which is considered to investigate the groundwater quality parameters for irrigation purpose (Figure 1).

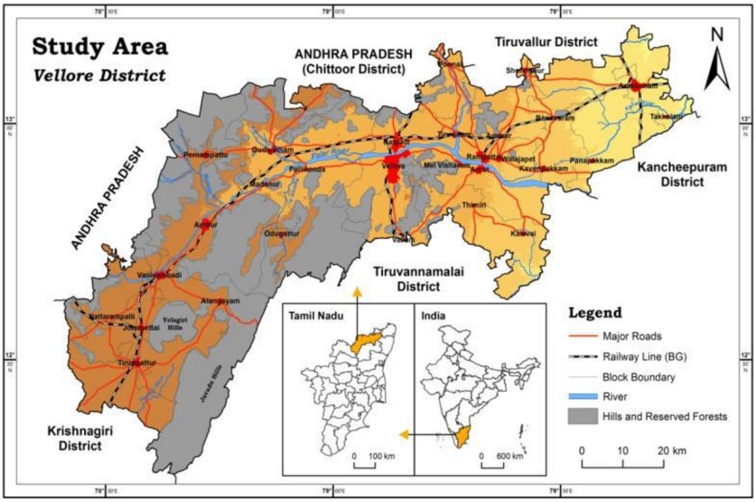

Fig. 1. Study Area - Vellore District

Data and Methodology

Eighty-two observation wells, uniformly distributed throughout the study area, have been considered for investigation (Figure 2). The groundwater quality data for the present study is extracted from the historic and field collection sources. The seasonal groundwater quality data (pre-monsoon and post-monsoon) is procured from Water Resources Organisation, Public Works Department, Chennai for the period of 19 years from 1989 to 2007 and seasonal groundwater samples are collected for one year (2008). These samples are further analysed to understand the exact and dynamic status of groundwater quality in the present environment. The data related to the concentrations of general parameters (pH, electrical conductivity), major cations (calcium, magnesium, sodium and potassium) and major anions (bicarbonate, carbonate, sulphate, chloride and nitrate) are considered for the present study. From these data (both pre- and post-monsoon seasons), the average values are estimated for the period of twenty years (1989-2008).

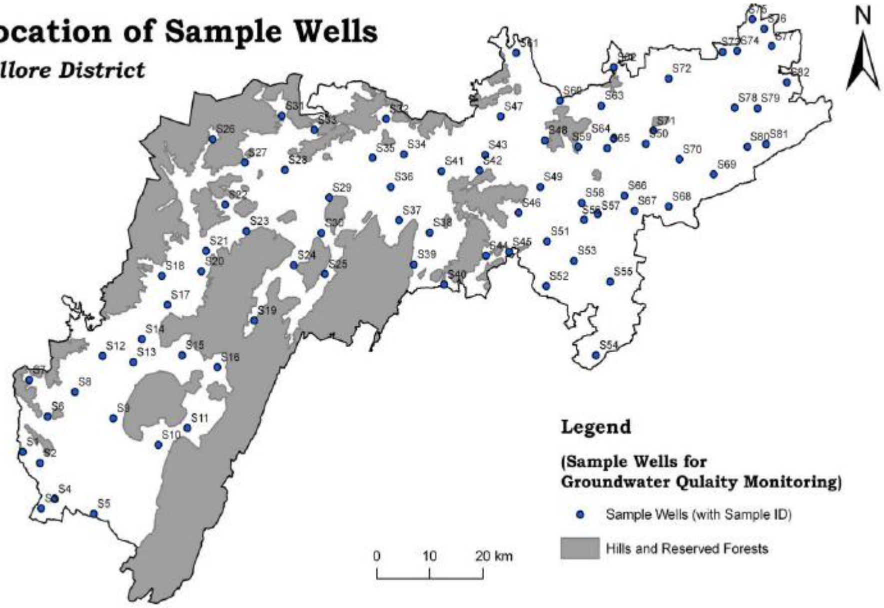

Fig. 2. Location of Sample Wells

A number of methods are applied frequently for evaluating chemical characteristics of groundwater. These characteristics are represented in diagrammatic forms after estimating the results using mathematical formulas, from which the interpretations are made. They are US Salinity Laboratory's (USSL's) diagram, Wilcox's diagram, Doneen's classification, Residual Sodium Carbonate (RSC) method, Kelley's ratio, Magnesium Ratio (MR), Non-Carbonate Hardness (NCH) method etc. The ionic concentrations of all parameters are expressed in epm (equivalents per million).

By adopting the US Salinity Laboratory's (USSL, 1954) method, the irrigation water is classified into various saline-alkaline classes. Sodium concentration is very important in classifying the irrigation waters because, by the process of base exchange, the sodium replaces calcium in the soil there by reducing the permeability of soil, which has greater effect on the plant growth. Sodium Adsorption Ratio (SAR): Excess sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability (Kelley, 1951). Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation (Nagaraju *et al*., 2006). The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the ratio called Sodium Adsorption Ratio (USSL, 1954). It is an important parameter for the determination of suitability of irrigation water because it is responsible for sodium hazard (Todd, 1980). The following formula is used to derive SAR,

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+} + Mg^{2+} / 2)}}$$

There is a significant relationship between Sodium Adsorption Ratio (SAR) for irrigation water and the extent to which sodium is absorbed by the soil. The SAR ratio is plotted on arithmetic scale against specific conductance (EC) on a log scale and different classes of water have been marked on the diagram. From this plot, water can be classified for irrigation purpose (Chachadi and Mahapatra, 1982).

Wilcox diagram has been manually constructed by using percent sodium (%Na) and total concentrations of all ions in epm. Sodium content in groundwater chemical analyses is reported as percent sodium (% Na), which is defined as

$$\%Na = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \times 100$$

Doneen has classified the irrigation water based on Permeability Index (PI) against total soluble cation. The PI can be calculated using the following formula.

$$PI = \frac{Na^{+} + \sqrt{(HCO_3^{-})}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100$$

Karanth (1987) has stated that the precipitation of calcium and magnesium increases the percentage of sodium in the groundwater. This effect is appreciably quite more when the carbonate and bicarbonate ions are in excess of calcium and magnesium and forms sodium carbonate, which affects the soil structure. This process is called Residual Sodium Carbonate (RSC) and this can be calculated using the following formula.

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Kelley's Ratio method is used to classify the water for irrigation. Sodium measured against calcium and magnesium is considered by Kelley (1940) and Paliwal (1967) to calculate this parameter.

$$Kelley's\ Ratio = \frac{Na^{2+}}{Ca^{2+} + Mg^{2+}}$$

Magnesium Ratio helps to identify the dominant alkaline earth element in water. Generally, calcium and magnesium maintain a state of equilibrium in most waters. In this equilibrium, more magnesium in water adversely affects the crop yield. The formula for calculating Mg ratio is,

$$Magnesium\ Ratio = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100$$

Non - Carbonate Hardness (NCH) of water relates to the reaction with soap, since Ca^{2+} and Mg^{2+} ions precipitate soap. Hardness is expressed as mg/l of $CaCO_3$. If the hardness as $CaCO_3$ exceeds the difference between the alkalinity as $CaCO_3$ and hardness as $CaCO_3$, it is called Non-Carbonate Hardness. The NCH is used to evaluate the permanent hardness of waters and it is represented as,

$$NCH = [(Ca^{2+} + Mg^{2+}) - (CO_3^{2-} + HCO_3^{-})] \times 50$$

Corrosivity of groundwater is another phenomenon having significant relationship with groundwater quality. Generally corrosion is the deterioration of a material due to the interaction of the material with the environment. Pipes and pipe fittings are damaged when waters with high corrosive capacity are transmitted through them. The Corrosivity Ratio (CR) is estimated as:

$$CR = \frac{Cl^{-} / 35.5 + 2\,(SO_4^{2-} / 96)}{2\,(CO_3^{2-} + HCO_3^{-}) / 100}$$

A technique was evolved by Kumaraswamy (1984) to classify different water types based on USSL diagram in a spatial manner. In this study, the same technique is also attempted to few other diagrams for better understanding of groundwater quality status of the study area in spatial manner. Finally, ArcGIS software has been used for reclassification after assigning the ratings and weights as per the importance given to each and every parameter, then the overlay operation is carried out to identify the suitability of groundwater quality for irrigation purpose.

Results and Discussion

Groundwater Chemistry and its Suitability for Irrigation

Agriculture in India is the dominant sector of the economy. It is the source of livelihood of almost two thirds of the workforce in the country. Indian agricultural production in most parts of the country is closely associated to skillful and wise water-management practices and depends predominantly on groundwater. Groundwater is the main source of irrigation in most of the districts in Tamil Nadu. Therefore, it is essential to evaluate the spatial characteristics of groundwater quality for irrigation purpose.

The quality of surface water and underlying soil characteristics play a major role in determining the composition and quality of the groundwater in a region. Hence, this attempt has been made here to understand the suitability of groundwater for agriculture in general and irrigation purpose in particular by using different methods and approaches to understand the groundwater suitability for irrigation purpose in the study area.

US Salinity Laboratory's (USSL's) Classification of Groundwater for Irrigation

A method formulated by the US Salinity Laboratory (USSL, 1954) for the classification of irrigation waters with reference to SAR as an index of sodium (alkali) hazard and electrical conductivity EC as an index of salinity hazard. The classification of water for irrigation can be evaluated by plotting the results of Sodium Adsorption Ratio (SAR) and EC on USSL diagram. Electrical Conductivity in µmhos per centimetre at 25° C is plotted on X-axis against SAR on Y-axis. Based on this, waters have been divided into C1, C2, C3, C4 and C5 types on the basis of salinity hazard and S1, S2, S3 and S4 types on the basis of sodium hazard. According to Richards (1954), groundwater can be classified based on degree of risk while using it for irrigation. The significance and interpretation of quality ratings on the USSL diagram can be summarised as follows: (a) Low salinity water - C1 (EC: <250 µmhos/cm): can be used for most crops on most soils with little likelihood of soil salinity development, (b) Medium salinity water - C2 (EC: 250 – 750 µmhos/cm): can be used if a moderate amount of leaching occurs, (c) Medium to high salinity water - C3 (EC: 750 – 2,250 µmhos/cm): can be the satisfactory level for plants having moderate salt tolerance, on soils of moderate permeability with leaching, (d) High salinity water - C4 (EC: 2,250 – 6,750 µmhos/cm): cannot be used on soils with restricted drainage, (e) Very high salinity water - C5 (EC: >6,750 µmhos/cm): is not suitable for irrigation under ordinary conditions, but may be used infrequently, under very special circumstances.

High level of salt concentration in water leads to formation of saline soil, a high sodium concentration leads to development of an alkaline soil (Singh *et al*., 2008). Irrigation with sodium (Na) enriched water results in ion exchange reactions: it uptakes the Na^+ and releases the Ca^{2+} and Mg^{2+}. This causes soil aggregates to disperse, reducing its permeability (Tijani, 1994). SAR is used to classify the irrigation water based on the effect of exchangeable sodium of the soil. Low sodium water - S1 (SAR: <10 epm) can be used for irrigation on most of soils with little danger on harmful levels of exchangeable sodium.

Medium sodium water - S2 (SAR: 10 – 18 epm) will present an appreciable sodium hazard in fine-textured soils, especially under low leaching conditions, but may be used on coarse textured or organic soils which have good permeability. High sodium water - S3 (SAR: 18 – 26 epm) may produce harmful levels of exchangeable sodium in most soils and needs special soil management approaches like good drainage, leaching and addition of organic matter. Very high sodium water - S4 (SAR: >26 epm) is generally unsatisfactory for irrigation purposes unless special action is taken.

The EC and SAR values of groundwater samples are plotted in the graphical diagram of irrigated water for pre- and post-monsoon seasons (Figure 3) and the quality zones are tabulated in Tables 1 and 4. The plotting of the groundwater chemical data in the diagram gives a clear idea about the suitability of groundwater for irrigation. Then only it would be possible to group the areas with good, moderate, poor and very poor groundwater zones for irrigated agriculture.

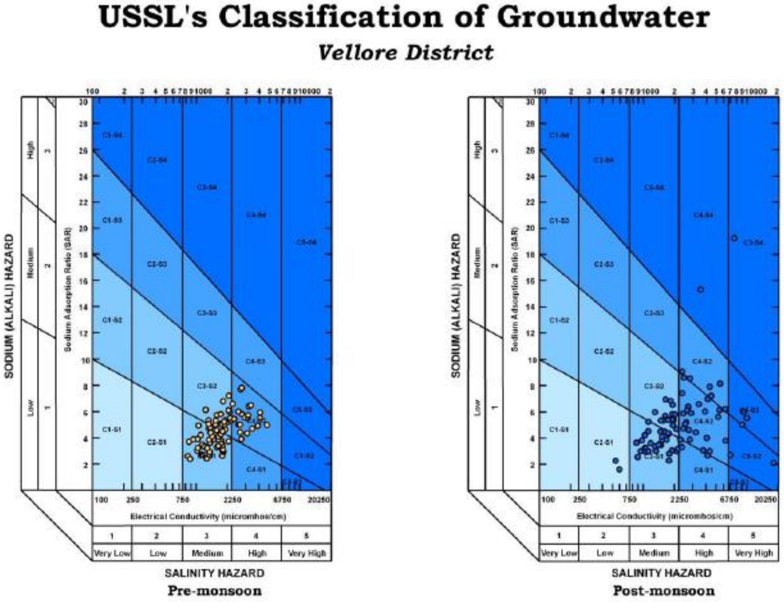

Fig. 3. USSL's Classification of Groundwater during Pre- and Post-monsoon Seasons

The USSL diagrams illustrate that during pre-monsoon season, the entire samples fall within two types of water classes (moderate and poor). Moderate quality of water occupies about 74.4% and poor water quality occupies in 25.6% of the total samples. Among these, 47.6% of the samples (39 samples) of C3-S1 category and 26.8% of the samples (22 samples) of C3-S2 category are found under moderate quality of water and the remaining 25.6% of the samples (21 samples) of C4-S2 category are found and confirmed as poor quality. During post-monsoon season, the samples are identified in all type of water classes (good, moderate, poor and very poor). Good quality of water is found in 2.4% of the samples (2 samples) with C2-S1 category, moderate quality is noticed in 52.5% of the samples (43 samples) with C3-S1 and C3-S2 categories. About 36.6% of the samples (30 samples) fall under the poor quality water of C4-S1, C4-S2 and C4-S3 categories. Very poor quality of water is also identified in 8.5% of the samples (7 samples) in C4-S4, C5-S2, C5-S3 and C5-S4 categories. The changes identified from USSL diagrams between pre-monsoon and post-monsoon seasons explain that good quality water has increased by 2.4% of the samples, but the moderate and poor quality have decreased by 21.9% and 11% of the samples respectively. At the same time very poor quality water has increased by 8.5% of the samples and it is not found during pre-monsoon season.

Based on USSL methods of classification, the irrigation water samples of the study area are qualitatively classified and spatially interpolated as per the procedures followed by Sivagnanam and Kumaraswamy (1988). As per the Table 4, in most of the locations, the EC values of the samples are found >750 μmhos/cm during both the seasons. During pre-monsoon season, the SAR level in all samples is <10 epm but during post-monsoon season, just 2 locations are found exceeding the limit of (SAR) 10 (S37: Ussoor – 15.27 epm and S71: Banavaram – 19.17 epm) and others are found within the value of (SAR) 10 epm. The prevailing criteria are to evaluate water quality and their associated potential hazards to crop growth are salinity and sodium hazards. The quality of groundwater of the study area is evaluated on the basis of these criteria (Table 1, 2). In the USSL diagram, the level of electrical conductivity is generally good up to 2,250 μmhos/cm and it is tolerable up to 6,750 μmhos/cm. In SAR level, <18 epm are generally good, 18 to 26 epm found to be tolerable level and more than 26 epm will be beyond tolerable level for irrigated agriculture (Table 3).

Table 1. Groundwater Classification for Irrigation Purpose during Pre-monsoon and Post-monsoon Seasons

Sample No.	Pre-monsoon							Post-monsoon						
	SAR	PI	RSC	MR	KR	NCH	CR	SAR	PI	RSC	MR	KR	NCH	CR
S1	4.39	70.30	-1.47	74.02	1.27	73.42	2.64	5.25	74.12	-0.55	75.70	1.50	27.64	2.32
S2	5.22	67.78	-1.00	67.58	1.21	50.14	1.94	8.48	74.66	-1.88	71.27	1.92	93.88	3.41
S3	4.89	68.66	-2.84	53.87	1.34	142.23	2.02	3.10	59.59	-3.51	64.42	0.86	175.41	3.60
S4	2.86	54.50	-4.44	71.28	0.69	222.01	2.62	2.71	60.12	-2.35	56.48	0.73	117.55	1.86
S5	5.54	57.89	-8.70	70.40	1.00	434.91	4.78	5.62	53.99	-13.56	65.42	0.93	678.19	8.35
S6	3.92	66.95	-1.74	68.83	1.05	87.16	1.86	3.96	67.31	-2.14	66.00	1.09	106.92	1.98
S7	4.83	73.83	0.26	67.23	1.36	-12.99	1.39	4.42	69.77	-1.26	64.81	1.18	63.20	1.51
S8	3.22	64.83	0.35	64.92	0.87	-17.27	0.98	3.15	59.51	-2.83	81.32	0.83	141.57	1.88
S9	6.70	82.48	2.50	73.55	2.03	-125.05	1.56	6.60	77.55	1.43	66.31	1.75	-71.33	1.61
S10	2.58	44.75	-8.28	56.34	0.52	413.88	4.24	2.93	51.09	-6.12	57.55	0.64	305.82	3.03
S11	6.40	62.04	-6.92	78.50	1.17	345.83	4.05	7.87	70.47	-3.75	74.57	1.63	187.37	3.53
S12	3.47	68.24	-0.52	63.08	0.97	25.81	1.11	3.09	63.23	-2.10	70.53	0.85	105.23	1.59
S13	6.02	65.79	-4.18	77.17	1.26	209.19	3.18	4.95	63.34	-4.60	65.08	1.09	229.98	3.46
S14	6.46	61.21	-8.45	76.06	1.17	422.52	5.30	6.98	67.47	-4.91	70.51	1.46	245.73	4.52
S15	5.34	64.88	-3.16	81.80	1.15	158.04	2.04	6.12	65.50	-4.93	80.33	1.26	246.66	3.08
S16	4.94	43.77	-23.56	80.52	0.63	1177.93	8.08	6.18	49.56	-22.28	77.33	0.83	1113.83	11.61
S17	5.89	53.65	-14.64	72.61	0.91	731.75	7.21	5.52	45.11	-26.27	82.90	0.71	1313.28	14.25
S18	3.25	56.53	-4.53	65.24	0.80	226.29	3.39	2.73	54.59	-4.16	45.06	0.67	207.76	2.57
S19	5.22	68.80	-1.59	65.81	1.27	79.32	2.16	5.38	70.52	-1.09	73.45	1.37	54.35	2.56
S20	4.86	48.29	-11.84	56.54	0.77	592.23	5.25	5.98	55.14	-14.23	64.36	0.99	711.43	11.52
S21	4.27	51.18	-11.01	74.84	0.78	550.38	7.35	2.12	37.92	-10.49	50.21	0.39	524.30	3.01
S22	2.56	56.34	-3.13	66.88	0.70	156.42	2.89	2.31	50.28	-4.53	64.66	0.57	226.43	2.85
S23	3.85	61.40	-3.26	76.32	1.50	163.01	2.17	3.78	62.03	-2.71	63.96	1.01	135.44	1.89
S24	2.65	57.74	-2.49	69.17	0.70	124.48	1.96	3.01	61.92	-1.63	75.55	0.82	81.47	1.72
S25	2.69	61.63	-0.80	57.28	0.76	39.77	1.26	3.37	66.78	-0.41	63.84	0.95	20.54	1.35
S26	5.32	78.53	0.06	74.27	1.64	-2.85	1.57	2.24	71.48	0.32	57.90	0.77	-15.96	4.18
S27	3.65	77.23	0.58	72.51	1.24	-29.04	0.73	7.22	80.39	-0.86	57.03	2.16	42.86	1.46
S28	5.65	77.75	0.39	63.31	1.69	-19.44	1.84	6.78	80.53	0.20	67.14	2.09	-10.00	2.68
S30	4.99	69.96	-0.50	77.42	1.25	25.00	1.75	6.08	62.67	-7.71	65.44	1.24	385.34	6.69
S31	4.60	69.31	-1.37	69.30	1.23	68.61	2.21	5.43	68.59	-2.47	62.54	1.32	123.49	2.63

S32	3.88	73.64	-0.27	62.21	1.21	13.41	1.34	5.22	76.06	-0.16	66.84	1.57	8.14	1.90
S33	3.77	61.44	-2.30	68.11	0.89	115.10	1.97	2.98	77.97	1.14	66.64	1.05	-56.92	0.82
S34	3.95	60.87	-4.12	57.28	0.94	205.79	2.81	4.46	73.41	0.79	75.32	1.27	-39.39	1.24
S35	5.46	63.56	-4.78	65.50	1.15	239.17	3.43	2.75	51.56	-5.38	54.51	0.63	269.02	3.16
S36	5.48	66.66	-3.32	59.67	1.26	165.87	3.55	4.57	53.54	-9.53	59.07	0.84	476.61	4.91
S37	7.72	73.92	-1.18	74.93	1.75	59.10	2.86	5.83	67.49	-3.92	54.74	1.36	196.23	4.43
S38	3.65	52.50	-7.51	61.67	0.75	375.73	4.97	15.27	81.28	-4.37	68.21	3.20	218.71	4.52
S39	3.60	66.87	-0.48	79.95	1.00	24.20	1.65	3.84	44.75	-14.87	62.80	0.65	743.64	11.68
S40	4.42	52.53	-10.09	77.49	0.83	504.36	6.57	3.46	62.00	-2.30	72.43	0.89	115.20	2.25
S41	3.22	70.84	-0.68	63.74	1.08	34.21	1.94	4.70	57.92	-7.34	68.98	0.98	367.22	5.66
S42	4.06	65.77	-2.82	67.28	1.11	141.03	3.20	2.53	68.35	-0.74	49.82	0.89	36.99	1.67
S43	7.20	78.80	-0.90	57.06	2.07	45.10	3.42	4.12	66.54	-2.96	62.30	1.18	147.85	4.12
S44	4.98	72.27	-0.99	75.18	1.39	49.64	2.45	9.04	81.40	-1.11	48.40	2.57	55.48	4.61
S45	5.34	72.93	-1.54	64.43	1.46	76.85	2.65	5.68	76.17	-0.66	54.71	1.69	32.92	2.68
S46	2.40	64.01	-1.15	73.49	0.75	57.27	1.72	3.03	64.53	-1.93	54.93	0.89	96.37	2.14
S47	5.79	71.94	-2.20	62.75	1.50	110.10	2.12	3.24	68.13	-1.06	65.14	1.03	53.20	1.75
S48	5.21	59.97	-7.17	63.49	1.06	358.40	5.25	3.82	65.84	-1.95	49.48	1.01	97.58	2.05
S49	3.89	77.60	-0.20	55.52	1.40	9.98	2.08	5.70	56.82	-11.70	60.32	1.05	585.19	10.98
S50	4.47	65.37	-3.34	65.62	1.17	167.24	3.97	3.58	76.47	-0.31	61.92	1.32	15.56	1.90
S51	3.32	59.14	-2.20	65.37	0.79	110.11	1.89	4.30	74.47	-0.52	55.28	1.37	26.24	3.21
S52	4.17	62.01	-4.22	62.56	1.03	210.93	3.98	3.61	65.19	-0.64	63.86	0.95	32.01	1.52
S53	6.61	69.89	-4.01	58.85	1.56	200.64	4.77	3.84	65.50	-2.68	52.30	1.07	134.12	3.19
S54	4.94	67.56	-2.81	70.18	1.25	140.27	3.43	7.39	73.12	-3.42	64.11	1.78	170.80	4.96
S55	3.90	46.81	-13.13	66.83	0.68	656.26	9.46	3.48	65.16	-1.40	64.61	0.97	69.96	2.14
S56	4.99	54.95	-10.65	73.92	0.92	532.49	8.02	5.12	57.34	-9.37	58.26	1.01	468.26	8.29
S57	5.04	70.29	-2.49	60.87	1.37	124.53	3.44	2.89	65.30	-1.91	51.81	0.91	95.66	2.47
S58	5.99	68.05	-4.21	61.62	1.38	210.38	4.19	4.47	70.34	-2.00	48.27	1.33	99.94	3.73
S59	4.06	66.52	-1.50	64.37	1.06	75.09	2.07	3.87	55.35	-6.50	59.41	0.81	325.01	4.38
S60	6.09	70.61	-2.33	69.37	1.44	116.35	2.73	3.90	65.05	-2.06	62.73	1.02	103.18	2.38
S61	7.66	73.98	-2.46	66.79	1.83	123.23	4.18	4.73	68.74	-1.56	62.64	1.20	78.00	2.16
S62	4.65	74.64	-0.28	56.78	1.40	13.77	1.81	6.38	66.62	-4.90	63.92	1.36	245.17	4.69
S63	3.54	56.04	-5.87	57.30	0.82	293.38	4.55	5.21	81.97	0.59	58.68	1.81	-29.64	1.86
S64	5.50	59.56	-8.10	60.21	1.05	404.88	5.01	2.78	53.00	-5.10	55.17	0.68	255.09	5.34
S65	5.35	66.13	-2.99	55.46	1.20	149.58	3.38	3.29	47.09	-9.61	58.36	0.64	480.54	6.35
S66	5.82	61.00	-7.98	53.59	1.14	399.11	6.31	5.06	65.43	-4.32	57.47	1.21	216.04	3.74
S67	5.08	75.23	-1.45	63.99	1.61	72.61	3.65	5.85	60.31	-8.50	56.95	1.13	425.14	6.56
S68	4.90	72.09	-1.84	68.26	1.41	92.15	3.34	5.93	83.04	-0.11	48.27	2.11	5.30	3.12
S69	2.98	50.91	-5.29	64.25	0.65	264.67	3.18	5.32	68.73	-3.46	59.30	1.41	173.18	4.83
S70	3.14	50.43	-7.42	60.65	0.68	371.04	5.14	5.83	69.51	-2.74	57.83	1.48	136.90	3.96
S71	3.36	54.86	-5.58	65.19	0.75	279.11	3.40	5.36	69.22	-3.70	50.59	1.42	185.08	4.63
S72	2.97	64.91	-1.94	58.82	0.90	97.01	2.55	19.18	78.87	-13.20	46.45	3.15	659.78	18.16
S73	2.69	54.77	-3.85	60.34	0.68	192.64	3.05	1.58	58.84	-1.62	49.13	0.54	81.24	1.43
S74	2.41	53.40	-3.44	71.98	0.63	171.79	2.93	4.36	60.00	-5.26	62.01	1.00	262.95	4.61
S75	2.57	66.13	-1.15	56.87	0.84	57.35	1.91	3.60	65.31	-2.77	52.01	1.06	138.55	3.64
S76	4.69	48.19	-16.17	54.24	0.74	808.45	10.49	2.98	69.38	-1.16	38.08	1.01	57.78	2.11
S77	5.07	63.30	-3.04	79.34	1.07	152.20	2.76	8.12	57.76	-19.53	52.81	1.14	976.43	10.72
S78	3.28	67.42	-1.03	65.18	0.95	51.27	1.87	5.78	76.11	-0.14	69.66	1.64	6.99	2.89
S79	6.13	85.20	1.50	64.84	2.23	-75.16	1.64	8.55	77.63	-1.34	62.81	2.08	67.06	3.32
S80	2.92	54.95	-3.98	68.78	0.69	198.99	3.43	6.91	82.04	0.67	63.97	2.17	-33.44	2.22
S81	4.19	76.08	-0.22	64.28	1.40	10.76	2.14	6.52	75.76	-1.80	63.21	1.87	89.83	4.48
S82	5.73	57.96	-9.89	67.07	1.05	494.66	7.03	4.16	79.05	0.02	51.97	1.60	-1.03	2.47

Table 2. USSL Classification of Salinity Hazard for Irrigation

Electrical Conductivity in µmhos/cm	Salinity Condition	Quality of Water
< 250	Low Salinity	Excellent
250 – 750	Medium Salinity	Good
750 – 2,250	High Salinity	Doubtful
> 2,250	Very High Salinity	Unsuitable

Table 3. Qualitative Classification of Irrigation Water

Salinity Class	Electrical Conductivity in µmhos/cm	Sodium Class	Alkalinity Hazard (SAR in epm)
C1	< 250	S1	< 10
C2	250 – 750	S2	10 – 18
C3	750 – 2,250	S3	18 – 26
C4	2,250 – 6,750	S4	> 26
C5	> 6,750	-	-

In the USSL diagram, the groundwater categories namely C2-S1, C3-S1, C3-S2, C4-S1, C4-S2, C4-S3, C4-S4, C5-S2, C5-S3 and C5-S4 fall under four different classes as shown in Table 4. As per the class of good water, the only category C2-S1 is found during post-monsoon season at Gundalapalli (S26) in Pernambattu block; and Gudalur (S72) and Ozhugur (S65) in Kaveripakkam block. While looking at the moderate class of groundwater, it has C3-S1 and C3-S2 categories during pre- and post-monsoon seasons. During pre-monsoon season, a majority of areas in the eastern half (parts of Madhanur, Anaicut, Katpadi, Walajapet, Arcot, Timiri, Sholinghur, Kaveripakkam and Nemili blocks) and some of the areas in western half (Tiruppathur and Natramppalli blocks) of the study area are found falling in moderate class of groundwater category. The poor class of groundwater is found in C4-S2 category during pre-monsoon season and C4-S1, C4-S2 and C4-S3 categories during post-monsoon season. The southern portion of Kandhili and Madhanur blocks; few portions of Tiruppathur, Alangayam, Pernambattu, Vellore, K.V.Kuppam, Sholinghur and Arcot blocks; and the eastern portion of Timiri and Arakkonam blocks are found with poor quality of groundwater during pre-monsoon season. However, during post-monsoon season, the poor quality of groundwater has increased almost in the entire western half of the study area (Kandhili, Tiruppathur, Jolarpet, Natrampalli, Alangayam and Gudiyatham blocks). While in the eastern half, the condition exists in a few small portions in Vellore, Katpadi, Timiri, Sholinghur and Kaveripakkam blocks; and eastern portion of Arakkonam block. The C4-S4, C5-S2, C5-S3 and C5-S4 categories constitute very poor quality of groundwater. During pre-monsoon season, not a single sample is found in very poor water class category. But in post-monsoon season, a few pockets are found in the western parts from the Yelagiri Hills; some parts of Pernambattu, Madhanur and Vellore blocks in the western half of the study area; and the areas around Banavaram Reserved

Forest in the eastern portion of the study area are identified with very poor class of groundwater quality (Figures 4 and 5).

Table 4. Quality of Irrigation Water based on US Salinity Laboratory Diagram

Water Class	Category	Pre-monsoon		Post-monsoon	
		No. of samples	% of samples	No. of samples	% of samples
Good	C2-S1	-	-	2	2.4
Moderate	C3-S1	39	47.6	29	35.4
	C3-S2	22	26.8	14	17.1
Poor	C4-S1	-	-	3	3.7
	C4-S2	21	25.6	21	25.6
	C4-S3	-	-	6	7.3
Very Poor	C4-S4	-	-	1	1.2
	C5-S2	-	-	2	2.4
	C5-S3	-	-	3	3.7
	C5-S4	-	-	1	1.2

Wilcox's Classification of Groundwater for Irrigation

Wilcox (1948) proposed a method for evaluating irrigation waters, based on percent sodium (soluble sodium percentage) and electrical conductivity. The diagram is composed of five distinct classes such as excellent-good, good-permissible, permissible-doubtful, doubtful-unsuitable and unsuitable. Sodium concentration is an important parameter in classifying irrigation waters because sodium reduces the permeability nature of soil while reacting with that. Excess sodium in waters produces undesirable effects of changing soil properties and reducing soil permeability (Kelley, 1951). The calculated values of percent sodium ranges from 34.06 (S10: Kurusilapattu) to 68.03 (S79: Poyapakkam) during pre-monsoon season and from 27.76 (S21: Kommeswaram) to 75.85 (S71: Banavaram) during post-monsoon season (Table 1). A maximum of 60% sodium in groundwater is allowed for agricultural purposes (Ramakrishnan, 1998). The crop yields are generally low in lands irrigated by the waters of doubtful-unsuitable category. This may be due to the presence of excess sodium salts (causes osmotic effects on soil plant system) and when the concentration of sodium is high in irrigation water, sodium ions tend to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. This exchange process of Na^{+} in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage. Hence, air and water circulation is restricted during wet conditions and such soils are usually hard when dry (Collins and Jenkins, 1996; Saleh *et al*., 1999).

Wilcox diagram has been constructed with the percentage of sodium and electrical conductivity of groundwater samples. During pre-monsoon season, 40.2% of the samples (33 samples) fall under good-permissible category, 25.6% of the samples (21 samples) with permissible-doubtful category, 23.2% of the samples (19 samples) in doubtful-unsuitable category and the remaining 11% of the samples (9 samples) fall under unsuitable category for irrigated agriculture.

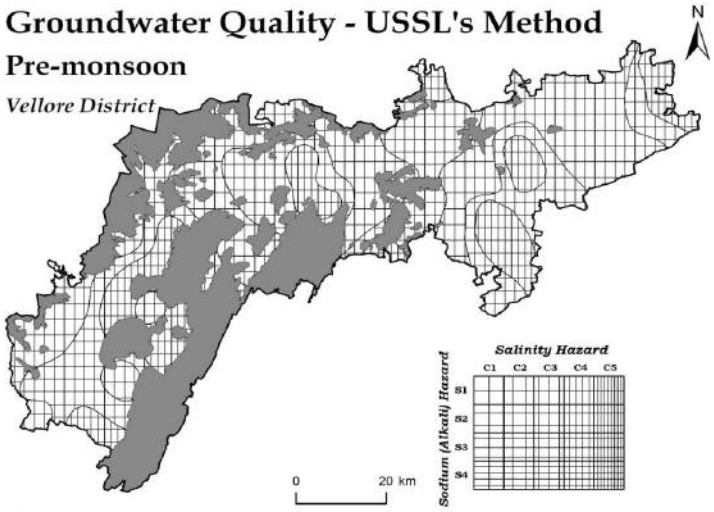

Fig. 4. Spatial Characteristics of Groundwater Quality using USSL's Method – Pre-monsoon

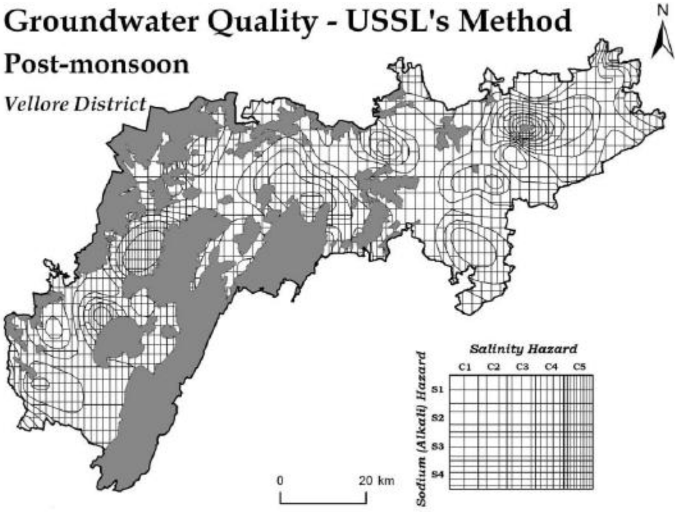

Fig. 5. Spatial Characteristics of Groundwater Quality using USSL's Method – Post-monsoon

While this is the condition in pre-monsoon season, post-monsoon season is observed with slight modification: 2.4% of the samples (2 samples) in verygood-good category, 24.4% of the samples (20 samples) in good-permissible category, permissible-doubtful and doubtful-unsuitable categories are found with 23.3% and 23.3% of the samples (total 38 samples) respectively. As much as 26.8% of the samples (22 samples) are classified as unsuitable category for irrigation purpose in the study area (Table 5; Figure 6).

Table 5. Wilcox's Classification of Groundwater for Irrigation

Wilcox's Classification of Groundwater	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
Excellent-Good	-	-	2	2.4
Good-Permissible	33	40.2	20	24.4
Permissible-Doubtful	21	25.6	19	23.2
Doubtful-Unsuitable	19	23.2	19	23.2
Unsuitable	9	11.0	22	26.8

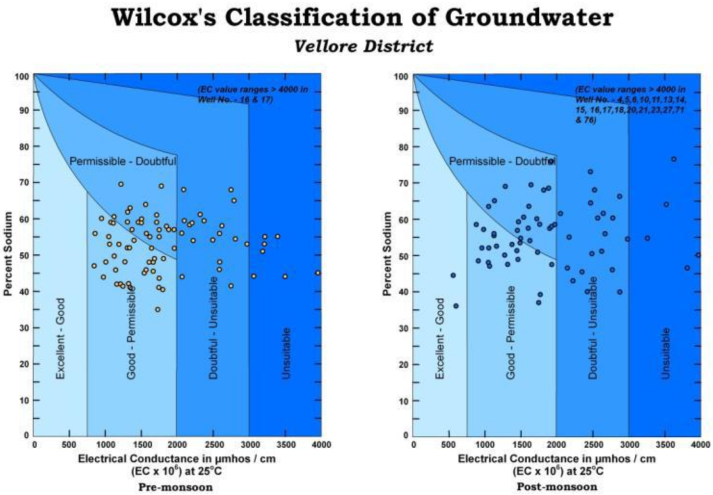

Fig. 6. Wilcox's Classification of Groundwater during Pre- and Post-monsoon Seasons

During pre-monsoon season, a majority of portions belonging to Natrampalli, Pernambattu, Anaicut, Katpadi, Arcot, Timiri, Kaveripakkam and Nemili blocks fall under good-permissible category of groundwater. The regions that fall under permissible-doubtful exist in some parts of Jolarpet, Tiruppathur, Pernambattu, Vellore, Walajapet and Sholinghur blocks; and as pockets at Nemili and Arakkonam blocks. Doubtful-unsuitable quality of groundwater is found as small pockets in Kandhili, Alangayam, Pernambattu, K.V.Kuppam, Vellore, Kaniyambadi, Walajapet, Sholinghur, Arcot and Timiri blocks. Unsuitable regions are found in southern portion of Kandhili, Tiruppathur, Alangayam, Pernambattu, Madhanur and the eastern portion of Arakkonam blocks (Figure 7). While looking at the scenario during post-monsoon season, the entire western portion of the study area falls under unsuitable category of groundwater (Kandhili, Tiruppathur, Jolarpet, Natrampalli, Alangayam, southern portion of Pernambattu and Madhanur blocks). Only the central and eastern portions exhibit diversified nature of groundwater quality. Excellent-good water quality is found in some of the portions of Pernambattu and Kaveripakkam blocks.

Good-permissible quality of groundwater is found in Anaicut, K.V.Kuppam, Katpadi, Arcot, Timiri, Walajapet and Kaveripakkam blocks of the study area. However, permissible-unsuitable quality of groundwater is found as small pockets in Natrampalli, Madhanur, Gudiyatham, K.V.Kuppam, Anaicut, Kaniyambadi, Walajapet, Timiri, Kaveripakkam, Sholinghur and Nemili blocks (Figure 8).

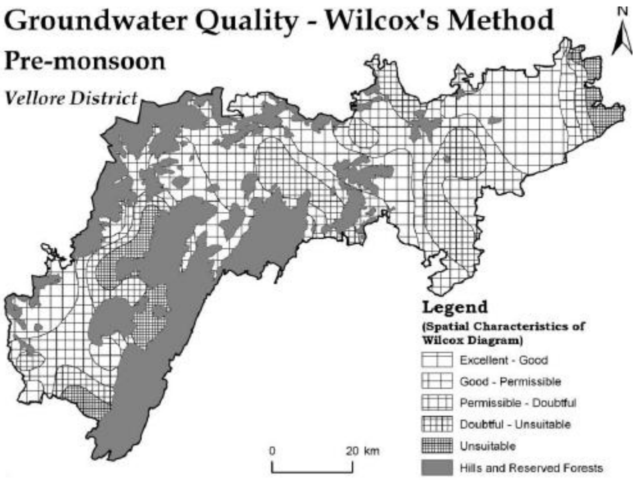

Fig. 7. Spatial Characteristics of Groundwater Quality using Wilcox's Method – Pre-monsoon

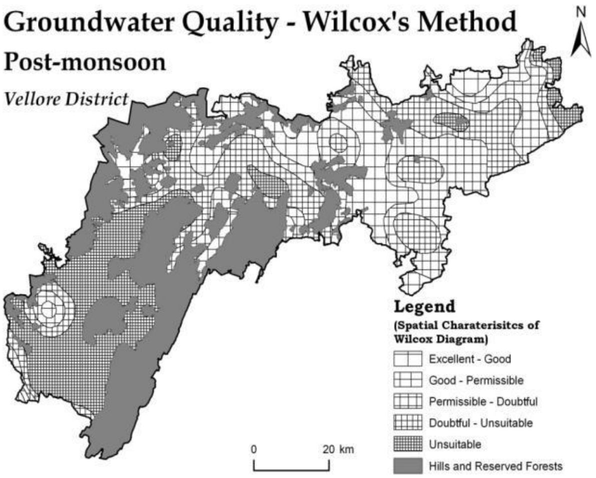

Fig. 8. Spatial Characteristics of Groundwater Quality using Wilcox's Method – Post-monsoon

Doneen's Classification of Groundwater

Doneen (1961) has evolved a diagram with the combination of permeability index and total salinity, which is divided into three parts representing each class of water. Classification of water for irrigated agriculture can be evaluated by Permeability Index (PI) proposed by Doneen (1966). The values of PI ranges from 43.76 epm (S16: Alangayam) to 85.19 epm (S79: Poyapakkam) during pre-monsoon season and from 37.91 epm (S21: Kommeswaram) to 83.03 epm (S67: Athipattu) during post-monsoon season. Based on permeability index and total salinity the groundwater samples are classified into three types. By analysing the Table 6, it is observed that 92.7% of the samples (76 samples) fall under class I and the remaining 7.3% of the samples (6 samples) found in Class II during pre-monsoon season.

Table 6. Doneen's Classification of Groundwater for Irrigation

Doneen's Classification of Groundwater	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
Class I	76	92.7	77	93.9
Class II	6	7.3	1	1.2
Class III	-	-	4	4.9

The post-monsoon season exhibits 93.9% of the samples (77 samples) in Class I, while Classes II and III are occupied with 1.2% and 4.9% of the samples (1 sample and 4 samples) respectively. While looking at the results of Class I, no variations are found between pre- and post-monsoon seasons. But the samples found in Class II during post-monsoon season is reduced to 1 sample from 6 samples (pre-monsoon season) and 4 samples are found in Class III. These results clearly show that the quality of groundwater during post-monsoon is bit deteriorated compared to pre-monsoon season (Tables 1 and 6; Figure 9).

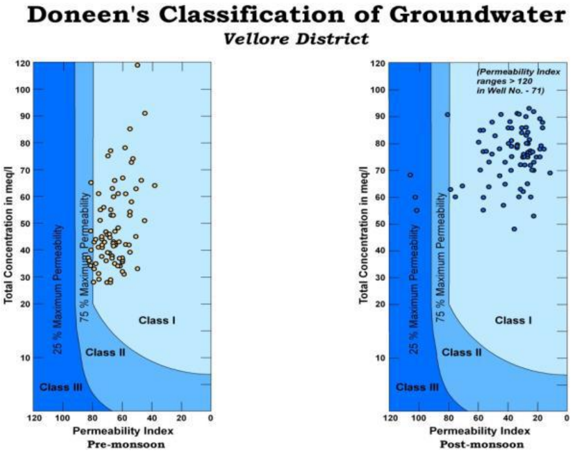

Fig. 9. Doneen's Classification of Groundwater during Pre- and Post-monsoon Seasons

The spatial characteristics of Doneen's groundwater classification explicates that the entire study area falls under Class I and Class II (suitable and moderately suitable) type of groundwaters during both pre- and post-monsoon seasons. A few pockets of Class III (unsuitable) type of groundwaters are found during post-monsoon season at the foot hill regions of Javadu and Yelagiri Hills (Alangayam and Madhanur blocks); and the areas around Banavaram Reserved Forest and the northern portion of Arakkonam block (Figures 10 and 11).

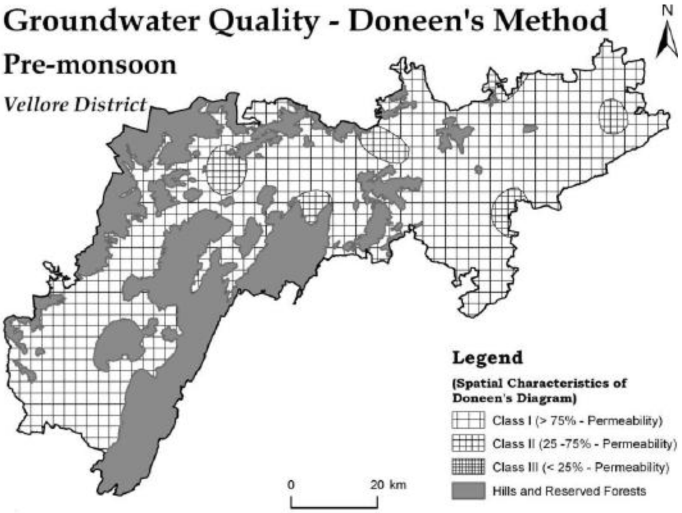

Fig.10. Spatial Characteristics of Groundwater Quality using Doneen's Method – Pre-monsoon

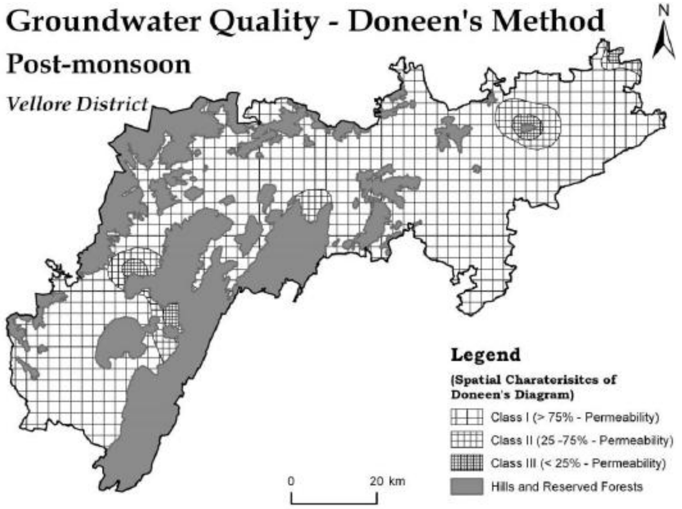

Fig. 11. Spatial Characteristics of Groundwater Quality using Doneen's Method – Post-monsoon

Magnesium Ratio

In general, calcium and magnesium maintain a state of equilibrium in most waters. In the equilibrium, more magnesium in waters adversely affects soil quality, rendering it alkaline, resulting in decreased crop yields. Paliwal (1972) introduced an important ratio called index of magnesium hazard. Magnesium ratio with more than 50% would adversely affect the crop yield as the soils become more alkaline. The result reveals that all the pre-monsoon samples (82 samples) fall with the magnesium ratio class of more than 50% and during post-monsoon 89% of the samples (73 samples) had magnesium ratio more than 50%. The magnesium ratio for each and every sample is estimated based on the formula and the study area is divided into various zones (including pre- and post-monsoon seasons), they are less than 25 epm (suitable), 25 – 50 epm (permissible), 50 – 75 epm (doubtful) and greater than 75 epm (unsuitable). In the study area, during pre-monsoon season, the magnesium ratio ranges from 53.59 epm (S66: Sumaithangi) to 81.79 epm (S17: Vellakuttai) and during post-monsoon season, it ranges from 38.08 epm (S75: Narayanamangalam) to 82.90 epm (S17: Minnur) (Tables 1 and 7). The dominance of magnesium is noticed throughout the study area next to sodium (among cations) during both the seasons. Higher content of magnesium affects the crop yield in several places of the study area.

The spatial distribution of magnesium ratio during pre-monsoon season shows that a substantial portion of the study area falls under doubtful category except small pockets and patches between Yelagiri and Javadu Hills (near Tiruppathur and Alangayam blocks). Further, the blocks like Kandhili, Madhanur, Anaicut, Vellore, Kaniyambadi and Arakkonam fall under unsuitable category of magnesium ratio. During post-monsoon season, permissible level of magnesium ratio is observed in some portions in Pernambattu, Katpadi, Arcot, Kaveripakkam and Arakkonam blocks. At the same time, the area that fall under unsuitable category is minimised while comparing the results of pre-monsoon season. The unsuitable category is found in Natrampalli, Tiruppathur, Madhanur, Anaicut and Gudiyatham blocks and the remaining areas fall under doubtful category in respect of magnesium ratio.

Kelley's Ratio

Sodium measured against calcium and magnesium constituents in a water sample is known as Kelley's ratio, based on which irrigation water can be rated (Kelley, 1940; Paliwal, 1967). Groundwaters having Kelley's ratio less than one are considered as suitable for irrigation. In the study area, the ratio varies from 0.52 epm (S10: Kurusilapattu) to 2.22 epm (S79: Poyapakkam) during pre-monsoon season and in post-monsoon season it ranges from 0.38 epm (S21: Kommeswaram) to 3.19 epm (S37: Ussoor). Therefore according to Kelley's ratio, 39% of the samples (32 samples) in the pre-monsoon season and 36.6% of the samples (30 samples) during post-monsoon season are found to be suitable for irrigation. Kelley's ratio is estimated for all samples based on the formula (Tables 1 and 8) and the study area has been divided into various zones (including pre- and post-monsoon seasons) representing Kelley's ratio values in epm and the zones are with the ratio greater than 2, 1.5 – 2.0, 1.0 – 1.5 and less than 1. The interpolated surface of Kelley's ratio explains that a major portion of the study area falls under unsuitable level of Kelley's ratio during pre- and post-monsoon seasons. Some of the areas in Kandhili, Tiruppathur, Alangayam, Natrampalli, Pernambattu, Madhanur, Anaicut, Kaniyambadi, Arcot, Timiri, Kaveripakkam, Nemili and Arakkonam blocks during pre-monsoon and the areas of Kandhili, Tiruppathur, Natrampalli, Pernambattu, Madhanur, Anaicut, Kaniyambadi, K.V.Kuppam, Arcot, Timiri, Sholinghur, Walajapet, Kaveripakkam and Arakkonam blocks during post-monsoon seasons fall under suitable level of Kelley's ratio for irrigated agriculture. While looking at the results of both the seasons, it is confirmed that the area under suitable level of Kelley's ratio is reduced in post-monsoon when comparing to the results of pre-monsoon season.

Sodium Adsorption Ratio

As per the Richards (1954) classification of Sodium Adsorption Ratio (SAR) values (Table 7, 8), 100% (82 samples) of the pre-monsoon season samples and 97.6% (80 samples) of the post-monsoon season samples fall under excellent category. The SAR is an important parameter for determining the suitability of irrigation water because it is responsible for the sodium hazard (Todd, 1980). The high value of SAR (>18 epm) implies a hazard of sodium (alkali) replacing calcium and magnesium of the soil through cation exchange process. This situation eventually causes damage to soil structure, which ultimately affects fertility status of soil and reduces crop yield (Gupta, 1987). The SAR is estimated for all the samples during both the seasons (Tables 1 and 9). The interpolated raster surfaces have been generated to understand the spatial pattern of SAR in the study area. The sodium hazards of water classification proposed by Richards (1954) are given in the Table 9. During pre-monsoon season, the SAR concentration ranges from 2.40 epm (S46: Ayilam) to 7.71 epm (S37: Ussoor) in the study area. In this season, all samples are found within the limit of excellent SAR (<10 epm). During post-monsoon season, the SAR values range from 1.57 epm (S72: Gudalur) to 19.17 epm (S71: Banavaram). As per the classification, about 97.6% of the samples (80 samples) are found with excellent water category (<10 epm). The good water class is found (10 – 18 epm) in only one sample location at Ussoor (S37) and the permissible level of SAR is identified in Banavaram (S71). With the results above, it is clear that the entire region falls within the permissible limit and hence the water is useful for agriculture purpose.

Table 7. Magnesium Ratio for Irrigation Water

Mg Ratio Category (values in epm)	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
< 25 (Suitable)	-	-	-	-
25 – 50 (Permissible)	-	-	9	11
50 – 75 (Doubtful)	71	86.6	66	80.5
> 75 (Unsuitable)	11	13.4	7	8.5

Table 8. Kelley's Ratio for Irrigation Water

Kelley's Ratio Category (values in epm)	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
> 2.0	3	3.7	8	9.8
1.5 – 2.0	8	9.8	10	12.2
1.0 – 1.5	39	47.6	34	41.5
< 1.0	32	39	30	36.6

Table 9. Classification of Irrigation Water based on Sodium Adsorption Ratio

Sodium Adsorption Ratio (SAR) in epm	Water Class	Pre-monsoon		Post-monsoon	
		No. of samples	% of samples	No. of samples	% of samples
< 10	Excellent	82	100	80	97.6
10 – 18	Good	-	-	1	1.2
18 – 26	Permissible	-	-	1	1.2
> 26	Unsuitable	-	-	-	-

Residual Sodium Carbonate

Residual Sodium Carbonate (RSC) is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose (Eaton, 1950). The water gets more precipitated with Ca^{2+} and Mg^{2+} and as a result Na^{+} in water gets increased in the form of sodium carbonate. The variation of RSC, is drawn using Richards (1954) classification as good (<1.25), moderate (1.25 – 2.5) and poor (>2.5) categories. During pre-monsoon season, the RSC ranges from -23.55 epm (S16: Alangayam) to 2.5 epm (S9: Fakirithakka) and during post-monsoon, it ranges from -27.26 epm (S17: Minnur) to 1.42 epm (S9: Fakirithakka). During both the seasons, 97.6% of the samples (80 samples) fall in good type of water class and the remaining water fall under moderate and poor types (Tables 1 and 10). The interpolated raster surface of RSC reveals that during pre-monsoon season the entire study area falls under good quality of RSC except a few pockets found under moderate quality in Jolarpet and Arakkonam blocks. Further, a tiny spot is identified with poor quality water in Jolarpet block. While this is the status during pre-monsoon season, the post-monsoon season illustrates that the entire study area exhibits good quality except some patches in northern portions (Gudiyatham, K.V.Kuppam, Sholinghur and Kaveripakkam blocks), which fall under moderate quality of RSC in the study area.

Permeability Index

The soil permeability is affected by long-term use of irrigation water and is influenced by sodium, calcium, magnesium and bicarbonate contents of the soil. Doneen (1964) has evolved a criterion for assessing the suitability of water for irrigation based on Permeability Index (PI). Doneen (1964) and Raghunath (1987) have developed a norms for classifying the water as class I (>75% of PI), class II (25 – 75% of PI) and class III (<25% of

PI) (Table 11). The PI of the groundwater samples in the study area ranges from 43.76 epm (S16: Alangayam) to 85.19 epm (S79: Poyapakkam) during pre-monsoon season and from 37.91 epm (S21: Kommeswaram) to 83.04 epm (S67: Athipattu) during post-monsoon season. The PI of the study area shows that the entire region is shared by moderate and maximum levels during both the pre- and post-monsoon seasons. About 89% (73 samples) and 79.3% (65 samples) of the samples are identified under moderate level (25 – 75) of PI during pre- and post-monsoon seasons respectively. The remaining 11% (9 samples) and 20.7% (17 samples) of the samples fall under maximum level (>75) of PI during both the pre- and post-monsoon seasons respectively (Tables 1 and 11). The interpolated raster surface of pre-monsoon season explains that in parts of Jolarpet, Gudiyatham, Katpadi and Arakkonam blocks; and some small pockets in Vellore and Arcot blocks fall under maximum level of PI and the remaining regions are found to contain moderate level of PI. During post-monsoon, the areas under maximum level of PI are found in some parts of Gudiyatham, Vellore, Katpadi, Arcot, Kaveripakkam, Nemili and Arakkonam blocks. The remaining portions fall under moderate level of PI. As suggested by Raghunath (1982), on the basis of USSL diagram and Doneen's chart, the groundwater in the study area is found to be suitable for irrigation purpose.

Table 10. Classification of Irrigation Water based on Residual Sodium Carbonate

Residual Sodium Carbonate (RSC) in epm	Water Class	Pre-monsoon		Post-monsoon	
		No. of samples	% of samples	No. of samples	% of samples
< 1.25	Good	80	97.6	81	98.8
1.25 – 2.5	Moderate	1	1.2	1	1.2
> 2.5	Poor	1	1.2	-	-

Table 11. Classification of Irrigation Water based on Permeability Index

Permeability Index (PI) in epm	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
< 25 (Minimum)	-	-	-	-
25 – 75 (Moderate)	73	89	65	79.3
> 75 (Maximum)	9	11	17	20.7

Non-Carbonate Hardness

Hardness of water samples can be classified into two types: temporary hardness and permanent hardness. The temporary hardness can be removed by boiling the water and as a result carbon dioxide is driven out and the carbonate gets precipitated. Permanent hardness is otherwise called Non-Carbonate Hardness (NCH). Higher values of permanent hardness indicate higher alkalinity in water. It leads to deterioration of soil quality and as a result, crop yield decreases. The NCH ranges between -125.04 epm (S9: Fakirithakka) – 1,177.92 epm (S16: Alangayam) and -71.33 epm (S9: Fakirithakka) – 1,313.27 epm (S17: Minnur) during pre- and post-monsoon seasons respectively. During pre- and post-monsoon seasons, the positive values of NCH is observed in 91.5% and 90.2% (75 and 74 samples) of the samples respectively and the remaining samples show negative values with 8.5% and 9.8% (7 and 8 samples) of the samples respectively (Tables 1 and 12). The interpolated raster surface shows that during pre-monsoon season, the entire study area is dominated by unsuitable (positive) nature of NCH with some small patches of suitable (negative) condition in Natrampalli, Jolarpet, Pernambattu, Gudiyatham, Anaicut, Vellore, K.V.Kuppam, Katpadi, Sholinghur, Kaveripakkam and Arakkonam blocks. During post-monsoon season, the similar situation prevails except a few pockets in Arcot and Walajapet blocks, which fall under suitable condition of NCH in the study area.

Table 12. Classification of Irrigation Water based on Non-Carbonate Hardness

Non-Carbonate Hardness (NCH) in epm	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
Negative	7	8.5	8	9.8
Positive	75	91.5	74	90.2

Corrosivity Ratio

Corrosivity ratio is a method proposed by Ryzner (1944) to evaluate the corrosive tendency of groundwater on metallic pipes. The corrosivity ratio <1 epm is considered to be non-corrosive and metallic pipes can be used and the ratio with >1 epm is considered to be corrosive in nature and metallic pipes can be replaced by PVC pipes. In the study area, corrosivity ratio ranges between 0.732 epm (S27: Nalanganallur) and 10.48 epm (S76: Valarpuram) during pre-monsoon season and during post-monsoon season it ranges between 0.82 epm (S32: Panamadangi) and 18.15 epm (S71: Banavaram) (Tables 1 and 13). The interpolated raster surface illustrates that the waters in the entire study area are found to be corrosive (>1 epm) except some pockets (<1 epm). During pre-monsoon season, some parts of Natrampalli and Gudiyatham blocks fall under corrosive nature of groundwater (>1 epm) and during the time of post-monsoon season, some of the portions of Natrampalli, Pernambattu, Gudiyatham, K.V.Kuppam, Katpadi, Sholinghur and Kaveripakkam blocks and few pockets of Anaicut, Kaniyambadi and Arcot blocks were indentified as corrosive nature of groundwater (>1 epm).

Table 13. Corrosivity Ratio for Irrigation Water

Corrosivity Ratio (values in epm)	Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples
< 1	2	2.4	1	1.2
> 1	80	97.6	81	98.8

Analysis of Groundwater Suitability for Irrigation Purpose using Overlay Technique

The groundwater suitability for irrigation has been analysed by applying the formula given below and raster overlay techniques available in ArcGIS 9.3. The important ratios and indices (USSL's classification, Wilcox's classification, Doneen's classification, Permeability Index, Schoeller's Water Type, Magnesium Ratio, Sodium Adsorption Ratio, Residual

Sodium Carbonate, Non-Carbonate Hardness, Kelley's Ratio, Corrosivity Ratio etc.) are considered to evaluate the groundwater for agriculture purpose.

Table 14. Parameters Used in Overlay Analysis for Irrigation Water Quality Zones

Parameters	Pre-monsoon		Post-monsoon	
	Classes	Ratings	Classes	Ratings
USSL's Diagram	Good	9	Good	9
	Moderate	6	Moderate	6
	Poor	4	Poor	4
	Very Poor	2	Very Poor	2
Wilcox's Diagram	Excellent-Good	10	Excellent-Good	10
	Good-Permissible	8	Good-Permissible	8
	Permissible-Doubtful	6	Permissible-Doubtful	6
	Doubtful-Unsuitable	4	Doubtful-Unsuitable	4
	Unsuitable	2	Unsuitable	2
Doneen's Diagram	Class I	9	Class I	9
	Class II	6	Class II	6
	Class III	3	Class III	3
Permeability Index	Maximum	9	Maximum	9
	Moderate	6	Moderate	6
	Minimum	3	Minimum	3
Schoeller's Water Type	Type – I	9	Type – I	9
	Type – II	7	Type – II	7
	Type – IV	3	Type – IV	3
Magnesium Ratio	Suitable	10	Suitable	10
	Permissible	6	Permissible	6
	Doubtful	4	Doubtful	4
	Unsuitable	2	Unsuitable	2
Sodium Adsorption Ratio	Excellent	10	Excellent	10
	Good	8	Good	8
	Permissible	6	Permissible	6
	Unsuitable	2	Unsuitable	2
Residual Sodium Carbonate	Good	10	Good	10
	Moderate	6	Doubtful	6
	Poor	2	Unsuitable	2
Non-Carbonate Hardness	Suitable	8	Suitable	8
	Unsuitable	3	Unsuitable	3
Kelley's Ratio	Suitable	8	Suitable	8
	Unsuitable	3	Unsuitable	3
Corrosivity Ratio	<= 1	8	<= 1	8
	> 1	3	> 1	3
Total Dissolved Solids	<= 1,000 mg/l	10	<= 1,000 mg/l	10
	1,000.1 – 3,000 mg/l	6	1,000.1 – 3,000 mg/l	6
			> 3,000 mg/l	2
Total Hardness	<= 300 mg/l	10	<= 300 mg/l	10
	300.1 – 600 mg/l	8	300.1 – 600 mg/l	8
	600.1 – 900 mg/l	6	600.1 – 900 mg/l	6
	900.1 – 1,200 mg/l	4	900.1 – 1,200 mg/l	4
	> 1,200 mg/l	2	> 1,200 mg/l	2

Further, these parameters are reclassified with ratings ranging from 10 (highly suitable) to 2 (highly unsuitable). The formula given below is applied and the parameters are reclassified for overlay operation using raster calculator (Table 14).

$$IWQ_i = \sum_{i=1}^{14} (R_i)$$

where, IWQ_i = Irrigation Water Quality Index for a mapping unit

R_i = Rating factor for parameter $_i$

The overlay operation is carried out on different indices and ratios to identify the suitability of groundwater quality for irrigation purpose. The area covered by highly suitable level of groundwater quality for irrigation purpose (77 – 85.8 and 71 – 82.2 of index values during pre- and post-monsoon seasons) are observed in 223.4 sq.km and 249.8 sq.km (5.5% and 6.1% of the investigated area) of the investigated area (study area excluding hills and reserved forests) during pre- and post-monsoon seasons respectively. The suitable level (85.81 – 94.6 and 82.21 – 93.4 of index values during pre- and post-monsoon seasons) of groundwater quality is identified in 829.3 sq.km and 1,086.8 sq.km of areas (20.3% and 26.7% of the investigated area) during pre- and post-monsoon seasons respectively and the moderately suitable level (94.61 – 103.4 and 93.41 – 104.6 of index values during pre- and post-monsoon seasons) is found in 2,185.2 sq.km and 1,810.4 sq.km of areas during pre- and post-monsoon seasons respectively. During pre-monsoon season, the unsuitable (103.41 – 112.2 of index values) and highly unsuitable (112.21 – 121 of index values) levels are found in 592.3 sq.km and 246.8 sq.km of areas (14.5% and 6.1% of the investigated area) respectively. During the time of post-monsoon season, the unsuitable (104.61 – 115.8 of index values) and highly unsuitable (115.81 – 127 of index values) levels are found in 829.9 sq.km and 100.1 sq.km (20.4% and 2.5% of the investigated area) of areas respectively in the total investigated area (Table 15).

Table 15. Groundwater Suitability for Irrigation Purpose

Classification of Groundwater for Irrigation Purpose	Spatial Extent of Dominance			
	Pre-monsoon		Post-monsoon	
	Area in sq.km	% of Area	Area in sq.km	% of Area
Highly Suitable	223.4	5.5	249.8	6.1
Suitable	829.3	20.3	1086.8	26.7
Moderately Suitable	2185.2	53.6	1810.4	44.4
Unsuitable	592.3	14.5	829.9	20.4
Highly Unsuitable	246.8	6.1	100.1	2.5

The interpolated raster surface explains that during pre-monsoon season, the highly unsuitable and unsuitable levels of groundwater quality are found in southern portions of Kandhili, Madhanur and Katpadi blocks; some parts in Tiruppathur, Alangayam, Pernambattu, K.V.Kuppam, Vellore, Sholinghur, Arcot, Timiri and Walajapet blocks; and a few small pockets in Anaicut, Kaniyambadi and the eastern portions of Arakkonam blocks. Highly suitable and suitable levels of groundwater quality are found in some potions in Jolarpet, Natrampalli, Gudiyatham, Katpadi and Arcot blocks; and as small pockets in Kandhili, Tiruppathur, Anaicut, Sholinghur, Kaveripakkam and Arakkonam blocks. The remaining vast portion of area falls under moderately suitable level of groundwater quality for irrigated agriculture (Figure 12).

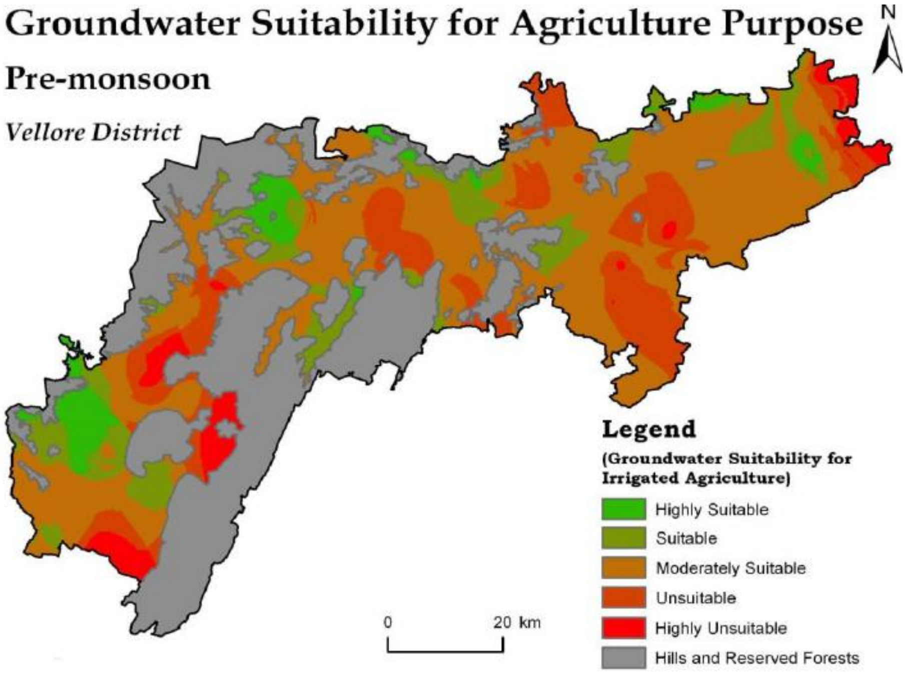

Fig. 12. Classification of Groundwater Suitability for Agriculture Purpose – Pre-monsoon

During post-monsoon season, most of the portions in the western half of the study area are found with highly unsuitable and unsuitable levels. The areas that fall under highly unsuitable and unsuitable levels are Kandhili, Jolarpet, Tiruppathur, Alangayam, K.V.Kuppam and Vellore blocks; Kaveripakkam and Arakkonam blocks; and as a small pockets in Natrampalli, Pernambattu, Gudiyatham, Katpadi, Sholinghur, Walajapet and Timiri blocks.

On the other hand, highly suitable and suitable levels are found in parts of Natrampalli, Pernambattu, Katpadi, Kaveripakkam and Sholinghur blocks; southern portion of Anaicut block and western portion of Arcot blocks. The remaining portions are dominated with moderately suitable of groundwater quality for irrigated agriculture (Figure 13).

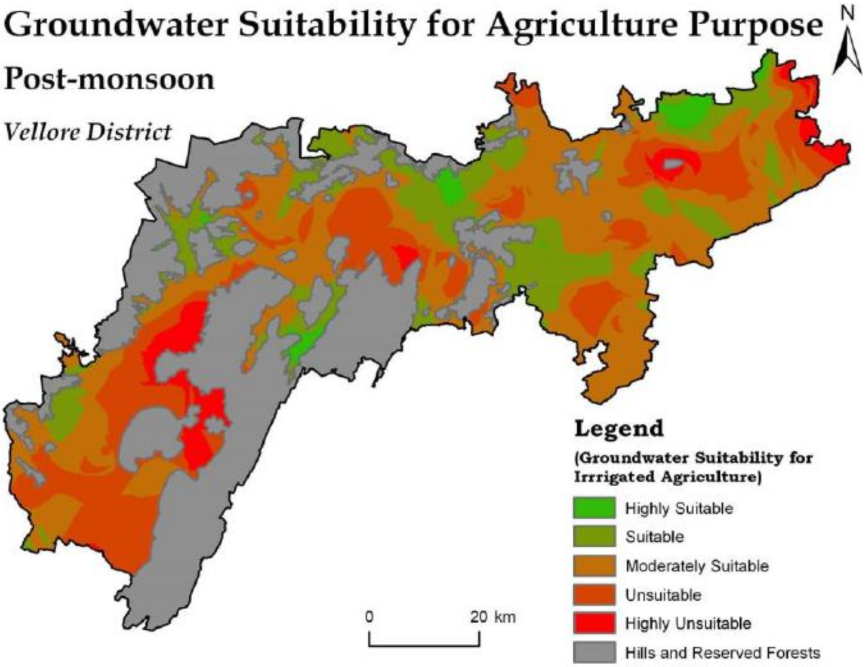

Fig.13. Classification of Groundwater Suitability for Agriculture Purpose – Post-monsoon

Conclusion

The groundwater quality of the study area is evaluated for its suitability to irrigation purposes by analysing 82 groundwater samples to understand the concentrations of major cations and anions. The groundwater suitability for irrigation purpose is examined by analysing the irrigation water quality parameters using the USSL's, Wilcox's, Doneen's methods, permeability index, Schoeller's water type, magnesium ratio, sodium adsorption ratio, residual sodium carbonate, non-carbonate hardness, Kelley's ratio and corrosivity ratio. These results are reclassified by assigning ratings and weights as per the importance given to each and every parameter of the groundwater samples. The final raster layers have been generated by performing overlay techniques in ArcGIS software and they illustrates that during pre-monsoon season, 5.5% (223.4 sq.km) and 20.3% (829.3 sq.km) of the investigated area are classified as highly suitable and suitable areas of groundwater quality (dominantly in Jolarpet, Natrampalli, Gudiyatham, Katpadi and Arcot blocks) for irrigated agriculture respectively. The areas that fall under unsuitable and highly unsuitable levels are found in 14.5% (592.3 sq.km) and 6.1% (246.8 sq.km) of the investigated area (Kandhili and Madhanur blocks) respectively. The remaining 53.6% (2,185.2 sq.km) of the investigated area falls under moderately suitable levels. During post-monsoon season, the results reveal that 6.1% (249.8 sq.km) and 26.7% (1086.8 sq.km) of the investigated area fall under highly suitable and suitable levels of groundwater quality (dominantly Natrampalli, Pernambattu, Katpadi, Kaveripakkam and Sholinghur blocks) for irrigated agriculture respectively; 20.4% (829.9 sq.km) and 2.5% (100.1 sq.km) of the investigated area are classified as unsuitable and highly unsuitable levels respectively (Kandhili, Jolarpet, Tiruppathur, Alangayam, K.V.Kuppam and Vellore blocks); and the remaining 44.4% (1,810.4 sq.km) of the investigated area is found under moderately suitable level of groundwater quality for irrigation purpose.

During pre-monsoon season, the unsuitable quality of groundwater is found with 20.6% of samples, suitable quality is identified with 25.8% of samples and the remaining samples are categorised as moderate quality. At the time post-monsoon season, the unsuitable quality of groundwater is found with 22.9% of samples whereas the suitable quality is identified with 32.8% samples. At last, the groundwater quality in post-monsoon season is considered as better quality and the suitable quality of groundwater for irrigation purpose is identified in Jolarpet, Natrampalli, Pernambattu, Gudiyatham, Katpadi, Arcot, Kaveripakkam and Sholinghur blocks. The unsuitable quality of groundwater is found in Kandhili, Jolarpet, Tiruppathur, Alangayam, Madhanur, K.V.Kuppam and Vellore blocks.

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LANDUSE / LAND COVER CHANGE DETECTION IN KUMBAKONAM TALUK, TAMIL NADU: A GEOINFORMATICS APPROACH

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Abstract

Landuse / land cover changes is one of the major components which approach for managing natural resources and monitoring environmental changes. The present natural resources, and the consequences of over exploitation of soil and water resources the land use, a land cover mapping and monitoring in the study area i.e. Kumbakonam Taluk. The present study has comprised of, satellite images for (March and November 1991 and 2006) were adopted for LULC (Landuse / Land Cover) map, and visual interpretation classification has been adopted with Five LULC classes. An Accuracy Assessment has done based on KAPPA index for the year 2006 satellite image, and Change Detection between both the images for all the land use and land cover classes were premeditated. The most widespread land cover changes of Kumbakonam Taluk's wasteland i.e. 37.70 %. The second most extensive land cover category is agricultural land, 27.15 %. The overall accuracy of classification is 80.5 percent.

Keywords: Landuse / land cover, Satellite data, Classification, Change detection

Introduction

Land cover is a disconnected term which often designates vegetation, natural or man-made features on the Earth's surface at a specific time of observation (Campbell, 2002). Generally, land cover shows the visible evidence of land use, to include both vegetated and non-vegetated features. Although land cover is used interchangeably with land use, there exists a clear distinction between the two since land use involves human beings taking full control of land for economic purposes. Whereas, land cover refers to all what is on the land, for example; dense forest, grasslands, ploughed land, urban structures and others (Campbell, 2002). A change in land cover has grown topically from research to environmental monitoring, planning and management. Land use and land cover dynamics are widespread, accelerating, and significant processes driven by human actions but also producing changes that impact humans (Agarwal et al., 2002). These dynamics alter the availability of different biophysical resources including soil, vegetation, water, animal feed and others. Consequently, land use and cover changes could lead to a decreased availability of different products and services for human, livestock, agricultural production and damage to the environment as well.

Land use is obviously constrained by environmental factors such as soil characteristics, climate, topography, and vegetation. But it also reflects the importance of land as a key and limited resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchment and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth. Often improper Land use is causing various forms of environmental degradation. Often improper Land use is causing various forms of environmental degradation. For sustainable utilization of the land ecosystems, it is essential to know the natural characteristics, extent and location, its quality, productivity, suitability and limitations of various land uses. Land use is a product of interactions between a society's cultural background, state, and its physical needs on the one hand, and the natural potential of land on the other. In order to improve the economic condition of the area without further failing the bio-environment, every bit of the available land to use in the most rational way.

Study Area

Kumbakonam is one of the oldest towns in Tamilnadu and is famous for its Mahamaham festival. In the 7th Century it was the Capital of Chola Kings. Kumbakonam, the famous temple town of South India, is attractively located among the two rivers, Cauvery and Arasalar. Kumbakonam is the temple city of South India situated in Thanjavur district of Tamil Nadu. It is primarily a market town for the predominantly agriculture-based villages surrounding. Kumbakonam is a busy, dusty commercial centre, nestled along the Cauvery River some 37 km northeast of Thanjavur. Kumbakonam is located at 10.97°N 79.42°E and it lies in the region called the 'Old delta' which comprises the north-western taluk of Thanjavur district that have been naturally irrigated by the waters of the Cauvery and its tributaries for centuries in contrast to the 'New Delta' comprising the southern taluks that were brought under irrigation by the construction of the Grand Anicut canal and the Vadavar canal in 1934. It has an average elevation of 26 metres (85 ft). The town is bounded by two rivers, the Cauvery River on the north and Arasalar River on the south.

Although the Cauvery delta is usually hot, the climate of Kumbakonam and other surrounding towns is generally healthy and moderate. The town of Kumbakonam is surrounded by extensive paddy fields.

Database and Methodology

The GIS provides new tools for mapping the landscape; land use and land cover are quite different; they are frequently taken together on a single map. Land use and land cover is very different ways of looking at the land: The use of remote sensing and Geographical Information System (GIS-Centre) for mapping land use and land cover change detection has drastically grown Land use and land cover change detection mapping techniques are highly developed using GIS. Whereas, land cover change analysis techniques are applied based on analysts' preferences. Therefore, Visual image interpretation technique adopted for satellite image classification these techniques are also classified as pre-and post-classification as well as spatial and temporal trajectory analysis well defined with help of geospatial analysis. Furthermore, land cover change detection has been carried out using the GIS techniques. Visual image interpretation technique adopted for satellite image classification

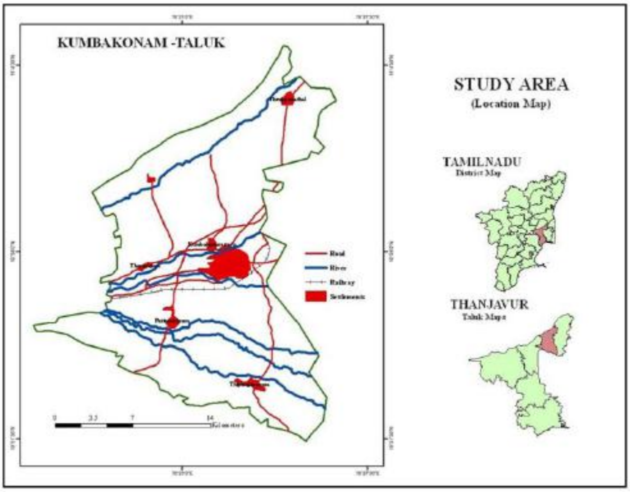

Fig. 1. Study Area - Kumbakonam Taluk

Results and Discussion

Land Cover

- The vegetative, barren, liquid or artificial (human-made) material covering the land.
- Land cover can be interpreted from aerial photographs or satellite imagery with varying degrees of accuracy.

Landuse

- The actual use of the land by its human inhabitants.
- Land use may at times be based on property boundaries (as in a municipal park), but the actual use of the land will not necessarily correspond to land ownership

Geographical Information System (GIS) is feasible to view land use and land cover in combined data layer, or as separate data layers. Some individual land use categories will be developed as GIS data layers completely separate from land use/cover mapping. For example, surface waters and wetlands, both components of a land cover map, are being developed as separate data layers. A land use/cover mapping project should make use of existing data layers when possible

Among the various assessment methods, the most efficient and widely used *error* *matrix* for image classification is used in the analysis. The accuracy of classification is enhanced by field verification. Latest satellite data has been considered for accuracy assessment in the year of 2006. Therefore, overall 44 sites are verified by the researcher, spreading over 35 places for agriculture and other uses along the Kumbakonam Taluk. 3 places were visited for built up, and 3 areas have been selected from the current fallow land too, 5 sites for chosen from waste land and finally, 2 sites are selected from waterbodies for verified, based on the completion of the ground truth verification. The errors found are recorded and its modification on the classified imageries have been made.

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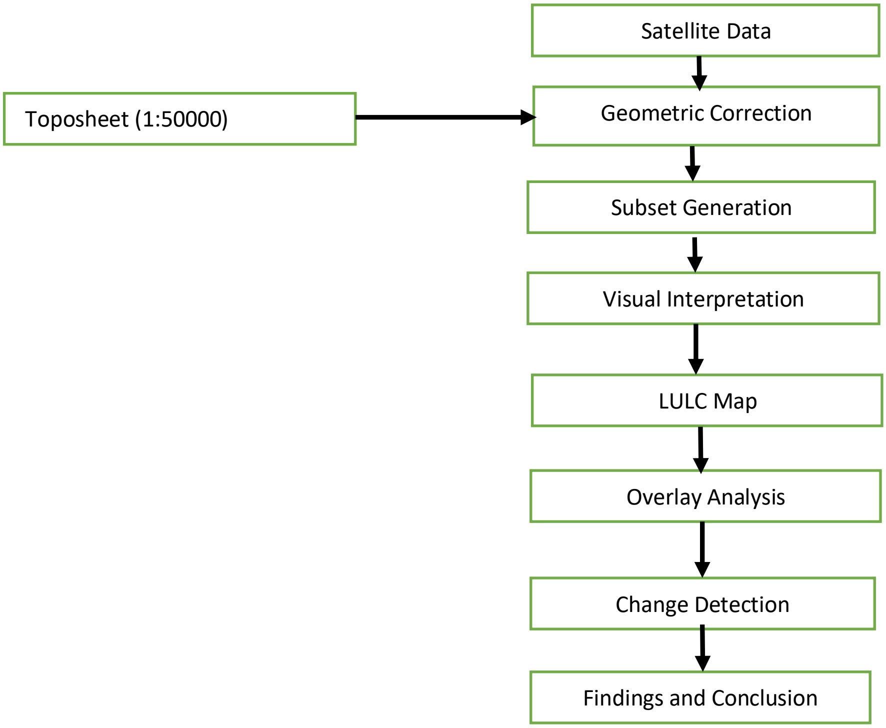

Fig. 2. Methodology Flow Chart

The error matrix and Cohan's Kappa (k) index calculated to measure the accuracy of classification. The error matrix is a square array of rows and Cohmn's in which row and each column represents one habitat category in the classification. Each cell comprises the number of sampling sites (pixels or group of pixels) which has given a particular land use category. Usually the columns consist of reference data and rows from the source satellite imageries.

$$\kappa = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}$$

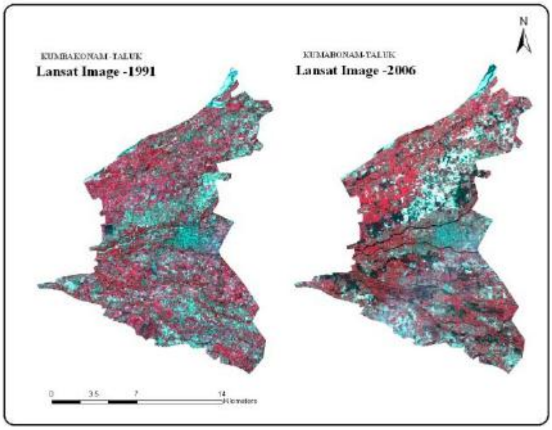

Fig. 3. Landsat TM Satellite Images

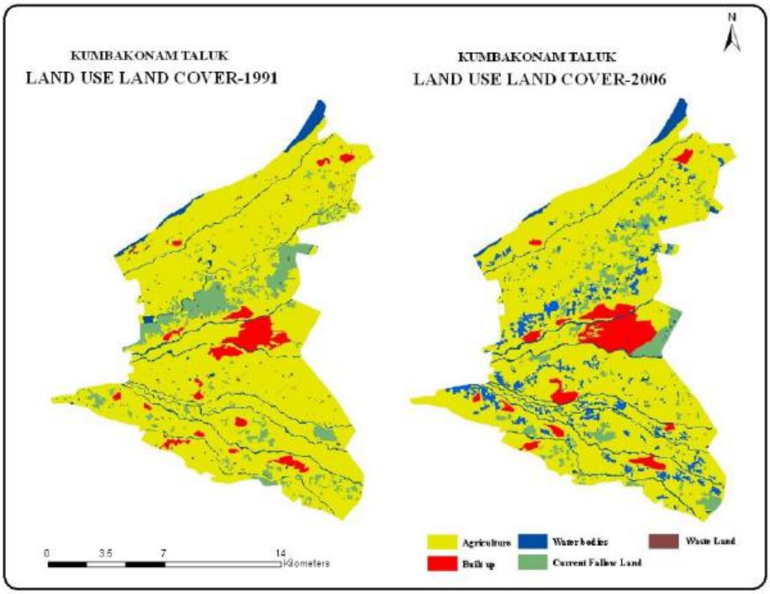

Fig. 4. Landuse / Land Cover

Table 1. Accuracy Assessment of Classified Image

	Agriculture	**Built Up**	**Current Fallow Land**	**Waste Land**	**Water Bodies**	**Total**	**User Accuracy**
Agriculture	25	1	1	1		28	83.33
Built up		3				3	100
Current fallow land		1	3			4	75
Waste land		1		5		6	83.33
Water bodies				1	2	3	66.66
Total	25	6	4	7	2	44	
Producer Accuracy	100	50	75	71.42	100		80.5

where, *N* is the total number of sites in the matrix, *r* is the number of rows in the matrix, *xii* is the number in row *i* and column *i, x+i* is the total row and *i, xi+* is the total for column *I* (Jensen, 1996). Kappa analysis is discrete multivariate technique which is used to assess classification accuracy from error matrix, kappa analysis generates a kappa coefficient that has a possible range from 0 to 1. Kappa index is less than the overall accuracy unless the classification is very good.

Analysis of Land use / Land cover changes

The Analysis of land use/land covers of Kumbakonam Taluk which is different time periods and it indicating the considerable changes. Primary land use is agricultural land and major changes have taken place particularly the built-up land and Waste land or current fallow area. In the spite of agricultural area has decreased by 10.89sq.km in the time period of 1991-2006. Water bodies also decreased 2.10sq km during this period. While built up area have increased 4.76sq.km respectively. Even though land use changes make known the differences in different periods. Agriculture land is a major source of utilization for other purposes.

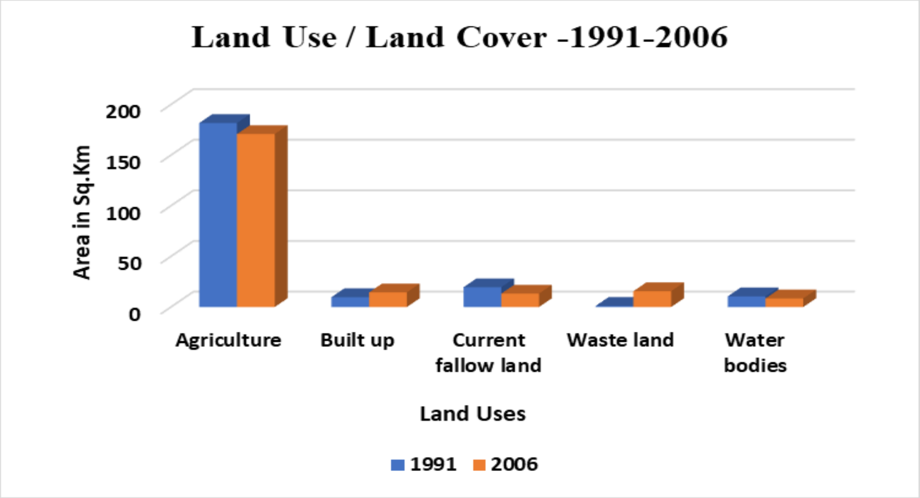

Fig. 4. Landuse / Land Cover

The development of 1991-2006 shows the area under paddy producer of agriculture land has decreased by 2.82 percentages during the 15 years fulfilling requirements of the growing population. Waste land also increased about 6.52 percentage, simultaneously, water bodies also decreased about 3.71 percentage over the past 15 years. The area under built up increased from 9.68sq km in 1991to 14.44 sq.km in 2006 by fulfilling the growing need of the urban population.

Table 2. Land use Types and Changes

Sl. No	Landuse Type	1991	2006	Change in sq.km	Change in (%)
1	Agriculture	181.734	170.841	10.89	28.15
2	Built up	9.683	14.446	-4.76	12.37
3	Current fallow land	19.507	13.222	6.29	16.32
4	Waste land	1.094	15.61	-14.52	37.70
5	Water bodies	10.552	8.451	2.10	5.46

Conclusions

The present study demonstrate that the Kumbakonam is an urban and rural area with mixed land cover/land use patterns that exhibits significant changes between 1991 to 2006. This research is exhibits detailed land use/Land use analysis of Kumbakonam. The main conclusions are that (i) the major land use/land cover categories of the Kumbakonam which comprises of cultivated lands, built up areas, current fallow land, waste land and waterbodies (iii) landuse / land cover types display variations in extent over the over the period cultivated lands and built up areas changing more drastically compared to the other land use categories. The results of land use/ land cover maps and change detection may be used to help an understanding the impact of several factors such as socio-economic trends and environmental changes in controlling the dynamics on land use changes. Furthermore, an understanding the drivers of land use changes might in turn contribute to model future evolution of land use patterns and future land use planning policies at the district or province level. Future research will focus on the identification of the drivers and impacts of land use / land cover changes.

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ASSESSMENT OF TRENDS AND VARIABILITY OF POST-MONSOON RAINFALL FOR SOME SELECTED DISTRICTS OF SUB-HIMALAYAN WEST BENGAL, INDIA

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Abstract

Post monsoon or the retreating monsoon season in West Bengal broadly coincides with two months namely October and November. The post-monsoon season is a period of transition between the south-west monsoon (June-September) and the dry cool winter (December-February). Many researchers have extensively studied the trends of Indian rainfall but the subject still remains complicated due to its high spatio-temporal variability. In the present study, an attempt has been made to identify the trend and variability of post-monsoon rainfall by analyzing monthly rainfall data of these two months (October and November) of some selected districts of sub-Himalayan West Bengal.

Keywords: Spatio-temporal variability, Surface run off, Water conservation, Rainfall anomaly

Introduction

Climate change is considered as the foremost global Challenge that the human beings are facing at the moment, even though it seems that not all places on the globe are affected (Obot et al. 2010). Shift of climatic conditions in a directional incremental mode is considered as climate change where values of climatic elements change significantly (Unganai 1996). West Bengal is considered as an agro-based state of India. The State is characterized by diverse natural resources and varied climatic conditions which provide a congenial situation for cultivation of a wide range of crops. A large number of crops are cultivated with the help of post-monsoon rainfall. The tropical cyclones which form over Bay-of-Bengal during this time create huge amount of rainfall over the coastal areas of West Bengal. Sometimes, these cyclones remain stationary stationary over a particular place and cause coastal flooding.

For the present study, six districts namely Darjiling, Jalpaiguri, Koch Bihar, Maldah, Uttar Dinajpur and Dakshin Dinajpur have been selected from the sub-Himalayan West Bengal where the primary source of livelihood is agro-based and cultivation of almost all the major crops depends on timely occurrence of rainfall. On an average, this region receives more than 75% of rainfall during monsoon season. During post monsoon there is basically no source of rainfall in West Bengal except in the coastal areas.

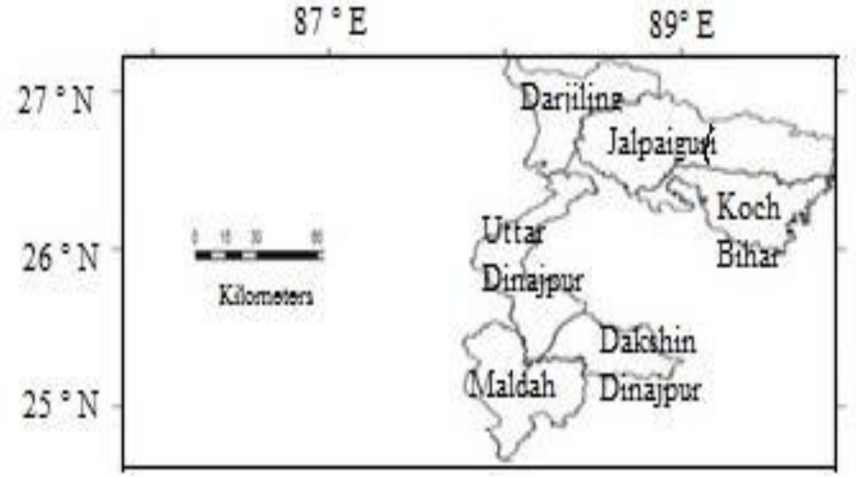


Fig. 1 Location of the Study Area

The retreating monsoon wind over the Bay of Bengal pick up moisture on their way and creates rainfall over Orissa, Tamil Nadu and some adjoining states. Overall economic and social well being of India is determined by the agricultural activities of the country (Mall et al. 2006). It may not be out of place to mention weather and climate variability has greater impacts on crop production. In addition, of course farming communities are aware of it. Under this situation, study of rainfall trend and its variability should be the priority of agro-climatic research. Rainfall is a climate parameter that not only affects the way and manner man lives but also controls every facet of the ecological system, flora and fauna inclusive (Obot et al. 2010). In this regard, the study of annual, seasonal and monthly rainfall will be helpful for understanding. A number of studies have been carried out for the assessment of trend and variability of rainfall (Fauchereau et al. 2003; Longobardi and Villani 2009; Mary and Majule 2009; Obot et al. 2010; Unganai 1996). So, keeping the above points in view, in the present study an attempt has been made to identify the trend and variability of post-monsoon rainfall of some selected districts of sub-Himalayan West Bengal.

Database and Methodology

For the present study, monthly rainfall data of the six districts namely Darjiling, Jalpaiguri, Koch Bihar, Maldah, Uttar Dinajpur and Dakshin Dinajpur have been collected from Agricultural Meteorology Division of the State Agriculture Department, Government of West Bengal and India Meteorological Department through the Indian water-portal website (http://www.indiawaterportal.org/). The data was analyzed on monthly basis and statistical parameters like standard deviation, coefficient of variability (CV) were determined. Rainfall anomaly has been calculated to show monthly rainfall departure from the mean rainfall. Statistical techniques viz. moving average and semi average methods have been used to investigate how the trend of rainfall has sequentially changed over the time period of 50 years (1961-2010) during post-monsoon.

Results and Discussions

Variability of rainfall

Coefficient of variation of rainfall, a relative measure of dispersion, is computed for the post-monsoon months of October and November. During November, most of the stations report high variability of rainfall. It is found that the rainfall variability is excessively high in Uttar Dinajpur and Dakshin Dinajpur districts. One of the most important feactures of the post-monsoon rainfall is its inter annual variability. In the month of November of post monsoon season, all the stations (excluding Jalpaiguri) report more than 100% variability.

The average post monsoon rainfall of these six districts was found to be 63.72 mm which ranges from 107.8 mm (lowest) over Uttar Dinajpur to 141.31 mm (highest) over Jalpaiguri with standard deviation (SD) of 54.54 mm and coefficient of variability (CV) of 96.14 %. Highest and lowest values of CV during these two months are found over Dakshin Dinajpur (108.24%) and Koch Bihar (92.41%) respectively.

Table 1. SD and CV of post-monsoon rainfall in the six districts (1961-2010)

Districts	Months			
	October		November	
	SD	CV	SD	CV
Darjiling	89.30	81.65	11.2	108.48
Jalpaiguri	116.5	88.71	9.75	97.63
Koch Bihar	99.58	76.3	8.96	108.51
Maldah	90.70	79.55	10.42	106.54
Uttar Dinajpur	74.31	75.27	10.40	114.6
Dakshin Dinajpur	120.77	98.52	12.63	117.95

Trend of Post-monsoon rainfall

Variations and fluctuations of rainfall from one place to another needs to be studied for proper agricultural planning.These four districts, on an average, experienced excessive post-monsoon rainfall in 1968, 1985, 1987 and 2009. Analysis of rainfall data of individual district revealed that all the studied districts of sub-Himalayan West Bengal experience maximum amount of rainfall in October. The linear trend of post-monsoon rainfall for the selected districts during the period 1961 to 2010 are represented in Figure 2 and 3.

It is found that the post-monsoon rainfall shows highest increasing and decreasing trend over Dakshin Dinajpur and Uttar Dinajpur respectively. All the districts exhibit decreasing trend of post-monsoon rainfall in the month of November. It is found that the district Dakshin Dinajpur shows highest increasing trend of 1.66 mm/year followed by Maldah (1.46 mm/year), Koch Bihar (0.62 mm/year) and darjilling (0.56 mm/year) in October.

Post-monsoon rainfall over Jalpaiguri shows a rising trend of 0.44 mm/year in the month of October while decreasing trend at the rate of -0.01mm/year is noticed in the month of November. District Uttar Dinajpur shows lowest increasing trend of Post-monsson rainfall in October at the rate of 0.18 mm/year. Decreasing trend of rainfall during November is found at the rate of 0.1 mm/year over Uttar Dinajpur followed by Dakshin Dinajpur (0.09 mm/year), Koch Bihar and Maldah (0.06 mm/year).

Table 2. Trend of rainfall and its anomaly in the study area (1961-2010)

Districts	**Rainfall trend**		**Rainfall anomaly**	
	Months			
	October	**November**	**October**	**November**
Darjiling	Sharp increase	Slight decline	Sharp increase	Remain same
Jalpaiguri	Sharp increase	Slight decline	Moderate increase	Slight decline
Koch Bihar	Sharp increase	Sharp decline	Sharp increase	Sharp decline
Maldah	Sharp increase	Sharp decline	Sharp increase	Sharp decline
Uttar Dinajpur	Moderate increase	Sharp decline	Moderate increase	Sharp decline
Dakshin Dinajpur	Sharp increase	Sharp decline	Sharp increase	Sharp decline

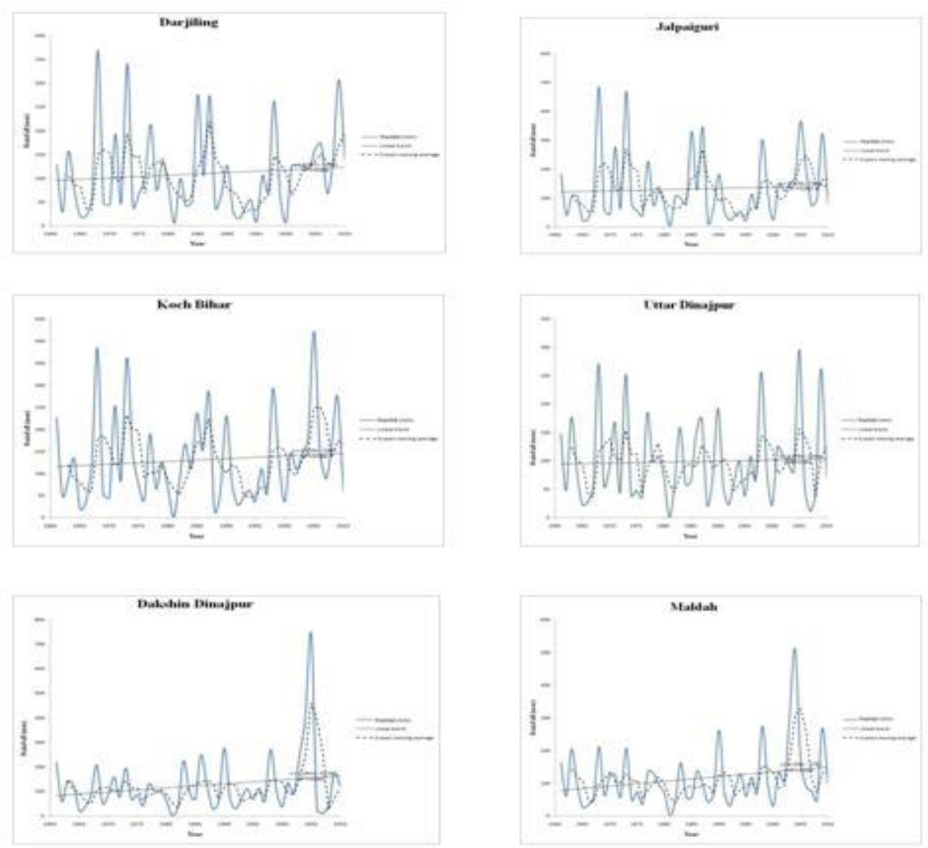


Fig. 2. Trend of Rainfall During October

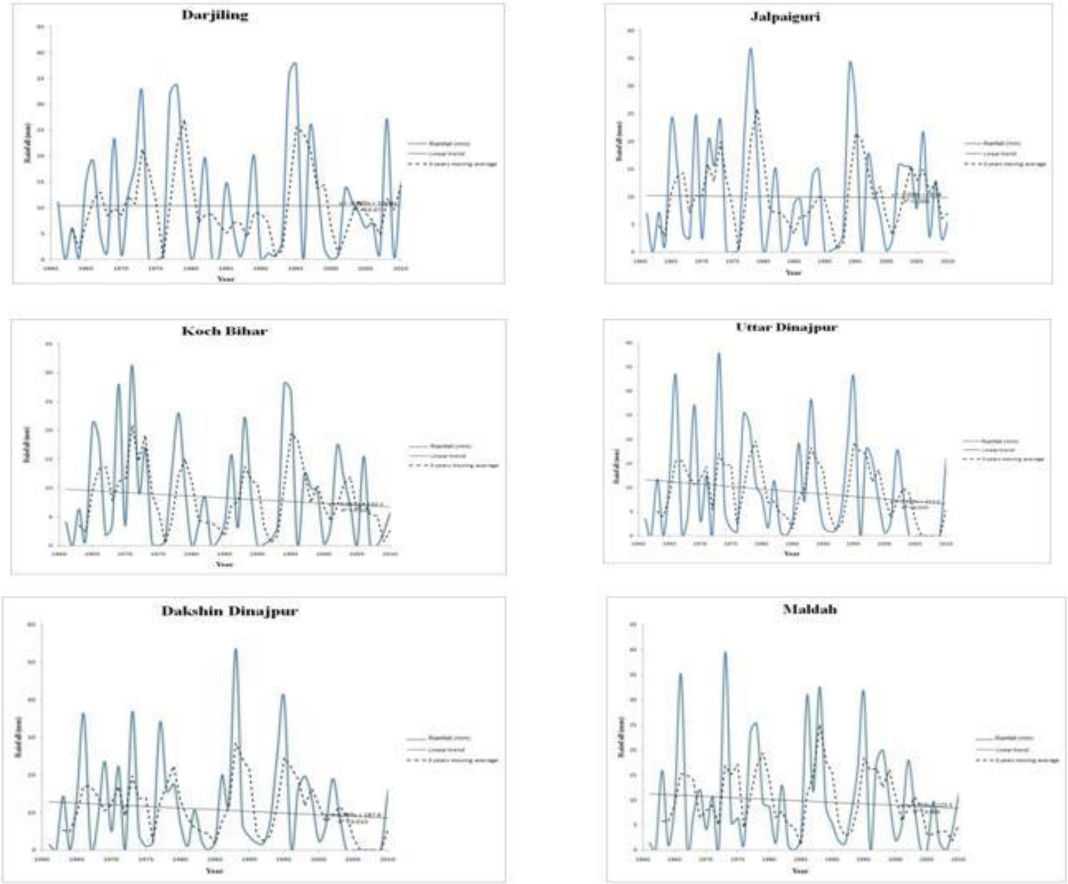
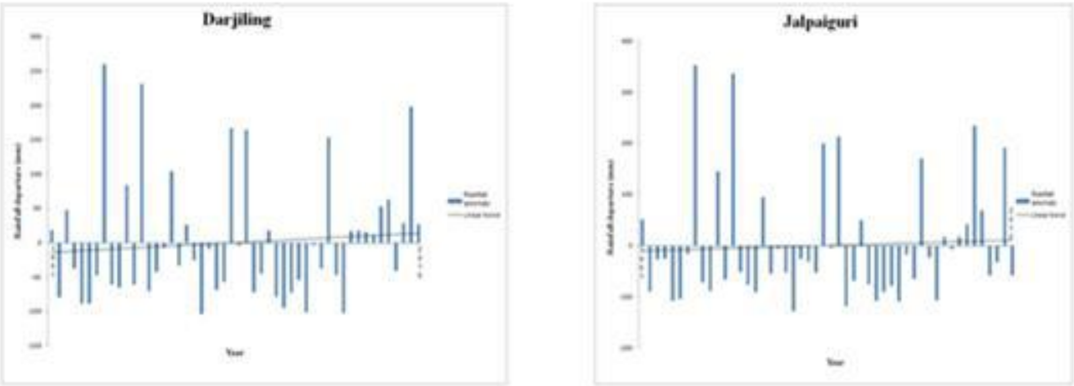


Fig. 3. Trend of Rainfall During November



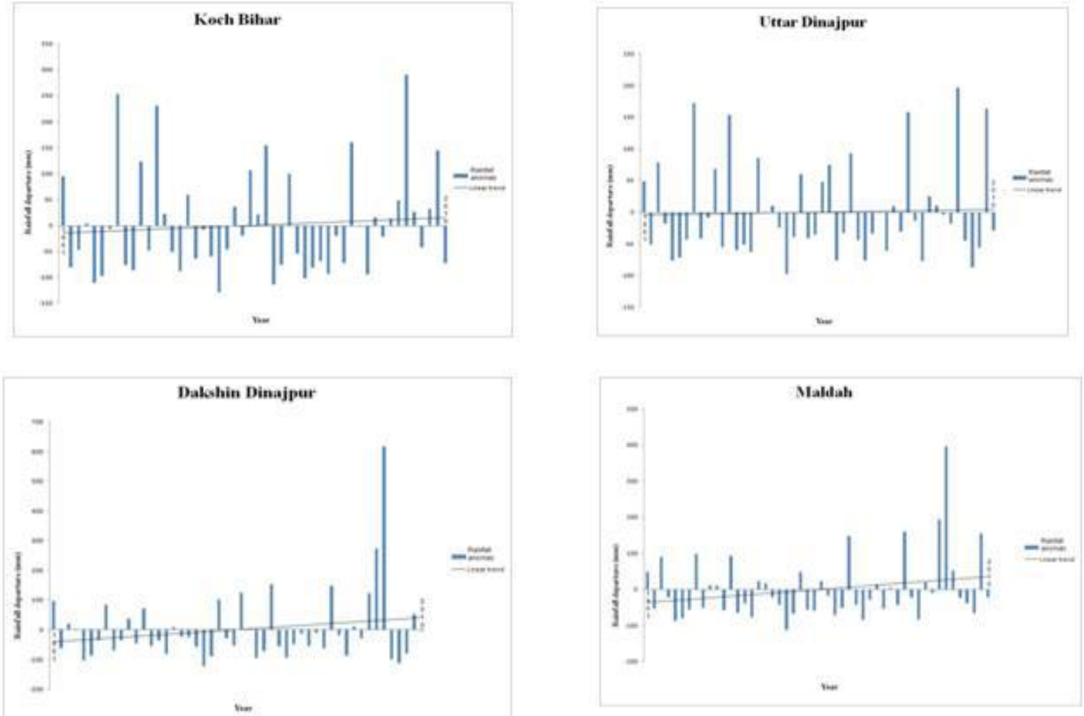
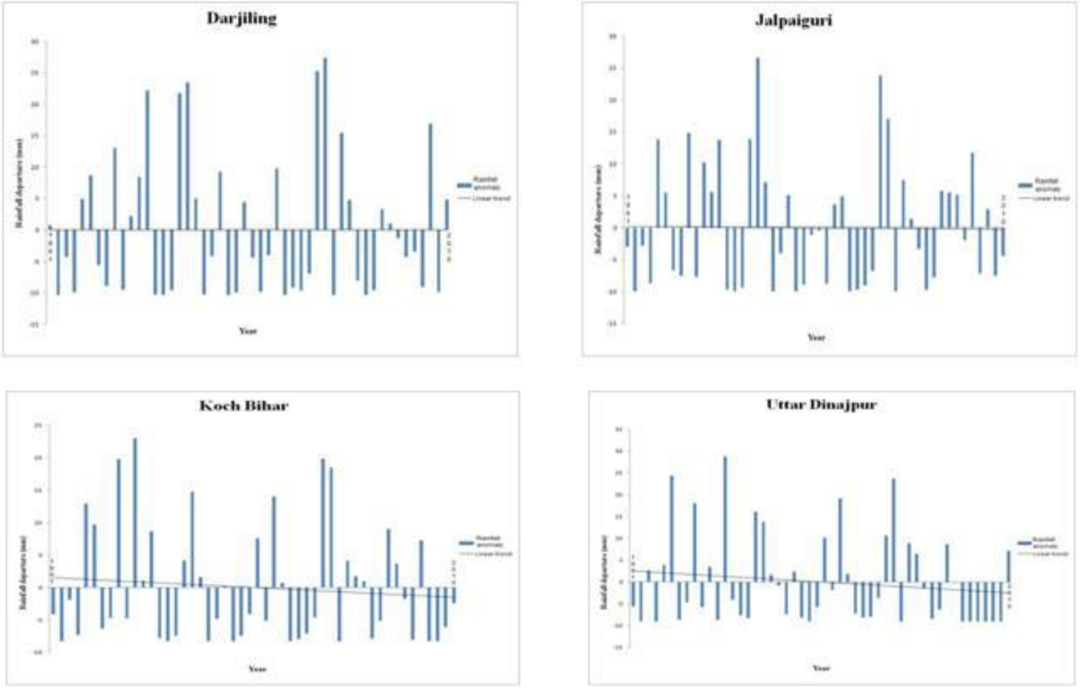


Fig. 4. Trend of Rainfall Anomaly During October



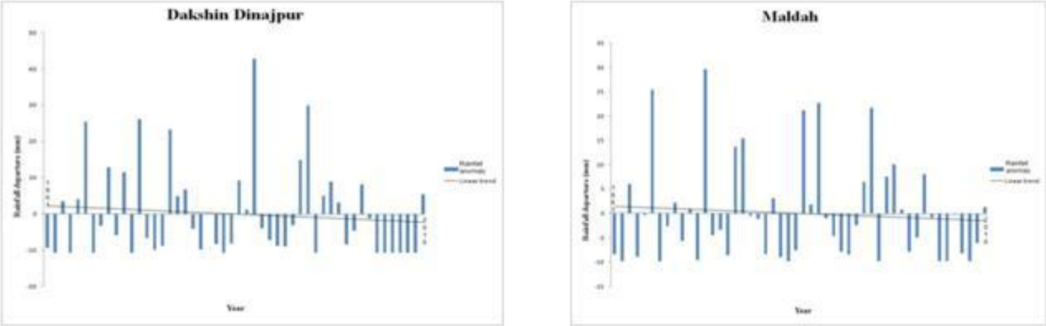


Fig. 5. Trend of Rainfall Anomaly During November

Rainfall anomaly

Figure 4 and 5 depict the trend of rainfall anomaly for the period 1961 to 2010. All the districts show increasing trend of rainfall anomaly during October while declining trend is noticed during November in all the districts of sub-Himalyan West Bengal except Darjiling where rainfall anomaly exhibits no clear trend.

Conclusion

Detailed knowledge of rainfall of an area is helpful for the planning of crop calendar. It may not be out of place to mention that meteorological factors influence and control agricultural activity starting from variety selection to the final stage of harvesting. So, an efficient and scientific management of these factors will be the best option for the proper utilization of the limited land resource.

Growing and harvesting of almost all the major crops depends on timely occurrence of post-monsoon rainfall. The present study concluded that the studied districts of sub-Himalayan West Bengal showed substantial changes in rainfall pattern during last 50 years i.e. from 1961 to 2010. A large data set was used, consisting of six districts with the length of data series of 50 years. One of the most important feactures of the post-monsoon rainfall is its inter annual and spatial variability. Nearly all the studied districts show rising and decreasing trend of rainfall in the month of October and November respectively. The excessive rainfall during post monsoon particularly in October may produce severe yield loss.

With the frequent change of post-monsoon rainfall, rescheduling of crop calendar and crop combination of post-monsoon season utilizing normal weather requirement of crop and actual weather data is inevitable for the synchronization of crop need and actual weather. The main strategy of mitigation should be the conservation of excess water which moves as surface run off after satisfying the need of evapotranspiration and its scientific use.

Acknowledgment

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A STUDY ON SACRED GROVES IN PUDUKOTTAI DISTRICT, TAMIL NADU

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Abstract

Natural resources are the base on which economic development is achieved. These resources may be available domestically and/or imported from other countries. The primary aim of the study is to understand the interrelationship between the social values and resource use pattern. The social values might very much differ across the villages and regions. As a case study, Mandayaur village in Pudukkottai District, a dry region, was chosen to assess the factors conditioning the resource use patterns. The basic natural resources are land, water and air. All these resources are gradually entering into the cruel hands of markets. This will certainly lead to unequal use of these resources - i.e. poor may be deprived of these resources, while the rich ones are likely to waste them. In this situation, to understand the background, data regarding these resources have been collected and presented for Pudukkottai District and for Mandayur village. The social system, values and resource use pattern have been analyzed for Mandayur village, a representative village of Pudukkottai District. It is found that in Pudukkottai District and in many other dry districts of Tamil Nadu, the sacred groves continue to be available, thanks to the existence of god-fear among the local people. These groves are very helpful in maintaining the ecological balances and hence they are very important (though not in monetary terms) for the villagers. They contain a lot of wealth for which economic values are yet to be assessed. In the absence of interest, appropriate knowledge, skill and technology, some amount of wealth of these sacred groves appear to decay and go waste. If government could take suitable steps, enormous amount of hidden wealth in these groves can be saved and utilized for economic development without making any loss to the sacred groves.

Keywords: Natural resources, Sacred groves, Land use pattern, Village gods / goddesses, Ecological balance, Social values

Introduction

The role played by natural resources in a country's economic development cannot be over emphasised. These resources are the base on which economic development is achieved. However, there are some exceptions (like Japan), which have achieved faster economic development without strong natural base of its own. If the human population is also considered as natural resources, obviously Japan has very high quality natural resources. Some countries like the United States of America (USA) have utilised the natural resources of other countries for their development. This has been possible through the trade that was twisted in favour of the developed countries. The dominant economic, political and military powers of the developed countries have also helped the process. The major scope of this study however, is not to enter into the politics in the resource use pattern, but only to indicate as to how the locally available resources are important for achieving development.

The quality of natural resources available domestically or through trade determines the quantity and quality of production, consumption and life of the people. The quality of the natural resources is determined not only by the size of it but also by the way in which they are blended and utilised. Ideal combination for all regions can neither be suggested in one line, nor can be achieved easily. The exact proportion of the resources, that have to be blended to give higher level of sustainable development in the quality of life, cannot be given in any number; this may vary across the regions and seasons. However, it is always possible to suggest some required satisfactory proportion of blending that can give sustainable improvement in the quality of life. Whether our ancestors knew this proportion of blending or not, what they have left to us indicates that there must have been some knowledge about this, though not with every individual and though not in written form.

It may also be argued that they were not technologically sufficiently endowed with (like us!) to exploit (and damage) the natural resources, hence the resources were left unutilised or underutilised. The technology issue can be agreed upon. Yes, earlier there was no much of technology that can deplete, pollute and contaminate the natural resources. Surely, they lived by using less of the resources than what we do now. We use and exploit more resources and we leave little to our future generation (this is called intergenerational equity issue). For example, earlier the durability of a product was given importance in deciding production and demand i.e., durable goods [vessels, furniture] were produced and demanded more. Now more and more disposable goods are produced and demanded.

Earlier parents were happy in transferring their goods and assets to their next generation. Now current consumption is given more importance, future is given less importance. Here another argument may come up in the following lines; i.e. we are using up more natural resources or even exhausting some of them, but leaving much more accumulated scientific knowledge to our future generation, as compared to what was given to us. It may be true. However, the question is: do we leave to our next generation, what is needed by them to improve the quality of living? Then the question will be on the concept of "quality of living" itself. The space here may not permit us to elaborate the concept of 'quality of living' in this study; but can easily be known over by using the available secondary information, whether the quality of living has been improving generation after generation or not. The relevant statistics would show that the present position, as compared to the earlier position, in terms of both quantity and quality of the available natural resources, is unequivocally worse.

Now more and more resources (like fuel wood, water, air) have become economic goods; new resource owners emerge; free, natural and common properties have become private properties; supply and demand are manipulated; and prices are fixed in favour of upper-class people. Those who are unable to pay the market prices of these basic resources are isolated, secluded and marginalized and are thrown (into the "dustbin") out of the mainstream. Thus, the present kind of development may not benefit all equally-well, and would further lead to undesirable and still more unequal situations, even in terms of essential resources. Therefore, people would be forced to work more and earn more, through all possible [desirable and undesirable, legal and illegal, moral and immoral, healthy and unhealthy] ways for the very survival. Greater achievements will be difficult in a society where very survival is threatened or not secure.

As the natural resources are the necessity for life, besides the trend described above, now efforts are also being made to retain them. Natural resources may be classified chiefly as water, air and land. The land area is very much limited, though to some extent, it can be extended by reducing water covered area, and by using the land more intensively (like vertical houses, more than one crop, mixed crop). The lands are classified into a few categories; they include the land under forest, barren and un-culturable waste lands, culturable waste lands, lands under miscellaneous tree crops and groves not included in the net area sown. The forest area is further divided into reserved forest, protected forest and social forest. Governments are reported to have made much effort to afforest the waste lands. The effects of such efforts are mixed. In some areas, the survival rates are reported (as shown by the study done by the Department of Economics Bharathidasan University) to range between 8 per cent and 50 per cent [i.e.8 to 50 saplings have survived out of every 100 saplings planted by social forestry programmes]. Some studies [M V Nadkarni] show that though the area under forest have declined less sharply, the density of forest has declined more sharply. The deforestation has been mainly influenced by the demand for fuel wood from urban population. Trees may be cut by the poor people, but, necessarily to satisfy the demands from the richer sections. The effects of social forestry programs on rural economies have also been studied [N.S.Jodha]. While in some cases the villages have benefited, in many cases the benefits are not substantial. The benefits include some employment in the forest area and small amount of brush wood, when the trees are cut. But the negative effects are stated to be much stronger. They are reduction in grazing area, loss of fuel wood, gum etc..

The waste lands are of many types. It may be fallow [current and/or permanent], culturable and/or unculturable lands and land under miscellaneous tree crops and groves. In many villages sacred groves are very common. The wastelands are generally called so because they do not yield any revenue to the government. However, they are really not waste from the view-point of the villagers. Those lands are very useful to the villagers. They supply fuel wood, gum and fodder to the animals. In many villages, rabbit, deer, peacock etc. are common. They are often hunted for food. Many kinds of plants are also available, which are often utilised for medicine preparation.

Still the uses of many plants and animals are not understood by the so-called modern scientists. Thus, the so-called waste lands are very much useful, sometimes more useful than the other categories of lands.The sacred groves called Kovil Kaadugal in Tamil (in the study village it is called Chedi, which means plant in English) also are useful for the villagers not only directly servicing their needs but also in maintaining ecological balance. As these kinds of forests are called Kovil kaadugal, normally no villager is dare to cut trees from these kaadugal. It is believed that those who aim at destroying the forest would get some misfortune. This kind of protection is also there for the birds and animals living in those Kovil kaadugal.

Water supply is not as restricted as the land area is. Thanks to almost constant level of rainfall, water supply is not very much affected in the long run (though now water supply, as compared to the excessive demand for water for all purposes, including agricultural purposes, appears to be relatively less). The seasonal and spatial variation in the rainfall may be larger, but the annual rainfall has not varied much (Table 1). However after the advent of new seeds, chemical fertilizers and water pumping technologies in agriculture, industrial technologies and changes in the life style, the demand for water has increased over a period. As a result, water has entered into the market; price for water has been going up. Thus, the water has almost (like land) become a private property; it might soon lead to monopoly kind of market and highly unequal distribution of water use. While rich may be able to get more than sufficient amount of water (even to waste), the poor may not be able to fulfill even their basic requirements. As Michael Lipton pointed out in the first chapter of his book entitled "Why Poor People Stay Poor: Urban Bias...", while playgrounds get more than sufficient water, agricultural fields do not get even minimum water.

Table 1. Rainfall in Three Southern States

States	**Actual Rainfall (in cm)**				
	1951	**1956**	**1961**	**1966**	**1971**
Andhra Pradesh	107	135	103	100	69
Kerala	23	272	400	255	306
Tamil Nadu	93	97	92	115	103

Source: *A Social and Economic Atlas of India, p.60.*

In the villages even now, many tanks and small ponds are maintained, which are used as percolation ponds and for collecting rain water for the domestic and agricultural uses. Of late, it is reported that the farmers use more than required water for the fields due to the uncertainty in getting water. Now water has become a commodity. Efforts are being made to save, consume and protect water. The third major natural resource that is being threatened is air. The quality of air has certainly been coming down in the cities. In the villages, though larger vacant lands and tree covered lands are found, the use of chemical pesticides and insecticides have, to some extent, spoiled the quality of air. Thus, all the natural resources are now endangered. Under these circumstances, the present study makes an attempt to understand the natural resources position in a village in an agriculturally (also ecologically) backward region. The present study specifically aims at 1) understanding and explaining the natural resources position at present in Pudukkottai and particularly in Mandayur village and 2) showing how the believes (whether superstitions or scientific) have helped in maintaining the natural resources (sacred groves).

Database and Methodology

In order to understand the natural resource position and the value systems in villages, this study has chosen Mandayur village in Viralimalai block, Kulathur taluk, Pudukkottai District in Tamil Nadu. Macro level data relating to the quality of land, water, air and forest cover are available.

Results and Discussions

Land and Forests in the Study Area

Pudukkottai is one of the districts with very small proportion of land under forest, however (to adjust that deficiency, perhaps) with very large proportion of land area under miscellaneous trees and groves. Pudukkottai District came into existence in the year 1974. The reserve forests are located in 48 different places in this district and in 15 different places in Kulathur taluk, where the study village namely Mandayur is located. Protected forest is there in Kandharvakottai in Pudukkottai District. Normal annual rainfall in this district is around 90 centimeters, concentrated mostly in September, October and November months. In the years 1974 and 1979, the rainfall was as meagre as 45 cm., while in the years 1978 and 1983, it was well above the average rainfall levels. There are large number of wells and tanks. Tanks are classified as Cauvery-Mettur Project system tanks (171), Public Works Department tanks (860) and Panchayat union tanks (4,354). These tanks vary to a very large extent in terms of size and ayacut area. Many are small ponds, irrigating as small as 10 acres of lands. This may be the reason why the numbers of tanks given by different official sources do not tally with each other. Majority of the system tanks are found in Arantangi taluk. Many small tanks are found in Kulathur taluk, where the study village Mandayur is located. Social forestry scheme is very popular in this district, for which the tank beds are also utilised.

Though large proportion of land area is reported to be irrigated, the quality of irrigation is very poor in many villages, for the tanks there are mostly rain-fed. Well (open and bore), canals and tanks are used for irrigation purposes. The farmers (mostly smaller ones) are not interested in de-silting their tanks (kanmais), for their expected income from agricultural operations is not very attractive. In Pudukkottai District, paddy is the major crop, cultivated in about 90 thousand hectares i.e. about 20 per cent of the geographical area. Of which, 12 per cent is rain-fed paddy crop. Even in irrigated area, the crop failures are frequent. Next to paddy comes groundnut in terms of area under cultivation. About 47 thousand hectares of land is under groundnut (i.e. about 50 per cent of the paddy area). Gingelly is also seen very rarely. Millets are gradually vanishing from the scene. Hardly 2.5 per cent of the net area sown is cropped more than once. Major land categories in Pudukkottai District are land put to agricultural (26 per cent) and non-agricultural uses (27 per cent) and current fallows (23 per cent). The last category is so large in Pudukkottai District because of the poor rainfall and irrigation systems.

Soil condition is also very much unfavorable to the villagers. Soil available in this district is highly porous. Moisture capacity is very poor, which implies that even short spell in the middle of monsoon will affect the rain-fed crops. Major soil types are 1) Vayalogam soil series, 2) Pattukottai series 3) Madukkur series and 4) Avudayar koil series. The soil types and low rainfall combined with poor irrigation system have forced the farmers to go for ground water utilization, wherever water quality is good and also the farmers can afford to spend a large sum on digging deep bore-wells and installation of powerful motors. The number of pump-sets energised in Pudukkottai District has very fast increased in the last two decades (the number was 35,052 as on 31st December 1995). About 18,600 pump-sets are pending for energisation which is slightly more than 50 per cent of the total number of pump-sets energised till then. Again these numbers are very high in Kulathur taluk (13,102 and 6,117), where the study village is located.

Land and Forests in Kulathur Taluk

The discussion in the foregone pages indicates that Pudukkottai District is one of the dry districts in Tamil Nadu, however with some ground water potential. Land area is still abundantly available for cultivation. In Kulathur taluk, the bore-well irrigation is increasingly popular even in tank-beds. In Kulathur taluk, still a very large proportion of land is fallow (32. 5%), 1.4 per cent current fallows and 31.1 per cent other fallows. Only about 26 per cent of the geographical area is used for cultivation (Table 2). In this taluk too (like other taluks in this district) there are large numbers of ponds, i.e., about 25,000 ponds, almost 1 pond per 1.3 hectare of cropped area. Major crop is paddy, covering about 80 per cent of cropped area. This is followed by groundnut, blackgram, gingelly etc.The geographical structure of this taluk is understood to have designed/developed in such a manner to collect the water in the ponds, minimize the water use/waste by carefully choosing appropriate crop patterns and leave a substantial portion of land under groves.

Resources, Forest and Sacred Groves in Mandayur

Mandayur is an average Tamil village in Kulathur taluk, Pudukkottai District in Tamil Nadu. In 1993, there were 1,178 households and 4,272 persons in this revenue village. The size of livestock was 3,715. This revenue village consists of twelve hamlets, excluding Mandayur (please vide Table 3). Mandayur is the main village with a population of 2,303 persons, 1,143 men and 1,160 women. The community-wise population in Mandayur is as follows: Scheduled Caste (SC) 8.9 per cent, Most-Backward Caste (MBC) 4.9 per cent, Backward Caste (BC) 85.5 per cent and Brahmins 0.7 per cent. Normally SC population engages in agricultural labour in Tamil Nadu. Therefore, they are mainly concentrated in wet and agriculturally active villages (like Thanjavur District). The BCs are small-land owning community.

Table 2. Land Use Pattern in Kulathur Taluk, 1997-1998

Type of land	Area in hectares	(%)
Net area cropped	34,661	26.4
Forest land	3,252	2.5
Barren and uncultivable waste	2,616	1.9
Land put to non-agricultural use	37,968	28.0
Cultivable waste	3,358	2.6
Permanent pastures	2,410	1.8
Area under tree crops	4,407	3.4
Current fallows	1,819	1.4
Other fallows	40,782	31.1

Table 3. Hamlets

1. Keela Medu	
2. Vaathra Medu	
3. Vada Kadu (Ambalakarar, Near to Forest)	
4. Kandian Kadu	
5. Thirumeyathan Kadu	
6. Arasi Kadu	
7. Ooruni Medu	
8. Navangi Kadu	
9. Natrayan Kadu	
10. Kottha Kadu	
11. Kummeseti Kadu	
12. Natha Kadu	a). South Natham
	b). North Natham
	c). Mandaga Patti
	d). Maayam Patti

The MBCs are service groups like dhobby, barber and pandarams, who perform pooja for village boundary-gods and goddesses (Ellai Dheivangal). Brahmins have already migrated to urban centers, occupying powerful government occupations. Whoever left in villages are doing pooja in saiva temples. In the temples, where animals are cut, the pandarams are poojaries.

Facilities

This village has got many modern facilities. It is located in a main road connecting Tiruchirapalli with Pudukkottai. One has to cross a manned railway gate to reach this village. There is a bus terminal. Dheeran Chinnamalai Transport Corporation (DCTC) bus plies eight trips with this village name-board. People are demanding for more trips. Government-run primary health center, Post office, Ration shop, Public call office are there. In many houses television-sets are available with cable connections and many channels. Many own motorised two wheelers. School started functioning as early as 1954 with five classes initially. Now there are nine classes.

The school-buildings are in two different places. One, new building is about 300 meters away from the village, nearby the *sacred groves.* Since some girls got ill after visiting the new building, the villagers have made arrangement to have the higher standard classes also in the old building, though it adds to the crowd. They say the Ellai dheivangal give troubles to the physically matured girl-students, if they cross the dheivangal to reach the new building during their menstrual cycles. There are seven teachers in the school. Besides this, adult education programme also functions. Now, one Ms. Akila, daughter of the post-master, is working in this programme. The primary health centre has now got a new building. The hospital was started in the year 1998. Earlier there were one lady doctor and one mid-wife. Now in the new buildings, since 1998, there are one lady doctor and five nurses. Nurses go to neighbouring hamlets also. New building consists of one bed, toilet and bath-room. A health inspector visits the hospital regularly (it is said to be daily).

Post-office was started in 1995. Initially an ex-service man (belonging to SC) was working as Post-Master, now the post-master belongs to Kallar caste of Mandayur. Public-call office is functioning since 1985. The post-master is in-charge of this service. Village people are permitted to make calls from this office on payment. In 1980, the first television (black and white) set came here. In 1985, five more television-sets (colour) were purchased by the residents. Many households have now cable connections. Besides these, each hamlet has got one television set, provided by government. Library has got some novels, poetry books and "Dhinakaran" news-paper (a news-papper supporting Dravida Munnetra Kazhagam (DMK) political party, for the Panchayat President belongs to the DMK party). Recently the district collector visited this village and gave away patta on the lands for many persons, mainly scheduled caste women.

Land and Water

Total geographical area of Mandayur is about 2,000 hectares. Poramboke land area is slightly above one fourth of the geographical area (Table 4). About 500 hectares of land is cultivated, two-third is irrigated by tanks, ponds and bore-wells. Paddy is the major crop followed by groundnut, tapioca, red-gram, gingelly and sugarcane. Teak and eucalyptus trees stand in large area. Coconut, tamarind, guava, lemon and jack-fruit trees are also there in the backyards.

Table 4. Head of Communal Poramboke in Mandayur -1996-1997

Categories	Area (hectares)
Village site (or) playground	20.75.0
School-site	*NA*
Grazing ground	8.61.0
Threshing ground	1.98.5
Burial ground	0.34.0
Cattle shed	*NA*
Pathai	29.22.5
Others	472.53.5

Source: *Records of District Statistical Office, Pudukottai* ***Note:*** *NA = Not Available*

The speciality (specialty) of Pudukkottai District and this village is the number of ponds/tanks. Many small tanks/ponds/oorunis (used for bathing and washing purposes) are found in this village (Table 5). Locally the terms Oorunis and Kulams are used interchangeably. The size and purpose of the Kanmais (tanks), Kulam and Oorunis are different. In this village, these resources are used for drinking (both for human and animals) purposes and also for irrigation purposes. Some of them are used for more than one purpose. Trees have also been planted in the catchment area by social forestry scheme. Fish is grown and harvested; the revenue from this harvest is used for temple maintenance and extension, construction of over-head water-tanks and purchasing bulbs for street-lights. The tanks with more than 100 acres of ayacut are maintained by Public Works Department, while those with less than 100 acres of ayacut are maintained by village Panchayat.

Table 5. Details of Tanks in Mandayur

Name of Tanks	Tank area (Ha.) (hectare)	Irricated Ayacut Area (hectare)
Oorani kulam	7.56.0	83.97
Arasi kulam	68.40.5	909.10
Arasi kulam & Oorani kulam	8.67.5	123.17
Banangondan & Arasi kulam	3.67.0	36.29
Kandiyan kulam	9.07.0	108.53
Motaiantalathi kulam	20.14.	187.79
Oduvan kulam	32.91.0	328.27
Oduvan kulam & Betheriyan kulam	0.48.5	6.26
Vaathira kulam	8.11.5	79.48
Mongaam kulam	1.06.0	5.24
Pappan kulam	41.81.5	356.16
Puthu Kulam	18.24.0	154.77
Behterian Kulam	30.57.0	346.44
Bidari Kulam	10.33.0	102.35
Naavalanki Kulam	18.53.5	123.89
Nattirayan Kulam	4.97.5	74.06
Kumbansetti kulam	1.12.0	8.30
Manak Kulam	2.36.0	20.58
Kummadi Kulam	7.81.5	77.24

***Source**: Records of District Statistical Office, Pudukkottai*

Sacred Groves

One of the ways of restricting/controlling the people from doing something wrong is to say that “god will punish them”. This has been a practice in Tamil villages for long. This has been used to produce many a time a good result for the community. This faith might also have been misused to punish the innocents in the village by the powerful ones. It is quite common to see the sacred groves in many villages, that is, a forest with local species of plants around temples and/or around the ponds in front of temples.

These groves have been protected by the local people for long and those groves are useful for the villages in more than one way. It is felt unnecessary in this place to list out the benefits of maintaining a forest in dry region, where the growth rates of trees are smaller due to low and concentrated rainfalls; where the wages are very low, hence people are motivated to cut and sell these trees for their livelihood; where the government is not much interested for these forest produces may not yield much revenues/benefits for them and, where it is difficult for governments to employ people (as nobody would like to be in dry regions) to safeguard the forests. Under such circumstances, the “god-fear” can alone be relied to do this good thing of maintaining a forest. And, this has been fruitfully used in Mandayur, also even in modern days, with modern living styles. This is an indigenous method.

The sacred grove in Mandayur is affectionate to the villagers. The sprawling area of about 300 acres is called as chedi (i.e. plant). The use of this grove may not be so encouraging to government. Hence, it may even be classified under waste-land. However, usefulness of this grove can neither easily nor correctly be measured by those people, who are obsessed only with tangible, immediate and monetary benefits and by the existing measures which are biased towards economic benefits alone. In the centre of the grove, there are two temples. They are 1) Iyyanar Kovil 2) Karuppasamy Kovil. Pooja for Iyyanar Kovil is done by a Brahmin, since no animal sacrifice is done here. Whereas in Karuppasamy Kovil animal sacrifice is done, hence pooja is done by two non-brahmin Palani and Subramanian, two brothers belonging to pandaram caste group. Every year, there is an annual celebration. During this function, the people (mostly Kallars and Yadavars, who migrated to urban areas on their jobs) from town come, gather and stay there for a week's period. One function is due, as there was a problem in nomination of the trustee. Since somebody from outside the village has been nominated as the trustee, the villagers do not show much interest in organizing the function. Moreover, now the villagers are not prepared to spend on hospitality for the guests, who are expected to stay in the village for days together.

Inside the village, there are many temples, almost one in each street/street corner. Some of them have occupied large area, about one acre. Buildings have been frequently renovated. It appears that the villagers take much care in maintaining those temples and for which they collect donations from others. They use the revenues from village common properties also on temples. In the village boundaries also there are goods/goddesses. These gods/goddesses are said to be powerful in punishing the wrong-doers. However, what is wrong is defined/decided by locally powerful people. As they have very strong faith in the gods inside the grove also, they are afraid of stealing any fuel wood from the grove. It is said a lot of jewel, which are adored to the gods during the annual function, are also kept inside the Kovil in the grove. The poojari initially hesitated to allow the researcher to have photograph of those gods.

Every household appears to have heaps of fuel wood nearby the house for their domestic uses. Some amount of commercialization of fuel wood also takes place. Even then, the people are not ready to cut the trees in the grove. Even animals are not hunted. Some years ago, some outsiders came and hunted rabbits, peacocks and deers in the grove, and it is alleged that they were duly punished by the gods and they became ill. In side this forest, there are many kinds of plants and trees (Table 6), which may be very much useful for medicinal purposes. However, it appears that no serious attempt has been made to assess the medicinal and/or economic values of these plants and trees. Only a local man is said to collect some plants for medicinal purposes. One can see the goats grazing here and there, but not in large scale. Normally the forest has no visitor at all. The grove is located in a slightly elevated area. Hence the rain water may not get collected much here. Therefore the trees here lose their leaves soon, immediately after the rainy season. Moreover the growth rate of these trees appears to be very low. Hence the trees are neither very tall nor very huge, though they are there for long. It is felt that frequently the branches of these trees are broken by the wind. Under these situations, if government could take some efforts, this area can be made still greener and more attractive. Similarly there could be many groves particularly in dry regions of Tamil Nadu. These groves should be properly protected from natural / human made disasters and be improved, and not be allowed to deteriorate.

Table 6. Plants and Trees in the Sacred Grove in Tamil Nadu

Major Plants	Major Trees
1. Thulasi	1. Puliya Maram
2. Aaduthinnapaalai	2. Palaa Maram
3. Vellargu	3. Vembu
4. Perumaathukodi	4. Karuvela Maram
5. Sappathikalli	

Conclusion

The primary aim of the study was to understand the interrelationship between the social values and resource use pattern. The social values might very much differ across the villages and regions. Hence, Pudukkottai District, a dry region, was chosen to assess the factors conditioning the resource use patterns. Again in Pudukkottai District, Mandayur was purposively selected for the in-depth survey. The basic natural resources are land, water and air. All these resources are gradually entering into the cruel hands of markets (land, water and air have already entered, though the degrees are different). This will certainly lead to unequal use of these resources- i.e. poor may be deprived of these resources, while the rich ones are likely to waste them. In this situation, to understand the background, data regarding these resources have been collected and presented for Pudukkottai District and for Mandayur village. The social system, values and resource use pattern have been analysed for Mandayur village, a representative village of Pudukkottai District. It is found in Pudukkottai District and in many other dry districts of Tamil Nadu that the sacred groves continue to exist, thanks to the prevalence of “god-fear” among the local people.

These groves are very helpful in maintaining the ecological balances and hence they are very important (though not in monetary terms) for the villagers. They contain a lot of wealth for which economic values are yet to be assessed. In the absence of appropriate interest, knowledge, skill and technology, some amount of wealth of these sacred groves appear to decay and go waste. If government could take some suitable steps, enormous amount of hidden wealth in these groves can be saved and utilised for economic development, without making any loss to the sacred groves.

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RURAL GEOGRAPHY

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Modern Geography is the Science of Human Environment. It describes and explains how the natural factors of environment such as soil, relief, temperature, and rainfall control life in general and human life in particular. This aspect of the subject has been called Physical Geography. But man, unlike other life-forms, is not a mere creature of circumstances. In a sense, he is a creator also, able to rise above his surroundings, and control and conquer Nature, by understanding and following her laws. This conquest of his environment by man falls within the purview of another aspect of geographical study known as Human Geography.

Both these aspects of the Geographical Science - the physical and the human - can be studied both in the urban area as well as in the rural. But God made the country while man made the town; and so the physical side can be better studied in the rural area, while the human can be better studied in the urban. With this difference, however, both aspects can be studied everywhere,

At the outset it may be worthwhile remarking that compared with the modern nations of the West, our country is one in which the .rural area and the rural population play a preponderant part in the national economy; hence the greater interest and importance which attaches to a proper study of our rural geography.

In this and the following papers, it is intended to touch upon a few of the important topics and problems of rural geography, with special reference to South India, and treat them in a popular way. Among these may be mentioned the following: - the village-name, its situation and probable origin, its initial advantages, its plan and parts, its climate and weather, and their effect on the life and activities of the villagers, its plant and animal life, its classes and com munities, its occupations and industries, its trade and transport, its social and religious life, etc. I confine my observations to the Madras village, but with necessary modifications the principles developed here may be found to be applicable elsewhere also.

The first point of interest about any place is its name- which often carries with it some amount of poetry and history, of ten giving us a clue as to its origin. In a large number of instances these names are connected with natural features and objects, such as a forest, a tree, a river, a mountain, a tank, soil; sometimes, they bear the name of a deity, king or other patron or founder. As illustrations may be mentioned the following names of villages from among several: - Arkadu, Mangadu, Vedaranyam, Bilvaranyam (Tiruvalam), Kattupakkam, Tiruvalangadu, Velur, amidipudi, Chintalacheruvu, Tenneri, Arpakkam, Panapakkam, Tatipaka , Kondapalli, Adavikolanu, Isukapalli, Kalmedu, Rallapalli, Gajapatinagaram, Mahendravadi, Kolattur, Chandragiri. Often times the size and original character of the village is also suggested in such endings of place names as the following: pattu, padu, parrukuppam, mangalam, pakkam, puram, varam, palayam, valasa, palli, halli, gudem, vadaorada. The study of place-names forms a very absorbing one, in the pursuit of which I should not be led away from the main subject. So, I stop. In dim far off times the whole of South India must have been covered with forests of the Savannah type, open woods with closer clusters of trees a long river -banks- or near other receptacles of water changing in to thickly wooded forests where the -rainfall rose beyond 60 inches per annum. The work of man has altered all this now, so that the greater part of the country is now covered with smiling fields, dotted with groups of human habitations, which we call villages. Before the present state of things came to be, an intermediate stage can be pictured, when the villages had arisen in the midst of clearances in forests, and when village was separated from village by uncleared, intervening forests i.e., untilled land over grown with natural vegetation. This stage still lives in tradition in the familiar grandmother's stories.

Probably we have a still earlier stage in the evolution of the village, traceable in the Asrama or hermitage of sages, who were real pioneers in this respect like the European back woodsmen in the North American forests, undergoing any amount of trouble (srama) at every stage. But this might account, if at all, for the origin of only one type of village.

Whatever the origin, there is no doubt that the forest had to be cleared first, and naturally men chose to do so at first at some favoured spots which had special advantages. Two such advantages that were invariably sought after were (a) a fairly raised stretch of land and (b) a good supply of water.

The site for the village: - The first consideration in the choice of a site is that it shall be a fairly level piece of land, high enough to be free from floods during rains, and one which will drain off the water in all directions. This is such a common and familiar feature of every village that it usually does not impress itself on one at first sight. The surf ace conditions near a village-the lie of the land round about it is an important controlling element in its life and activities. In a town, the relief of the place is hidden under man-made pavements and masonry work. But in the rural area, highland and lowland, slope and drainage are patent everywhere. The effect of relief is obviously seen in moisture control.

A good supply of water: - This leads us to the second consideration in the choice of a site for a village, which is even more important, proximity to a source of water-supply. Water is required in the first instance for man and beast for drinking and washing purposes. It is interesting to note in this connection that agraharams rose usually a long banks of rivers or near big tanks.

Since the Brahmin population living in them needed a perennial supply of good water for their daily ablutions. Water is also required for agriculture, and every village, however insignificant, needs its own source of supply for this purpose also. In fact, the size, wealth, and importance of a village depend upon an abundant and steady supply of water for irrigational purposes almost throughout the year. We know how the countryside is studded with hundreds of irrigation tanks, big and small, each of which irrigates from one to several villages. These reservoirs have served to increase the prosperity and importance of villages, whose origin was probably due to a meagre source of supply at first. Similarly, along river banks and spring-channels villages are to be seen like beads in a string.

A third consideration sometimes operating in the choice of a village-site is the soil of the land to be cultivated. This is not such an indispensable factor as a good water-supply. For, poor soil can be improved by means of manures, whose efficacy seems to have been known even from very early times. After all, soil control reduces itself again into moisture control. The difference, for example, between a sandy soil and a clayey one lies not merely in the absence of organic matter in the former, but also in its porosity, which prevents the retention of moisture. It seems to be the fact that soil controls not so much the choice of a village site as it does the further growth of it in wealth and prosperity, after! the village itself had come into being.

Sometimes, as a result of the additional advantages of good communication, a central situation or a strategic position or more often the lucky growth of certain industries, a village might continue to develop till it ceases to be a village and becomes a town. But in its origin, every village must have had these two initial advantages of a proper site and a good supply of water.

Every village consists of (1) the inhabited part, (2) the tank or other source of water-supply, (3) the cultivable lands, and (4) poramboke or public lands, generally left fallow, and used as grazing ground, where nothing better is available for the purpose. Each of these will be considered in its proper place in another paper; but, one thing that is worth noting at this stage is that the underlying basis of distinction is the natural feature of surface level or relief upon which depends the moisture-control of the whole village. The in habited part, as already pointed out, usually occupies a stretch of land which is above flood-level. The tank, if there is one in the village, affords-a very interesting example of human control of environment. Across a stretch of sloping country at a convenient spot a bund is erected, above which rain water instead of flowing down the slope collects and forms the tank proper. As a result what was origin ally a mere sloping land now divides itself into a catchment area, a tank and the cultivated fields irrigated from the tank. The fields themselves fall again in to different classes according to their level and the consequent availability of water into triple crop, double crop, single crop and dry crop fields. Then, there are poramboke lands i.e. lands sufficiently elevated, ordinarily uncultivable, but useful for various communal purposes.

The normal occupation of the bulk of the inhabitants of a village is agriculture, and the various operations connected with it are dependent upon the seasons. The effects of climate and weather on the life and activities of the village will be considered in the next paper.

N. SUBRAHMANYAM, M.A., L.T.

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Archives - 2

RURAL GEOGRAPHY

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II - The Seasons and Village Activities

Climatic control is the most insistent and far-reaching of all controls, which the factors of environment have on life in general and on human life in particular; and nowhere else does it show itself so fully, so freely and so obviously as in an Indian village. Surface and soil, man and animal, are all there; but they prove themselves inert and powerless, till the rhythmic swing of the Sun produces in its wake the wind and the rain in their season. The round of human activities and social life, resulting from the change of seasons, is one of the most interesting studies in the inter-play between man and his environment. Not less interesting is the other side of the picture, in which man is seen devising ways to get in dependent of the freakish bounty of Nature by means of his inventive ingenuity. The normal life and activities of the village are, however, governed by the Calendar, which practically summarises the seasonal play of the ages.

At the outset it may be pointed out that the six seasons of the Indian Calendar seem to be truer to the facts of Northern Indian Climate, and do not fit in exactly with the conditions of a Madras Village. The Seasons in South India on the East Coast may roughly be classified as follows: - (a) Hot and dry-during the months of Panguni, Chitrai and Vaiyasi, (from the middle of March to the middle of June); (b) Hot and rainy-during Ani, Audi and Avani, (from the middle of June to the middle of September); (c) Cold and rainy-during Perattasi, Arpasi and Karthikai, (from the middle of September to the middle of December); and (d) Cold and dry-during Margali, Tai and Masi, (from the middle of December to the middle of March). The hot and cold months occur when the Sun is north or south of the Equator, respectively. The rainy and dry months occur during Dakshinayanam (Sun's "Southern Journey") and Uttarayanam (Sun's "Northern Journey") respectively. This characterisation of the seasons, as stated above, is only a rough one; and it should be noted that there are in each season gradations of the characteristic features.

The Hindu New Year is born about the middle of April, when the Sun begins to get hotter and hotter and the water becomes scarcer by being used up or dried up. The normal life and activities of the village gradually get slackened. No doubt, certain industries connected with agriculture, such as the making of jaggery or turmeric, are carried on now; and certain favoured fields, with a better supply of water-due to situation or water works, have their third crop for the year or grow garden crops. For the average villager, however, it is comparatively a time of leisure.

His harvest has all been gathered; and flowers and fruits are in season both in plenty and in variety. It is now Vasantha or Spring of the Indian Calendar - the season of plenty and pleasure, off easts and festivities, of marriages and matings. It is now that debts are paid off and mortgages redeemed, lands purchased or improved., wells sunk or deepened, embankments put up or canals dug, journeys and pilgrimages undertaken, or friends and relations received and entertained. The peasant now renews his thatch or rebuilds his hut against the coming rains. Bricks are now made, lime-kilns are at work, trees are felled, and fences are put up. The building trade flourishes best at this season, unhampered by rains or by the normal agricultural operations of the village.

This is also the season, best enjoyed by the urban youth; for, as it is now the time of summer vacation, they happen to visit their rural relatives-fathers, uncles or fathers-in-law. Social amenities of rural life are no much in evidence, such as cock-fighting or play acting of Gangamma vesham or of epic stories or the singing of Bhajana concerts, celebrating the birth of Rama. While English rural life is controlled by temperature and the English peasant has his period of rest and enjoyment during the long winter evenings, it is interesting to note that Indian rural life is controlled by moisture and that the Indian peasant has his comparative leisure and enjoyment during the dry days of summer. Very true, indeed, are the words of the poetess Auvai that without rain there is no work to be done (for the farmer).

From this torpor and lethargy, the village springs up to sudden life and activity with the first rains in June. The month of Ani witnesses the drawing up of new lease-deeds of cultivator, and the sub-registrar's office now gets a sudden increase of work There is now also a sudden demand for cattle for the plough, and droves of them are led to and from the fair, while the middle men ply their business merrily. The western sky is anxiously watched day after day, and at last the rain cloud appears and brings the long-expected rain. An interesting feature at this time is the sudden demand for the services of the village carpenter for mending the plough. His temporary rise to importance has been preserved in the proverb " Audi Asari, Thai Thachappayyan". The Master carpenter of Audi (June-July) becomes the carpenter-boy of Thai (January- February).

On an auspicious day, the first plough, Ponneru as it is called, is drawn; and with the first rains commences usually the dry ploughing both for dry and wet crops. The village now begins to hum with new life. The half-built house, the half -cut wood, and the half raised wall are all left off suddenly to be taken up for completion at the next slack season. The Indian peasant knows instinctively the immense importance of taking time by the forelock. The sojourner in the town hurries back to his village on the first news of rainfall.

About the time that the courts and colleges reopen in the town the peasant, too, finds himself harnessed to his work; and for the next three months he gets deeper and deeper into it, day in, day out, ploughing and sowing, weeding and transplanting, watering and manuring. All hands are at it, male and female, young and old.

The occasional rains brought by the west winds during this season of the south-west monsoon, supplemented by the supply of spring-channels and wells, help the growth of this first crop, both dry and wet.

The monsoon turns about the time of Michaelmas or Dasara in the month of Purattasi (September-October); and now the early Kar crop and the dry crop are gathered in, while the Samba crop is in the seedling stage or is being transplanted. During the next two months, this principal paddy crop flourishes best in the monsoon rains of Arpasi and Karthi. The village is now almost completely surrounded by water. But, if the monsoon fails, all that the peasant had staked upon is lost; and his labour of three to four months as well as his little capital spent on manures, seeds, etc., is all waste; and famine stares him in the face. He runs into debt at a high rate of interest, mortgaging his land or his cattle or his petty homestead. If, on the other hand things go well for him and the seasonal rains do not fail, he is able to gather his main crop of the year about Christmas time, which synchronises with the winter solstice: On the first of Thai (about the middle of January) the peasant celebrates his fresh harvest and the commencement of the Sun's approach towards him in the Sankranthi or Pongal (new cooking) festival. Urgent debts are paid off now, and marriages are celebrated.

This is the season which the urban visitor to the village likes best. Except for a little sharpness in the night and for a little mist in the morning, the time is very pleasant and enjoyable, without drenching rain or scorching heat, with water and verdure wherever the eye can reach, and a bracing coolness which invites and compels tramping out.

But the peasant cannot have his rest for another three months. The second crop of medium lands, the third crop of the best lands, or the second dry crop has yet to grow; and all these depend not on rains, which are almost over for the year, but on stored-up or baled up water, while the dry crop depends partly on dew. As these crops are being gathered, the Sun gradually gets hotter and the water gets used up or dried up; and by the end of the year summer conditions of heat and drought have set in, and the cultivator has perforce to stop his normal activities.

This cycle of rural life and activity, closely coupled with and governed by the periodical swing of the seasons forms an interesting illustration of environmental control of man. But the other story of human control of environment in the rural area is no less interesting, and will be treated in the next paper.

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Archives - 3

RURAL GEOGRAPHY

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III - Other Natural Controls on Rural Life

The effects of climatic and seasonal control of rural activities were discussed in the previous paper; and, before we proceed to trace the work of Man in rural areas as an agent of his environment, let us indicate in brief the effects of the other chief physical controls, such as location and surroundings, structure and soils, flora and fauna. It is possible that in a particular rural locality there may be facilities enough for the people there to take to any work from hunting and fishing at one end of the scale to industries and trade at the other end. Fishing in the neighbouring river or tank, hunting for small game, cutting wood, or gathering forest produce in the neighbouring woods, grazing sheep or cattle in the dry uplands of the vicinity or in the uncultivated and poramboke lands of the village, cultivation of dry, wet and garden crops, planting of topes and orchards, working in quarries for limestone or building material, working on wood and metals, spinning and weaving-traces of several of these occupations can be seen in various villages taken together of a local grouping in a single tract. But the true measure of the natural facilities afforded for this or that occupation to prevail over the rest is a quantitative one. In what proportion do the inhabitants of a village take to the various occupations obtaining therein? What do the bulk of them work at? On the answer to this query, quite apart from man's skill in getting over natural obstacles, depends the impress of the environment on human activities of the locality, and these in turn mirror the features of that environment. Location is often thought to be a matter of secondary Importance. But it is a mistake. The location of a place is not merely a static fact-one of topography only-but it is of the highest dynamic value, leading to far-reaching consequences on the life and economy of its inhabitants.

Maritime or aquatic location: - All along the sea-coast and in the neighbourhood of the back waters there have sprung up hundreds of fishing villages, kuppams or mere hamlets, (like Parthasarathy Kuppam in Triplicane and Kasimode in Royapuram), whose inhabitants live by gathering the harvest of the sea in their primitive fashion The salinity and the sandy nature of the soil here, which are unsuited for agriculture, are, however. Specially, favourable for the growth of the cocoanut and the casuarina. Looking along the Madras coast from the sea, or travelling along the Buckingham Canal, one sees for miles and miles north and south of the city nothing else bilt groves of these two kinds of trees. In favoured spots, where the salinity is not very high and where a good supply of water is available, cultivation of a sort is carried on towards the interior, as in Tiruvamiyur and

Minjur; but, it is not the fishermen themselves that take to it. The facilities for transport control the expansion of such villages. For example, Ennore and Pulicat owe what little importance they have to their location on the backwaters and by the lagoon.

Hilly location: - A hilly or upland location, whether forested on account of heavy rainfall or barn owing to prevailing dry conditions results generally in a sparse population, as the means of subsistence there is precarious. The habitat ions are few and far between, while villages are little more than hamlets, whose inhabitants eke out a miserable living by hunting or tending sheep and goats Cutting stones and working in quarries, and cutting wood, working in timber and collecting forest produce from the neighbouring jungle for disposal in towns are other useful occupations in such areas. *Location on natural routes: -* Villages situated on highways and frequented routes, howsoever they may have originated at first, develop in course of time, as a result of the facilities of communication, into towns. For example, Villupuram, which is now a municipal town, was nothing more than a small village a few decades ago. Its growth, due at first to crossing of roads, has been accelerated by the railway junction. In such nodal villages, trade forms an important occupation, and there is much traffic in the needs of way farers. *Location near a water source: -* The bulk of the more important villages of South India are clustered in the plains, and grow wet crops, owing to their location in areas of good water supply either from rivers, tanks and springs, or by rainfall. Those in less rainy areas but still having dependable water-supply such as those in parts of Mysore or the Ceded Districts grow more largely the dry crops. Both these kinds of villages form the bulk of South Indian villages and are essentially agricultural in pursuits and outlook.

Slope and Drainage: - Next to location is the influence of Slope and Drainage. Slope control, however, ultimately resolves itself into moisture control. And, as pointed out above, villages in upland regions are few and sparsely populated, having insufficient facilities for the retention of water, while low-lying valleys and river-plains are studded with rich and populous villages. *Soil: -* Soil is a chief factor in determining the occupation, size and character of a village. The adverse effects of a saline sandy soil on agriculture and its usefulness for the growth of the cocoanut and the casuarina have been pointed out. Other kinds of poor soil-rock, laterite, etc. - have similar effects on agriculture. But, where soil is being constantly renewed in large quantities as in alluvial plains, agriculture flourishes best. Large villages. Spring up in great numbers, for example, in Deltas. *Natural flora and fauna: -* These did indeed influence the original choice of site of villages as well as their early growth and development. But in modern times it is very difficult to trace their direct effects on rural settlements. For, Man has cleared the forest and has hunted down or driven out the wild animals for his own safety. Cultivated plants and domestic animals have taken their place almost wholly.

These remarks are intended merely to point out how the physical factors bear on rural life and activities. In the next articles, we shall touch upon how man has shaped his own environment for his ends, in South Indian Villages.

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DETERMINATION OF CLIMATIC TYPE IN THE DROUGHT - PRONE AREAS OF JALGAON DISTRICT- MAHARASHTRA STATE, INDIA

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Abstract

The climatic behavior of each area is predictable using the long term data and applying the appropriate method of climatic classification for the area under study. The basic objective of the present study is to determine the climatic type of the drought prone areas. The tahsil - wise annual rainfall and temperature data have been collected for 09 drought - prone areas or stations during year 1970 - 2007 for the duration of 37 years. The next step using the De Martonne method drought coefficient for each listed years has been calculated. At last, drought coefficient obtained for 37 years is being averaged which comes to 18.9 As per De Martonne classification table, climatic type of the drought prone areas falls into the category of semi-dry climate. This means that the drought - prone meteorological stations experiences a dry seasons followed by rainy season. The dry season would be at least, more than three months. In the case of Drought prone areas, it observes dry season or low rainfall season for longer period that it's rainy season and often observes the activities associated with an air mass in range of our study stations during every year.

Keywords: Dry climate, drought coefficient, De Martonne index, semi dry climate etc.

Introduction

The major crisis in production of food materials in the world is caused by the widespread occurrence of frequent copious droughts particularly in India. Many of the social and environmental problems have arisen need to focus upon climatic factors. This recognition has been continuing since a lot of human problems depend upon fragile effects of climate (Faraji, 2005). Existence of different environmental economic potential, searching of human for increasing food resource and development of urban and industrial centers have increased amplitude of their information in different climate. Therefore, the climatic classification of an area has become necessary since many of the elements of weather and climate play crucial role in the developmental processes.

The climate of each area is average of the long term atmospheric condition for that area (Jafarpur, 2006). The atmospheric condition consists of observed rainfall, temperature, humidity, the sun radiation and speed of wind. These are really the result of the consequences of observed weather condition of the atmosphere at a particular space, and time from combination of these atmospheric weather elements of long period we determine climate of that area. Geographic position, topography, distance from sea, occurring in the direction of warm, cold and dry winds, weather and the combination of these factors beget the climatic brigade effectively. In fact the determination of type of climate of a region is the recognition of a method which is based on the application of a scientific method using relevant information and this might be useful in performance of different planning. Therefore in this paper an attempt has been made to determine the climatic type of the drought prone meteorological stations to help the various development programs.

This meteorological station is located in the centre of a big plateau, therefore the recognition of climate behavior of these stations will be of much significance and importance, especially in the adaptation of agricultural activities, Hitherto, and a lot of researches have been done regarding climatic classification using different methods of classification. He has arrived to the result that Iran experiences different types of climate i.e. hyper dry, semi dry, humid and hyper humid and the climatic category of hyper dry has had an ascending trend. The objectives are to capture the quantification of the aridity trend; to know particular wet and dry periods and to find yearly major trends and shifts in climate.

Social Relevance

If we know the current status of the climate and that in the recent past, we can begin to plan for the future. Climate classification must be carried out to determine the interaction between water resources. Climate conditions in cultivated land must be such that disease and pests are prevented from multiplying and spreading. Climate provides an essential resource planning endeavors in areas such as agriculture, water resources, emergency management etc.

Study Area

The study area is located in the drought-prone tahsils of Jalgaon District of Maharashtra State. These drought prone tahsils are identified by V Subramaniam (1987), Review Committee appointed by the Maharashtra State Government. These tahsils are Amalner, Dharangaon, Erandol, Parola, Chalisgaon, Bhadgaon, Jamner and Muktainagar. There are 09 tahsils which are selected for present study which cover an area 6994.54 sq.km. The area under study is located south of the Tapi River in Jalgaon district. It lies between 20^0 11’ to 21^0 13’ North latitudes and 74^0 46’ to 76^0 24’ East longitudes (Fig. 1).

The study region is a plateau area with variations of some uneven lands on the banks of rivers. The River Girna and Waghur is the architect of this plateau area. The more area of the study region is covered by plateau and least area comes under alluvial deposits of valise of Girna, Waghur, Tittur, Anjani, Bori and Purna rivers. The study region experiences the sub humid monsoon climate that is why the study region is rich in agricultural land, and produces many crops; viz. fruits, foods, cotton and vegetables.

There are three harvests viz. the Kharip, the Rabi and the summer. The summer is relatively of small significance. The important crops which are produced in the study area and which occupy more than one percent of the cultivated area are Jowar, Bajara, Corn, Pulses, Oilseeds, Onion, Fruits, Sugercane and vegetables.

Methodology

The Table 1 shows the pattern table for the De Martonne climatic classification method.

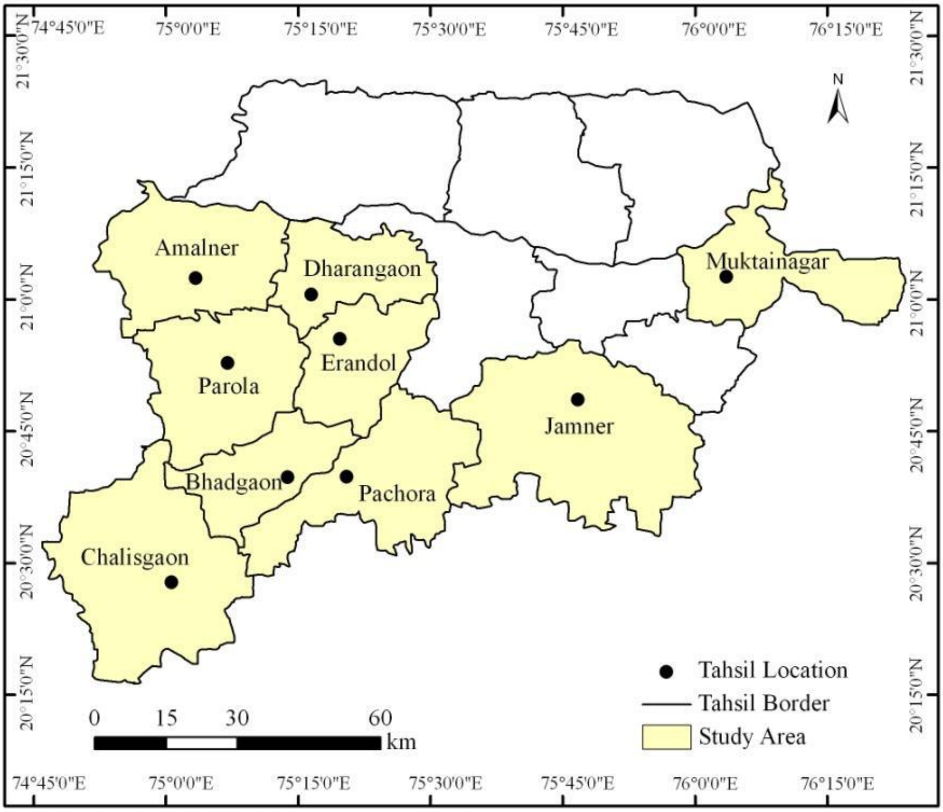

Fig. 1. Location of the Drought-Prone Tahsils of Jalgaon District of Maharashtra State

For determination of type of climate of the drought prone meteorological stations, De Martonne method has been used. Meteorological station wise total amount of annual rainfall and total average of annual temperature of these stations have been obtained for the period of 1970-2007. Then the concept of arithmetic average has been applied to calculate of the drought coefficient of these stations. To the other expression, drought coefficient has been calculated for the statistical periods from 1970 to 2007. The drought coefficients of each year and stations for the statistical period 1970-2007 of the drought prone meteorological stations is obtained by simple expression given below

Table 1. Climatic Classification by the De- Martonne Method

Climatic Type	**Drought coefficient**
Per-humid B	I > 55
Per-humid A	35 < I < 55
Humid	28 < I < 35
Sub humid	24 < I < 28
Mediterranean	20 < I < 24
Semi - dry	10 < I < 20
Dry	05 < I < 10
Extra dry	I < 05

$$I = \frac{P}{T + 10}$$

where,

P = total amount of annual rainfall in mm

T = total average annual temperature in ^{0C}

I = Drought coefficient

Results and Discussion

All these drought coefficients have been added together to get the average which has been obtained as 18.9 for the study region (Table - 2). The conformation of this drought coefficient with the De Martonne classification, it exists in the range of between 10 < I < 10. The result, according to the De Martonne climatic classification, the study region comes into the category of semi dry climate.

For determination of type of climate of an area, there are many of the climatic classification methods amongst which each one has more suitability and conformity to the prevailing climatic condition of that area. Hitherto several scientists have presented climatic classification schemes with specific degree of creditability. Rapid progress of technology and utilization facilities of computer software's like Arc GIS, and Arc Info which are giving us easy application opportunity and the possibility of utilization of several other complex parameters.

coefficient index ranges 7.8 and 37.0, therefore all stations except Chalisgaon station falls into dry climate during the year 2000. During the 2000 year drought coefficient index is found 8.2 which shows Dry climate due to the drought year. In the years 1983, 1989 and 1996 the drought coefficient index ranges 20 to 32. Hence more stations come into the Mediterranean type of climate. It is because of above 700 mm rainfall. According to De Martonne index in the study region meteorological stations drought.

Table 2. Tahsil wise Variation in Drought Coeffecient Obtained from Meterological Stations (1970-2007)

Year	Chalis - gaon	Bhad- gaon	Pachora	Parola	Erandol	Dharan - gaon	Amalner	Jamner	Muktai - nagar	Avg.
1970	34.9	19.6	18.5	16.9	17.9	20.0	16.5	24.1	19.2	18.9
1971	35.0	13.3	12.5	11.4	12.2	13.7	11.5	19.9	18.9	13.9
1972	35.1	12.1	11.8	10.3	11.4	11.6	9.9	16.4	11.7	11.8
1973	35.1	12.7	12.4	11.3	12.3	12.7	11.4	23.3	12.2	13.4
1974	35.0	22.7	21.2	18.3	20.2	21.9	17.4	22.2	18.3	19.9
1975	34.9	28.6	26.0	18.9	21.0	25.9	18.3	28.6	19.4	22.9
1976	34.7	24.6	27.4	18.7	20.0	28.2	19.0	33.8	18.7	23.5
1977	34.8	25.8	25.1	19.2	20.8	28.3	19.2	37.5	19.7	24.2
1978	34.9	23.6	22.9	18.1	19.4	25.0	19.5	34.2	19.2	22.4
1979	35.1	21.7	20.7	17.4	17.6	21.6	17.8	32.5	19.0	20.9
1980	35.0	19.1	17.1	15.6	14.4	20.1	18.4	36.1	15.4	19.3
1981	35.5	24.8	17.2	27.5	19.0	18.3	17.1	32.3	19.6	22.4
1982	36.2	9.4	13.3	8.7	7.2	10.1	14.4	17.1	10.4	11.1
1983	36.3	21.1	25.1	31.6	19.0	18.7	18.9	21.5	19.1	22.4
1984	36.5	14.1	10.9	16.5	15.2	18.4	18.7	18.8	11.2	15.8
1985	37.0	20.1	17.5	13.4	11.2	12.3	13.6	20.8	18.7	15.3
1986	37.2	14.7	13.8	18.6	18.5	13.2	10.2	16.3	14.4	17.5
1987	37.4	20.8	21.9	18.2	17.9	18.8	20.7	27.7	15.6	19.6
1988	37.6	26.3	27.8	18.0	20.3	18.0	20.4	19.6	20.6	20.4
1989	36.5	29.0	24.3	16.0	14.9	15.0	19.0	28.4	21.5	22.5
1990	37.8	25.2	22.6	18.8	28.6	19.5	19.0	30.1	20.9	23.1
1991	35.4	14.4	12.9	8.2	12.1	18.0	13.3	18.3	21.6	14.1
1992	37.0	21.4	16.6	24.5	27.4	21.3	43.7	29.1	16.8	24.0
1993	37.0	16.7	19.7	16.4	17.4	15.4	15.1	27.6	20.6	20.2
1994	37.0	16.9	10.6	21.0	19.0	18.4	20.1	28.6	20.0	19.2
1995	36.0	15.7	14.8	19.5	14.1	13.4	11.8	23.0	17.2	15.9
1996	39.0	14.9	25.1	17.7	20.9	16.4	19.7	16.6	14.4	19.7
1997	36.5	21.1	23.7	22.9	23.4	19.5	15.1	25.3	20.7	21.0
1998	36.8	31.6	36.8	27.9	27.4	26.7	18.9	31.1	19.4	26.2
1999	36.9	24.1	14.2	21.4	21.8	19.2	18.9	24.9	19.8	21.1
2000	37.0	8.3	8.2	8.2	7.8	10.6	8.5	8.2	12.4	9.0
2001	37.1	23.6	14.6	26.3	25.7	17.7	18.7	25.2	18.1	21.6
2002	37.2	16.8	15.5	18.0	14.7	19.1	14.5	18.3	19.7	17.1
2003	37.3	18.0	17.6	17.0	16.9	17.0	14.2	19.8	19.2	17.1
2004	37.4	24.4	15.1	16.1	23.0	19.8	18.5	19.0	19.6	19.6
2005	37.0	19.5	15.8	11.5	8.8	17.3	10.6	16.4	13.8	13.8
2006	37.0	30.8	19.4	21.3	16.3	16.2	18.7	18.6	21.0	20.0
2007	36.0	13.0	23.3	19.8	20.1	17.4	17.0	20.6	22.5	18.6
Avg	36.3	20.0	18.8	17.9	17.8	18.3	17.1	24.0	17.9	18.9

Source: Computed by the researcher, 2007

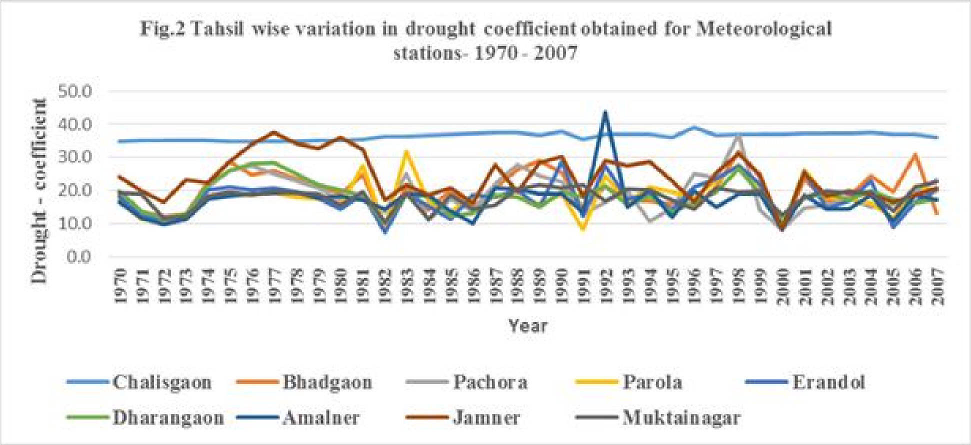

Fig.2 Tahsil wise variation in drought coefficient obtained for Meteorological stations- 1970 - 2007

Fig. 2. Variation in Drought Coefficient Obtained for Meterological Stations

Conclusions

The use of climate classification is shown to be useful for identifying long and short term climatic trends. Historically, wet and dry periods are also identified. Strong agreement is found between weather stations and classifications for wet and dry years, indicating that the same weather systems govern rainfall in this region. A district climatic gradient is identified from southern highland to northern dry continental interior. With careful observation of the available data of rainfall and temperature for duration of 37 years, and belief that the rainfall and temperature together play more that 80 % role in determination of climatic type, De Martonne method has been applied for the determination of type of climate of the study regions meteorological stations. Drought coefficient obtained by this method is 18.9, which as per table – 2 shows the semi – dry type of climate at the study region. The establishment of high pressure at the sub – tropical latitudes is in the end of spring and overall in the summer season. This phenomenon causes to prevent the occurrence of rainfall during this period. The proximity with the drought prone tehsils, causes to high temperature, sparse vegetation and aridity which prevent the necessary saturation condition for water vapour in the atmosphere at the end of spring.

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EVALUATION OF HYDROGEOCHEMICAL PARAMETERS FOR ASSESSMENT OF GROUNDWATER QUALITY IN VELLORE DISTRICT, TAMIL NADU, INDIA

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Abstract

The hydrogeochemical characteristics of groundwater in different seasons have been investigated with the data collected from 82 sample wells in Vellore District. The groundwater quality data for the period 20 years from 1989-2008 have been considered for this study. The major ionic concentrations with few general parameters are processed and utilised for the analysis. Geologically the entire district is broadly classified into hard rock and sedimentary formations. More than 90% of the area in this District is underlain by these formations. With these basic details, the Gibbs ratios, Chloro Alkaline Indices, Schoeller's water types and Piper's diagrams are estimated and drawn using ArcGIS software. The results show that the groundwater in the study area is influenced by rock dominance with the area equally shared by discharge and recharge zones; the increasing trend of ionic concentrations indicates the older waters dominates; and at last that alkalies exceed alkaline earths, strong acids exceed weak acids and sodium-chloride type are dominated during both the seasons.

Keywords: Hydrogeochemistry, Evaporation, Cations, Anions, Vellore District

Introduction

Groundwater is a globally important and valuable renewable resource for human life and economic development. It has been considered as one of the most important natural resources of our country. Also it extends its main role by supplying water for drinking, industrial and irrigation purposes throughout the nation. This accounts for about 80% of domestic water requirement and more than 45% of the total irrigation requirement of the country (Kaur and Rosin, 2007). Through greater utilisation of groundwater for industrial and domestic uses, and also owing to the increased use of agricultural chemicals, groundwater quality has started to deteriorate rapidly. For this, the evaluation of hydrogeochemical characteristics of groundwater for various purposes is necessary. Further, it is possible to understand the change in quality is due to rock-water interaction (weathering) or any other type of anthropogenic influence (Todd, 1980; Kelley, 1940).

There were numerous studies carried out on hydrogeochemical parameters of groundwater by Kumaraswamy *et al*., (1996), Sawant and Suryawansh (1998), Shanthakumari *et al*., (2010), and Sankaran *et al*., (2010). Hence, it is absolutely necessary to determine the hydrogeochemical characteristics of groundwater before it is used for human consumption and irrigation purposes.

Study Area

Vellore District, which is located in the northern part of Tamil Nadu has been chosen for this study. The spatial extent of the study area is situated between the latitudes 12°15' - 13°15' N and longitudes 78°20' - 79°50' E, which covers an area of 6,077 sq.km. However, hills and reserved forests occupies 2,000 sq.km of area amongst the total study area and the remaining 4,077 sq.km of area falls under plain region, which is considered to investigate the hydrogeochemical parameters of groundwater for various purposes (Figure 1).

Database and Methodology

For analysing the hydrogeochemical characteristics of groundwater in the study area, the geology layer is prepared from the map procured from concerned state and central government departments and using IRS 1C LISS III + PAN merged satellite data for the period of 2003-2004. Geologically the entire district is broadly classified into hard rock and sedimentary formations. More than 90% of the area in this District is underlain by these formations. The groundwater quality details from eighty-two observation wells, which are uniformly distributed throughout the study area, also been considered for this study (Figure 2). The groundwater quality characteristics are analysed for pre- and post-monsoon seasons by collecting 20 years of data from 1989 – 2008. For the year 2008, the groundwater samples were collected and analysed for pre- and post-monsoon seasons (groundwater quality data from 1989 to 2007 were collected from Water Resources Organisation, Public Works Department, Chennai). The data related to general parameters (pH, electrical conductivity), major cations (calcium, magnesium, sodium and potassium) and major anions (bicarbonate, carbonate, sulphate, chloride and nitrate) are carefully utilised. Most of geochemical calculations are fundamentally based on the concentrations of major dissolved ions in groundwater and they are estimated to understand the geochemical system because these ions are the primary contributors to solution ionic strength.

Gibbs diagrams are drawn to identify whether the groundwater chemistry is due to rock dominance or evaporation dominance or precipitation dominance. In this diagram, two ratios have been calculated for anions and cations respectively. They are,

$$Gibbs\ Ratio\ I\ for\ anions = \frac{Cl^-}{Cl^- + HCO_3^-}$$

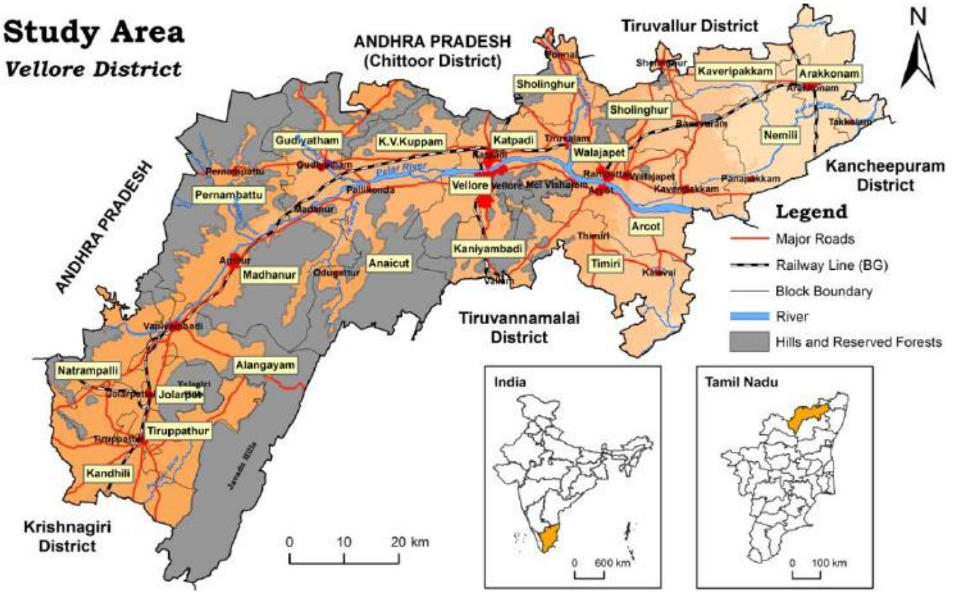

Fig. 1. Study Area - Vellore District

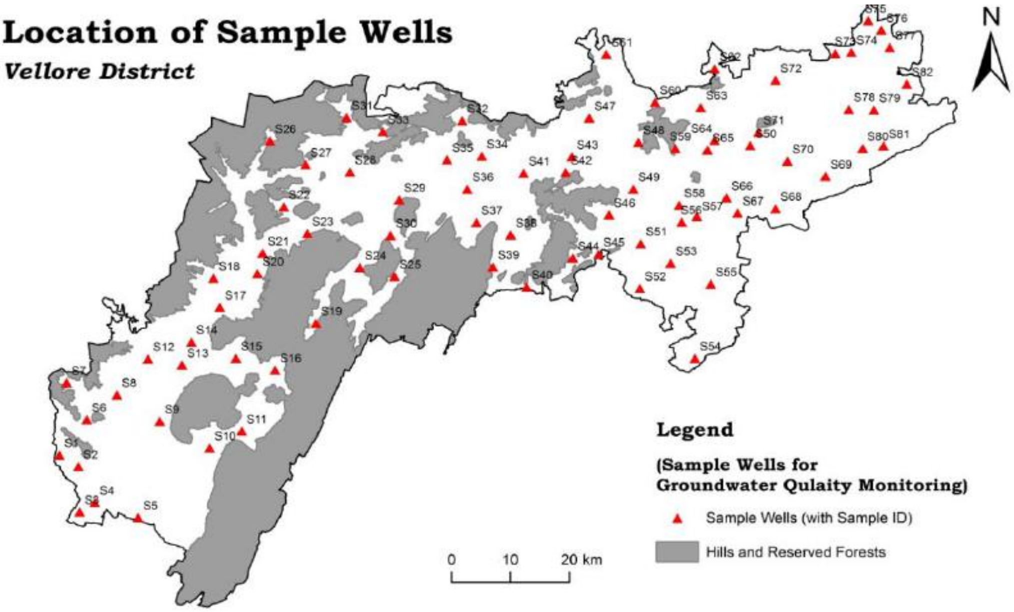

Fig. 2. Location of Sample Wells

$$Gibbs\ Ratio\ II\ for\ cations = \frac{Na^{+} + K^{+}}{Na^{+} + K^{+} + Ca^{2+}}$$

In both the ratios, all ionic concentrations are expressed in epm.

The study has been extended to analyse the metasomatism of groundwater (the change of groundwater quality from the point of entry to the point of exit). The chemical variations of groundwater during its travel in the underground are essential for proper interpretation of chemical analysis (Sastri, 1994). In this respect, Schoeller's Indices of Base Exchange (IBE), provides an insight on these phenomena. In the study area, there are some substances in the surface which can absorb and exchange their cations with cations that are present in the water. The Chloro-Alkaline Indices (CAI) are used to evaluate the extent of base exchange. They are calculated using the following formulae.

$$Chloro - Alkaline\ Index - I\ (CAI - I) = \frac{Cl^{-} - (Na^{+} + K^{+})}{Cl^{-}}$$

$$Chloro - Alkaline\ Index - II\ (CAI - II) = \frac{Cl^{-} - (Na^{+} + K^{+})}{SO_4^{2-} + HCO_3^{-} + CO_3^{2-} + NO_3^{-}}$$

(All the ionic concentrations are expressed in epm)

When there is an exchange between sodium and potassium $(Na^{+} + K^{+})$ in the water with magnesium and calcium $(Mg^{2+} + Ca^{2+})$ in the rocks, both these ratios are negative and when there is no base exchange, then the ratio becomes positive. Based on anions and cations, Schoeller has classified the groundwater into four types as Type I, Type II, Type III and Type IV. The Type I and II are called recent waters and Type III and IV are called older waters (Sastri, 1994). It can be observed that the first and foremost waters are those in which,

$$r\ CO_3^{2-} > r\ Cl^{-}\ or\ r\ SO_4^{2-}$$

(*r* is the epm representation of each ion)

But, if the increment is taken into consideration in total concentration under different situations, then the equation becomes

$$r\ CO_3^{2-}\ or\ r\ SO_4^{2-} > r\ Cl^{-}$$

and are classified as Type II waters.

If the same process of increment in total concentration of ions is continued, then the above relationship becomes

$$r\ Cl^{-} > r\ SO_4^{2-} > r\ CO_3^{2-}$$

and they are called Type III waters.

Further increment in total ion concentration leads to classify the water into Type IV and the equation becomes

$$r\,Cl^- > r\,SO_4^{2-} > r\,CO_3^{2-} \quad \text{and} \quad r\,Na^+ > r\,Mg^{2+} > r\,Ca^{2+}$$

Finally, the hydrochemical parameters of groundwater for both the seasons (pre- and post-monsoon seasons) have been examined using Piper's Trilinear diagram by using PLOTCHEM software and finally, ArcGIS software has been for spatial analyses and interpretations.

Results and Discussion

The chemical composition of groundwater is controlled by many factors including the composition of precipitation, mineralogy of the watershed and aquifers, and climate and topography. These factors combine to create diverse water types that change in composition spatially and temporally. The use of major ions as natural tracers has become a common method to delineate flow paths in aquifers (Back, 1966). The hydro-geochemical status of the groundwater is a cumulative function of its reaction with soil, lithology of water bearing materials and the residence time in the formation along the direction of its movement from the place of recharge to discharge (Sastri, 1994). The present standing of various cations and anions of groundwater samples of both pre- and post-monsoon seasons are studied in detail.

Mechanisms Influencing Groundwater Chemistry

Conway (1942), Gorham (1961), Mackenzie and Garrells (1966), Gibbs (1970), Ramesam *et al*. (1973), Price (1985) and Gowd (2005) have discussed a few mechanisms that control the major ion composition of the groundwater. The groundwater chemistry and the relationship of the chemical components of water to their respective aquifers such as chemistry of the rock types, chemistry of precipitated water, and rate of evaporation, Gibbs (1970) has suggested a diagram in which ratio of dominant anions and cations can be plotted against the value of TDS.

Gibbs diagram, representing the ratio – I for cations [($Na^+ + K^+$) / ($Na^+ + K^+ + Ca^{2+}$)] and ratio – II for anions [$Cl^- / (Cl^- + HCO_3^-)$] as a function of TDS are widely employed to assess the functional sources of dissolved chemical constituents, such as precipitation, rock, and evaporation dominance (Gibbs, 1970). The chemical data of groundwater infers that a majority of samples the chemical weathering of rock-forming minerals are influencing the groundwater quality through the interaction of groundwater and subsurface lithology. In this study, during pre-monsoon season, the Gibbs ratio – I diagram explains that 93.9% of the samples (77 samples) fall under rock dominance category and the remaining 6.1% of the samples (5 samples) fall in evaporation dominance category. In Gibbs ratio – II diagram, all 100% of the samples (82 samples) are identified in the zone of rock dominance.

The results of these diagrams illustrate that cations have been under least influence by evaporation compared to anions. During post-monsoon season, the Gibbs ratio – I diagram shows that 73.2% of the samples (60 samples) fall under rock dominance category and 26.8% of the samples (22 samples) are found in evaporation dominance category. In Gibbs ratio – II diagram, 81.7% of the samples (67 samples) are categorised as rock dominant samples and the remaining 18.3% of the samples (15 samples) fall in evaporation dominance category (Table 1; Figures 3 and 4).

An attempt has been made to classify the categories of mechanism that control the groundwater chemistry spatially as per the procedures followed by Sivagnanam and Kumaraswamy (1988). During pre-monsoon season, the result of Gibbs ratio – I shows that most parts of the study area fall under the category of rock dominant groundwater chemistry and a small pocket on the northern part of Natrampalli block; southern parts of Pernambattu and Madhanur blocks and eastern portion of Alangayam block are categorised under evaporation dominant groundwater (Figure 5). As per the result of Gibbs ratio – II, it is observed that the entire portion of the study area falls under rock dominant groundwater (Figure 6).

During post-monsoon season, the result of Gibbs ratio – I shows that most of the central and eastern portions (Tiruppathur, Gudiyatham, Anaicut, K.V.Kuppam, Vellore, Kaniyambadi, Katpadi, Sholinghur, Walajapet, Timiri, Arcot, Kaveripakkam, Nemili and Arakkonam blocks) of the study area fall under rock dominant groundwater. The groundwater chemistry at southwestern portions (northern portions of Alangayam and southern portion of Pernambattu blocks; some of the portions of Jolarpet, Tiruppathur and Kandhili blocks); central portion (Kaniyambadi block); a small portion around Banavaram Reserved Forest and extreme eastern part of Arakkonam block are the areas influenced by evaporation (Figure 7). The result of Gibbs ratio – II shows that central and eastern portions (Gudiyatham, Anaicut, K.V.Kuppam, Vellore, Kaniyambadi, Katpadi, Sholinghur, Walajapet, Timiri, Arcot, Kaveripakkam, Nemili Arakkonam blocks and few portions of Tiruppathur and Alangayam blocks) are influenced by rock dominant groundwater chemistry and most parts of southwestern portion (parts of Pernambattu, Madhanur, Natrampalli, Jolarpet, Tiruppathur and Kandhili blocks) are accompanied with evaporation dominant groundwater (Figure 8).

Seasonal variations in groundwater chemistry of any area are principally due to variations in groundwater recharge, pumping, well lithology, and geochemical reactions (Scheytt, 1997). The groundwater level fluctuation in the observation wells also influences the concentration of different chemical parameters in groundwater. It is well known that recharge water dilutes the chemical concentration during rainy seasons (post-monsoon) and evaporation influences the increased level of concentration in groundwaters during dry season (pre-monsoon). In the study area, the major ion chemistry of the groundwater is regulated by both mineral dissolution and anthropogenic activities. Mineral dissolution is dominated in sedimentary and hard rock formations. On the other hand, anthropogenic activities dominate in sedimentary formations compared to hard rock formations.

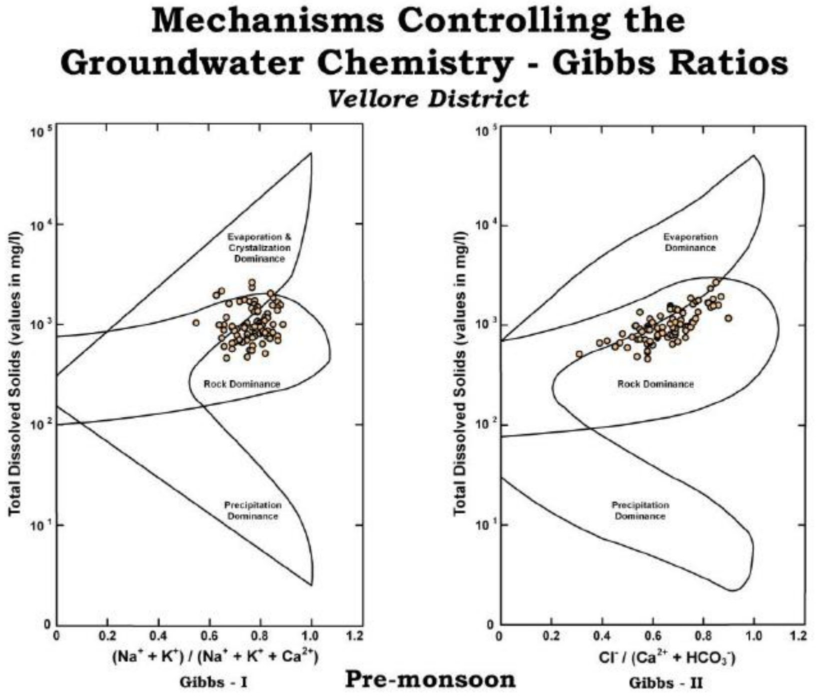

Fig. 3. Mechanisms Controlling the Groundwater Chemistry during Pre-monsoon Season

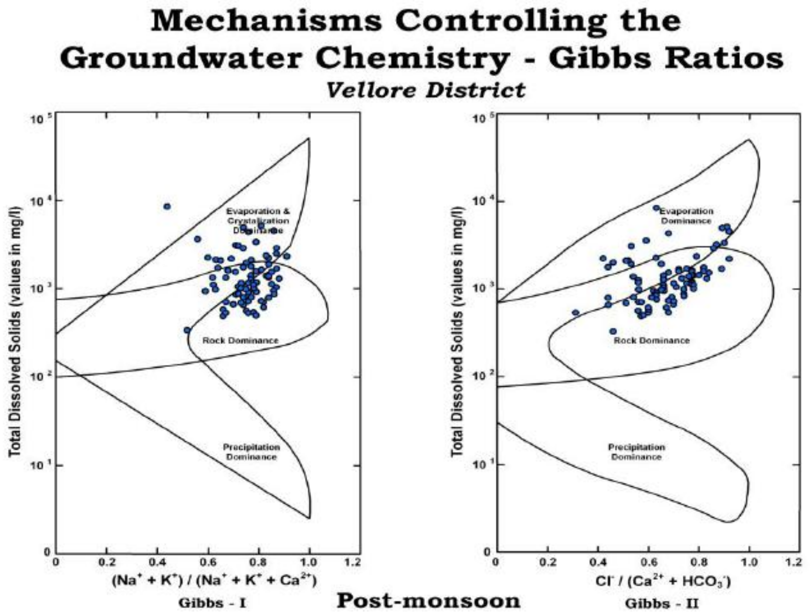

Fig. 4. Mechanisms Controlling the Groundwater Chemistry during Post-monsoon Season

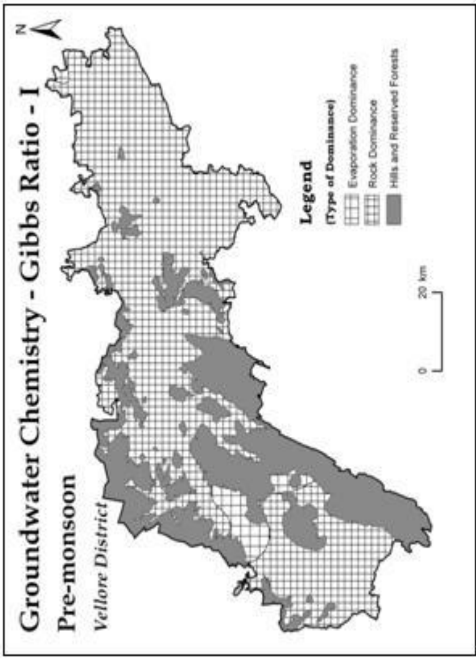

Figure 5: Groundwater Chemistry - Gibbs Ratio I (Pre-monsoon)

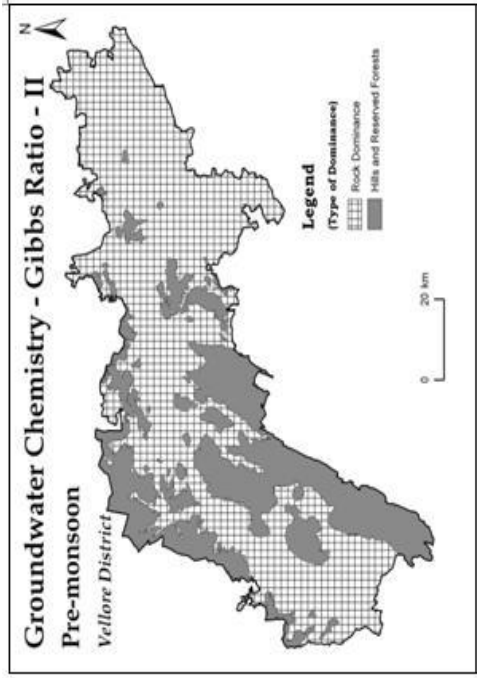

Figure 6: Groundwater Chemistry – Gibbs Ratio II (Pre-monsoon)

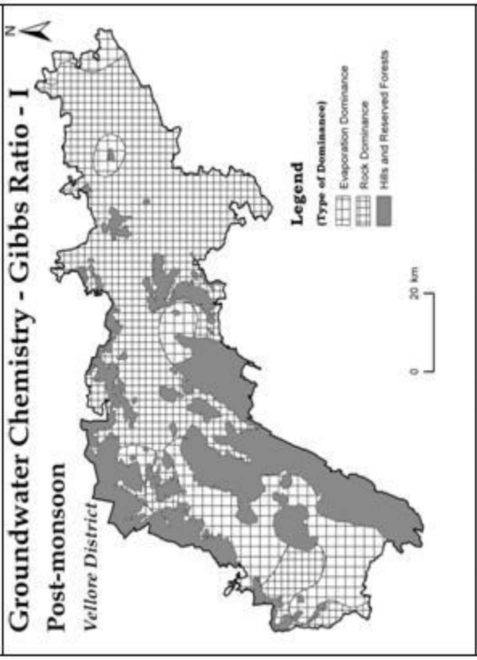

Figure 7: Groundwater Chemistry - Gibbs Ratio I (Post-monsoon)

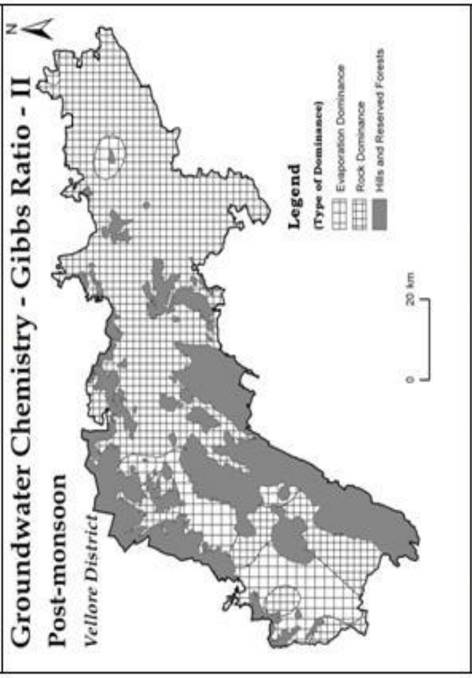

Figure 8: Groundwater Chemistry - Gibbs Ratio II (Post-monsoon)

Metasomatism of Groundwater

Metasomatism is a metamorphic process by which the chemical composition of a rock or portion of rock (clay minerals, glauconite, zeolites and organic substances) is altered in a pervasive manner and may sometimes absorb and exchange the chemical components as a result of the interaction of the rock with aqueous fluids (solutions). Kaolinite, illite, halite and chlorite are some of the clay minerals in which the ions are present and hence the exchange capacity is lesser.

Schoeller (1965) proposed a measure, named Index of Base Exchange (IBE) which describes this metasomatism in groundwater. Based on the two indices prepared by Schoeller, the study area can be divided into positive and negative zones (Table 2), demarcating the areas of recharge and discharge respectively (Schoeller, 1965; Sastri, 1994).

Two Chloro-Alkaline Indices (CAI-I and CAI-II) are used to evaluate the extent of base exchanges during rock-water interaction.

$$Chloro - Alkaline\ \ Index\ I \quad = \ Cl^{-}\ (Na^{+} + K^{+}) / Cl$$

$$Chloro - Alkaline\ \ Index\ II \quad = \ Cl^{-}\ (Na^{+} + K^{+}) / SO_4^{2-} + HCO_3^{-} + CO_3^{2-} + NO_3^{2-}$$

(All the ionic concentrations are expressed in epm)

When there is an exchange between $Na^{+} + K^{+}$ in water with $Mg^{2+} + Ca^{2+}$ rocks, both the ratios are found to be positive. If there is a reverse exchange, then values become negative. In the study area, the negative and positive ratios of chloro-alkaline indices I and II during pre- and post-monsoon seasons are shown in Table 2. Similar patterns of distribution among samples are observed in CAI-I and CAI-II during both the seasons. The number of samples found in CAI-I and CAI-II, during pre-monsoon season shows that 51.2% of the samples (42 samples) fall under negative ratios (discharge zone) and the remaining 48.8% of the samples (40 samples) found under positive ratios (recharge zone). While looking at the status of post-monsoon season, 57.3% of the samples (47 samples) fall under negative ratios and the remaining 42.7% of the samples (35 samples) found in positive ratios (Table 2).

The interpolated raster surfaces of CAI-I and CAI-II during pre-monsoon season (Figures 9 and 10) explain that some of the parts of Kandhili, Tiruppathur, Alangayam, Madhanur, Pernambattu, K.V.Kuppam, Katpadi, Vellore, Kaniyambadi, Arcot, Timiri, Walajapet and Sholinghur blocks; substantial portions of Kaveripakkam and Nemili blocks, and eastern portions of Arakkonam block are categorised as negative ratios (discharge zone) and the remaining portions are classified as positive ratios (recharge zone). During post-monsoon season, the similar kind of result is reflected as same as pre-monsoon season with negative and positive ratios (discharge and recharge zones) found in same regions with slight variations (Figures 11 and 12).

Based on Schoeller's principle, the groundwater of the study area is classified into three types of Schoeller's water (Type I, III and IV). About 86.6% (71 samples) and 81.7% (67 samples) of pre- and post-monsoon season samples fall into Type IV of water and the other types constitute only for limited extent (Table 3).

The interpolated raster surfaces of pre- and post-monsoon seasons explain that the entire study area is dominated by Type IV water compared to Type I and Type III waters. The Type I and Type III waters are found in the parts of Kandhili, Tiruppathur, Natrampalli and Alangayam blocks; southern portions of Madhanur, Anaicut, Vellore and Kaniyambadi blocks and northern parts of Sholinghur, Walajapet and Arakkonam blocks (Figures 13 and 14).

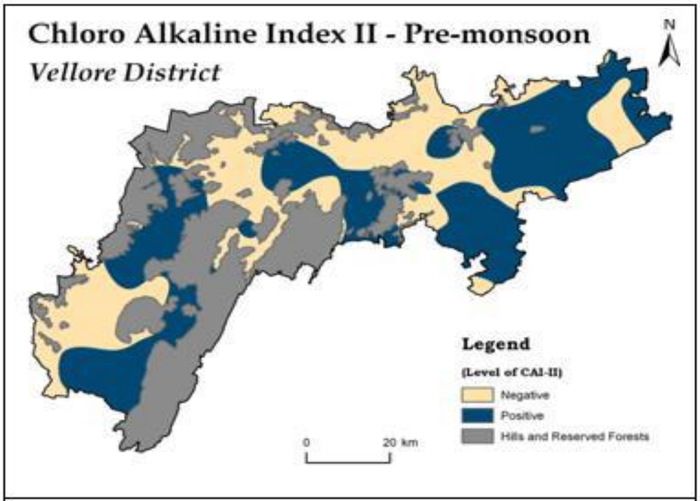

Figure 10: Chloro Alkaline Index II (Pre-monsoon)

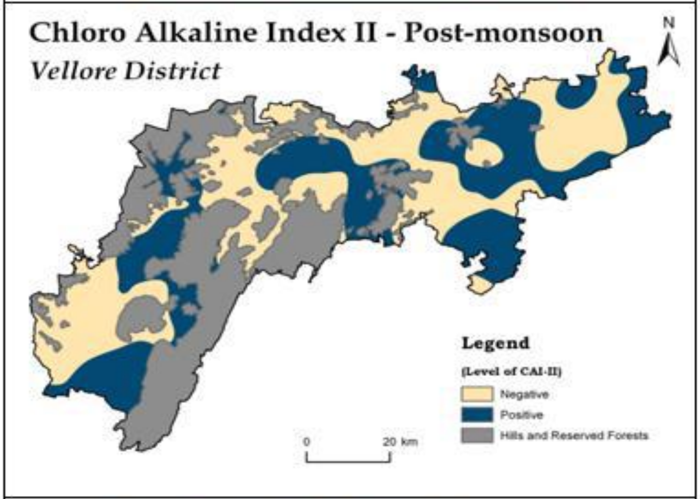

Figure 12: Chloro Alkaline Index II (Post-monsoon)

Table 1. Mechanisms Controlling the Quality of Groundwater

Type of Dominance	Gibbs Ratio – I				Gibbs Ratio – II			
	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
	No. of samples	% of samples	No. of samples	% of samples	No. of samples	% of samples	No. of samples	% of samples
Evaporation Dominance	5	6.1	22	26.8	-	-	15	18.3
Rock Dominance	77	93.9	60	73.2	82	100	67	81.7
Precipitation Dominance	-	-	-	-	-	-	-	-
No Type	-	-	-	-	-	-	-	-

Table 2. Chloro-Alkaline Indices of Groundwater

Chloro-Alkaline Indices of Groundwater	Pre-monsoon				Post-monsoon			
	Negative Ratio		Positive Ratio		Negative Ratio		Positive Ratio	
	No. of Samples	% of Samples	No. of Samples	% of Samples	No. of Samples	% of Samples	No. of Samples	% of Samples
CAI-I	42	51.2	40	48.8	47	57.3	35	42.7
CAI-II	42	51.2	40	48.8	47	57.3	35	42.7

Table 3. Schoeller's Water Types

Water Type	Pre-monsoon		Post-monsoon	
	No. of Samples	% of Samples	No. of Samples	% of Samples
Type I	6	7.3	3	3.7
Type III	4	4.9	11	13.4
Type IV	71	86.6	67	81.7

Table 4. Piper's Triangle Fields Classification

Subdivision of the Triangles		Characteristics of Corresponding Subdivisions of Triangle-shaped fields	Pre-monsoon		Post-monsoon	
			No. of samples	% of samples	No. of samples	% of samples
Cation Facies	A	Calcium type	-	-	-	-
	B	Magnesium type	-	-	-	-
	C	Sodium or Potassium type	51	62.2	56	68.3
	O	No dominant type	31	37.8	26	31.7
Anion Facies	D	Bicarbonate type	4	4.9	4	4.9
	E	Sulphate type	-	-	-	-
	F	Chloride type	55	67.1	55	67.1
	O	No dominant type	23	28	23	28

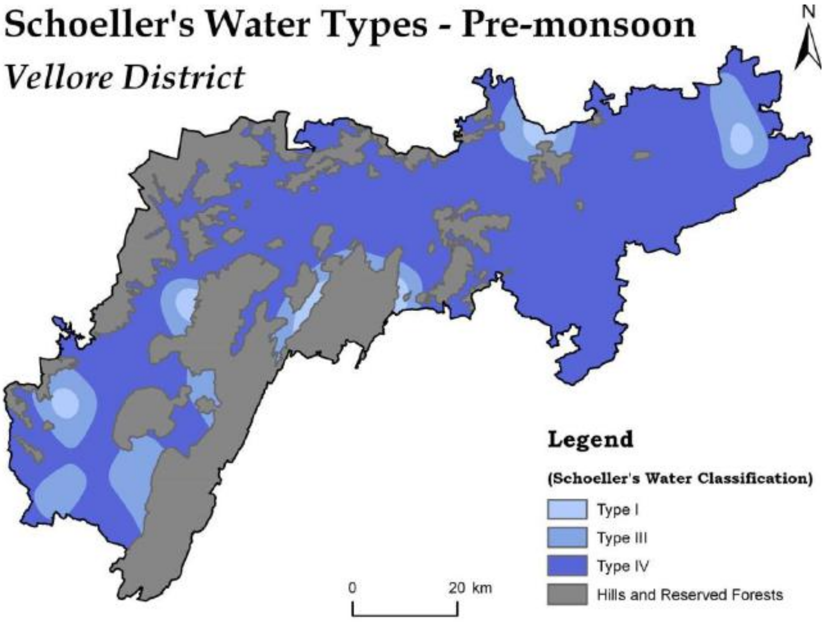

Fig. 13. Schoeller's Water Types - Pre-monsoon Season

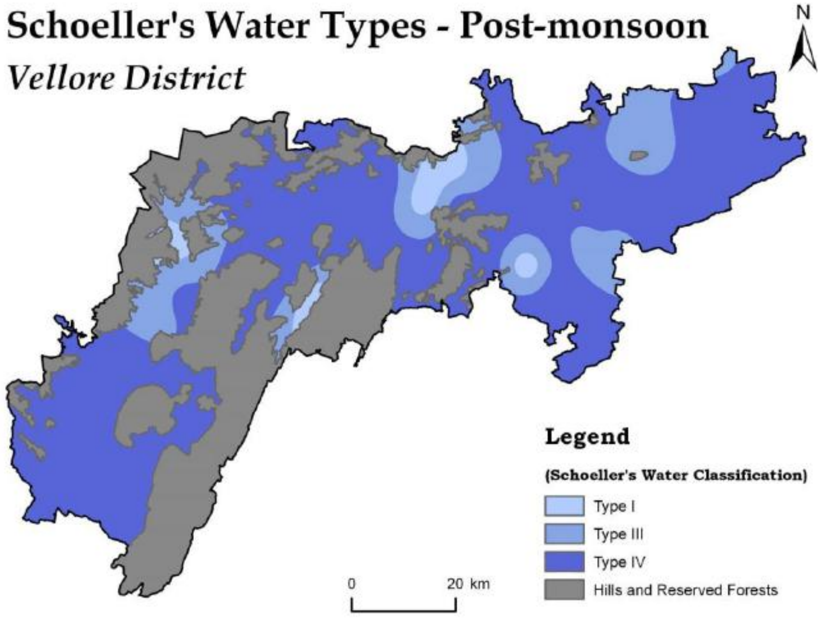

Fig. 14. Schoeller's Water Types - Post-monsoon Season

Hydrochemical Facies

One of the most interesting aspects of hydrochemistry is the occurrence of water bodies with different water chemistries in very close proximity to each other. This has been variously attributed to the surface and subsurface geology (Stallard and Edmand, 1983), limited climatic differences (Petrovic, 1980) and the flow direction (Lyons *et al*., 1992).

The Piper's diagram is widely used to understand the problems relating to the geochemical progression of groundwater. The diagram consists of two triangles (for cations and anions) and a diamond shaped field to study the hydro-geochemical facies of groundwater. The term 'hydrochemical facies' is used to describe the bodies of groundwater in an aquifer that differ in their chemical composition. The facies are a function of the lithology, solution kinetics, and flow patterns of the aquifer.

The concentrations of major ionic constituents of groundwater samples are plotted in the Piper's trilinear diagram (Piper, 1953) to determine the water type (Figures 15 and 16). The PLOTCHEM software is used to construct the Piper's trilinear diagram and the values are used in milliequivalents per litre (epm). The classification for cation and anion facies, in terms of major ion percentages and water types, is made according to the domain in which they occur on the diagram segments (Back, 1966). Diagrammatic representation of chemical constituents is very effective to understand the results of the analysis and to provide means for comparing the analysis with each other.

The cationic and anionic triangular fields of Piper's diagram, during pre-monsoon season, exhibit that 62.2% (51 samples) of the samples fall into the 'sodium or potassium type', and the remaining 37.8% (31 samples) of the samples are found in 'no dominant type' among cation facies. On the other hand, 67.1% (55 samples) of the samples fall into the 'chloride type'; 4.9% (4 samples) under 'bicarbonate type' and the remaining 28% (23 samples) into 'no dominant type' among anion facies (Table 4). During post-monsoon season, as per the cationic and anionic triangular fields of Piper's diagram, it is observed that 68.3% (56 samples) of the samples are found in 'sodium or potassium water type' and the remaining 31.7% (26 samples) of the samples fall into 'no dominant type' among cation facies. While looking at anionic facies, no difference is found between pre- and post-monsoon seasons, 'chloride type' is dominated with 67.1% (55 samples) of the samples; 4.9% (4 samples) in 'bicarbonate type' and other 28% (23 samples) into 'no dominant type' among anion facies (Table 4).

The plots of chemical data on diamond shaped trilinear diagram (Figures 15 and 16) reveals that a majority of groundwater samples during pre- and post-monsoon seasons fall in the field 2 (62.2% of pre-monsoon and 68.3% of post-monsoon seasons samples), field 4 (95.1% of pre-monsoon and 95.1% of post-monsoon seasons samples) and field 7 (61% of pre-monsoon and 64.6% of post-monsoon seasons samples) suggesting that alkalies exceeds alkaline earth; strong acids exceed weak acids; and the ions representing sodium-chloride type respectively (Table 5).

The diagram reveals that the total hydrochemistry is dominated by alkalies and strong acids. Conversely, some of the groundwater samples having high calcium and magnesium concentrations fall in the field 1 (37.8% of pre-monsoon and 31.7% of post-monsoon seasons samples) and in field 3 (4.9% of pre- and post-monsoon seasons samples) indicating alkaline earths exceeding alkalies and weak acids exceeding strong acids. A few samples also fall in the field 9 (35.3% of pre-monsoon and 34.2% of post-monsoon season samples) indicating mixed type water having whose cation-anion pair does not exceed 50% (Table 5).

While studying cation facies during pre-monsoon season, the interpolated raster surface shows that a major portion of the study area falls under 'sodium or potassium type' groundwaters. The parts of Natrampalli, Tiruppathur, Alangayam, Gudiyatham, Anaicut, K.V.Kuppam, Anaicut, Sholinghur, Vellore, Katpadi, Walajapet, Timiri and Arakkonam blocks are found under 'sodium or potassium type' groundwaters. As for as the cation is concerned, 'no dominant type' is found in most of the areas of Pernambattu, Kaveripakkam, Kaniyambadi and Arcot blocks; few pockets in Kandhili, Natrampalli, Tiruppathur, Alangayam, Madhanur, Katpadi and Sholinghur blocks (Figure 17a). Among the anion facies, it is clearly found that 'chloride type' groundwater is dominating throughout the study area, particularly in the eastern portion. The waters of Kandhili, Alangayam, Pernambattu, Gudiyatham, Anaicut, Vellore, Kaniyambadi, Walajapet, Arcot, Timiri, Sholinghur and Kaveripakkam blocks; southern portion of Nemili and northern portion of Arakkonam blocks are dominated with 'chloride type' waters. The 'bicarbonate type' water is found as a small pockets in areas of Natrampalli, Alangayam, Pernambattu, Gudiyatham and Anaicut blocks; and the remaining areas are found with 'no dominant type' (Figure 17b).

The diamond shaped facies clearly explain that 'sodium-chloride type' is the dominant groundwater type identified in the study area. A very few number of samples are found under 'magnesium-bicarbonate type' and the remaining samples fall into 'mixed type' groundwater. The areas of southern Kandhili, Natrampalli, Jolarpet, Alangayam, Gudiyatham, Anaicut, K.V.Kuppam, Katpadi, Vellore, Walajapet, Sholighur, Timiri and Arakkonam blocks are found with 'sodium-chloride type' of groundwater. Small pockets of portions in Natrampalli and Anaicut blocks are found with 'magnesium-bicarbonate type' and the remaining portions fall under 'mixed type' groundwater (Figure 17c).

During post-monsoon season, the interpolated surface of cation facies shows that the 'sodium or potassium type' is the dominant type of groundwater in the study area. The areas of Jolarpet, Tiruppathur, Anaicut, Gudiyatham, Vellore, Walajapet, Sholinghur, Arcot, Timiri, Kaveripakkkam, Nemili and Arakkonam blocks are dominated by 'sodium or potassium type' groundwater. The remaining portions fall into 'no dominant type' groundwater (Figure 18a). While looking at anion facies, it is clearly found that 'chloride type' is dominated all over the study area, mainly in the eastern portion covering parts of Kandhili, Tiruppathur, Alangayam, K.V.Kuppam, Vellore, Katpadi, Kaniyambadi, Timiri, Kaveripakkam, Nemili and Arakkonam blocks; and limited portions of Pernambattu, Madhanur, Gudiyatham, Anaicut, Walajapet and Sholinghur blocks.

Areas in Anaicut, Gudiyatham, K.V.Kuppam and Walajapet blocks are found with 'bicarbonate type' and the remaining areas are found under 'no dominant type' groundwaters (Figure 18b). The diamond shaped facies clearly describe that 'sodium-chloride type' is the dominant groundwater. The areas of southern Natrampalli, Gudiyatham, Anaicut, Vellore, Katpadi, Walajapet, Timiri, Nemili and Arakkonam blocks; and limited portions of Tiruppathur, Alangayam, Kaveripakkam blocks are found with 'sodium-chloride type' groundwater. Only a small pocket of Anaicut block is found with 'magnesium-bicarbonate type' and the remaining portions fall under 'mixed type' groundwater (Figure 18c).

Table 5 Characterisation of Groundwater Corresponding to the Subdivisions of Diamond-shaped Fields

Subdivision of the Diamond	Characteristics of Corresponding Subdivisions of Diamond-shaped Field	Pre-monsoon		Post-monsoon	
		No. of samples	% of samples	No. of samples	% of samples
1	Alkaline earths (Ca+Mg) exceeds alkalies (Na+K)	31	37.8	26	31.7
2	Alkalies exceeds alkaline earths	51	62.2	56	68.3
3	Weak acids (CO_3+HCO_3) exceeds strong acids (SO_4+Cl)	4	4.9	4	4.9
4	Strong acids exceeds weak acids	78	95.1	78	95.1
5	Magnesium-Bicarbonate type	3	3.7	1	1.2
6	Calcium-Chloride type	-	-	-	-
7	Sodium-Chloride type	50	61	53	64.6
8	Sodium-Bicarbonate type	-	-	-	-
9	Mixed type	29	35.3	28	34.2

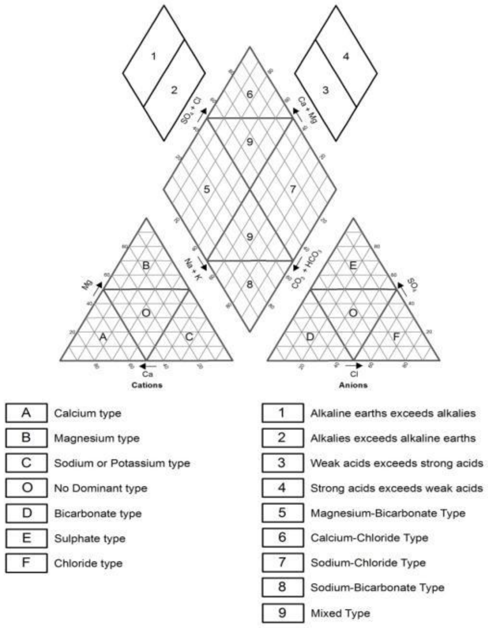

Fig. 15. Hydrochemical Facies of Piper's Trilinear Diagram

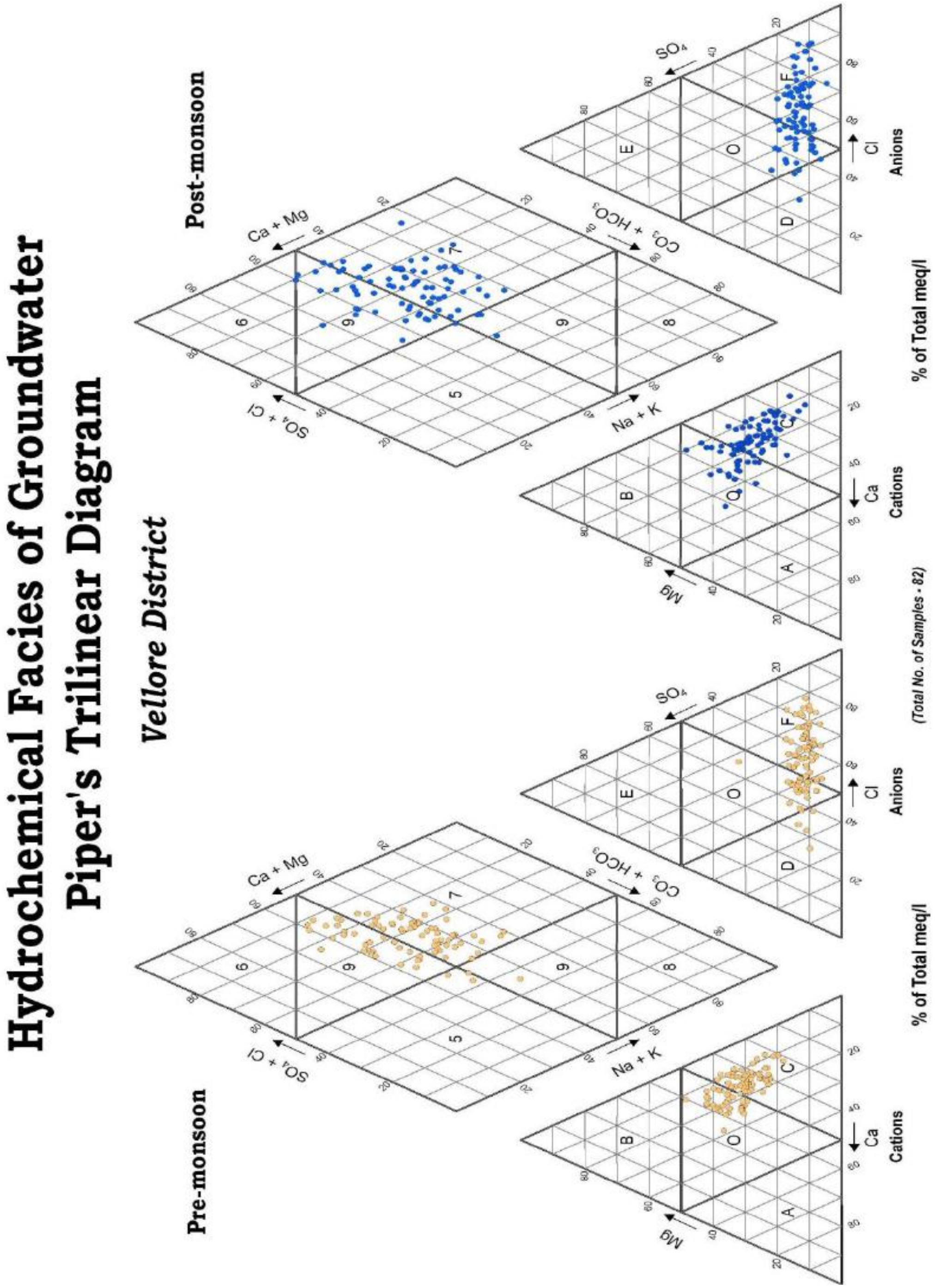

Fig. 16. Hydrochemical Facies of Groundwater - Piper's Trilinear Diagram (Pre- and Post-monsoon Seasons)

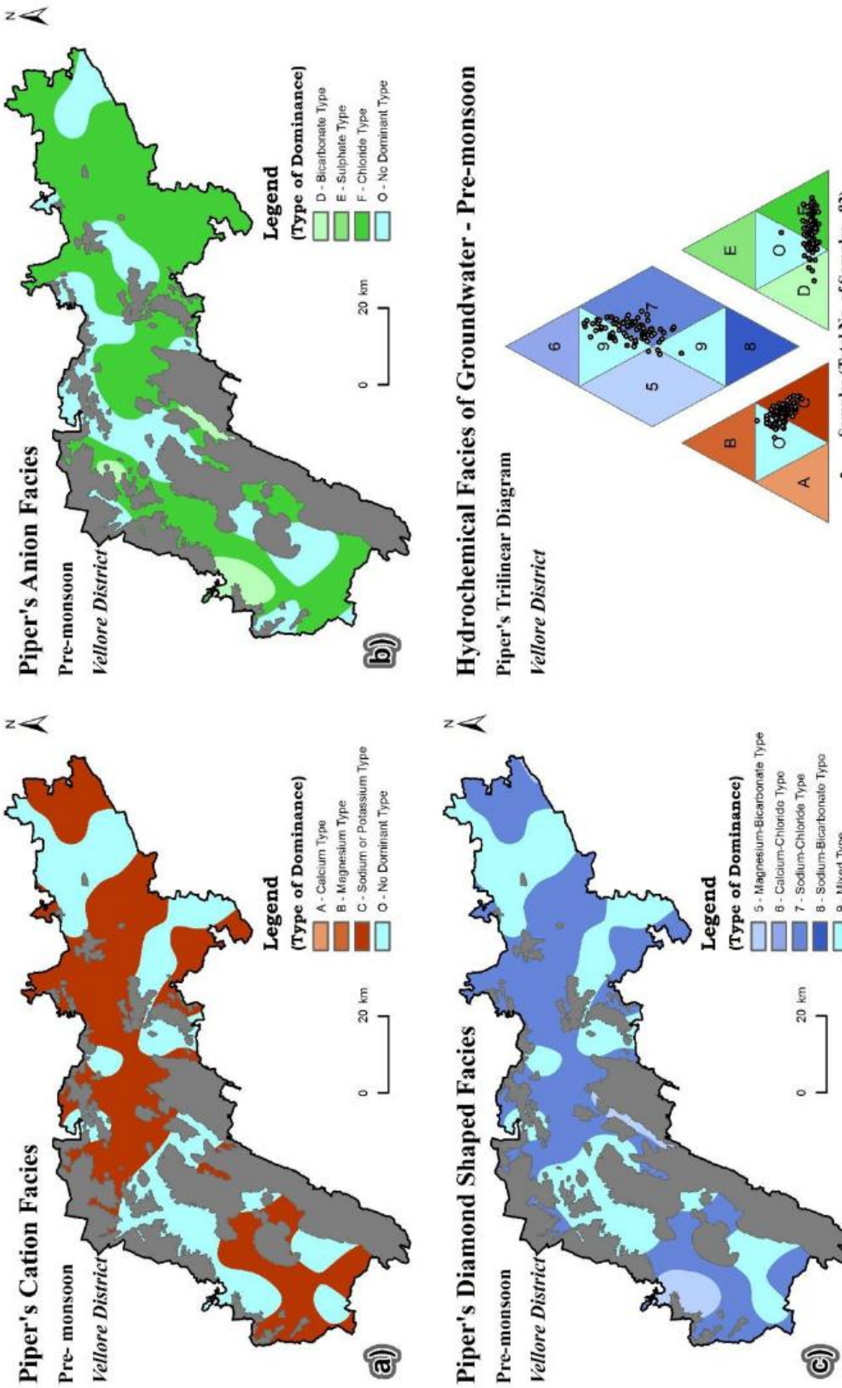

Fig. 17. a) Piper's Cation Facies; b) Piper's Anion Facies; and Piper's Diamond Shaped Facies - Pre-monsoon Season

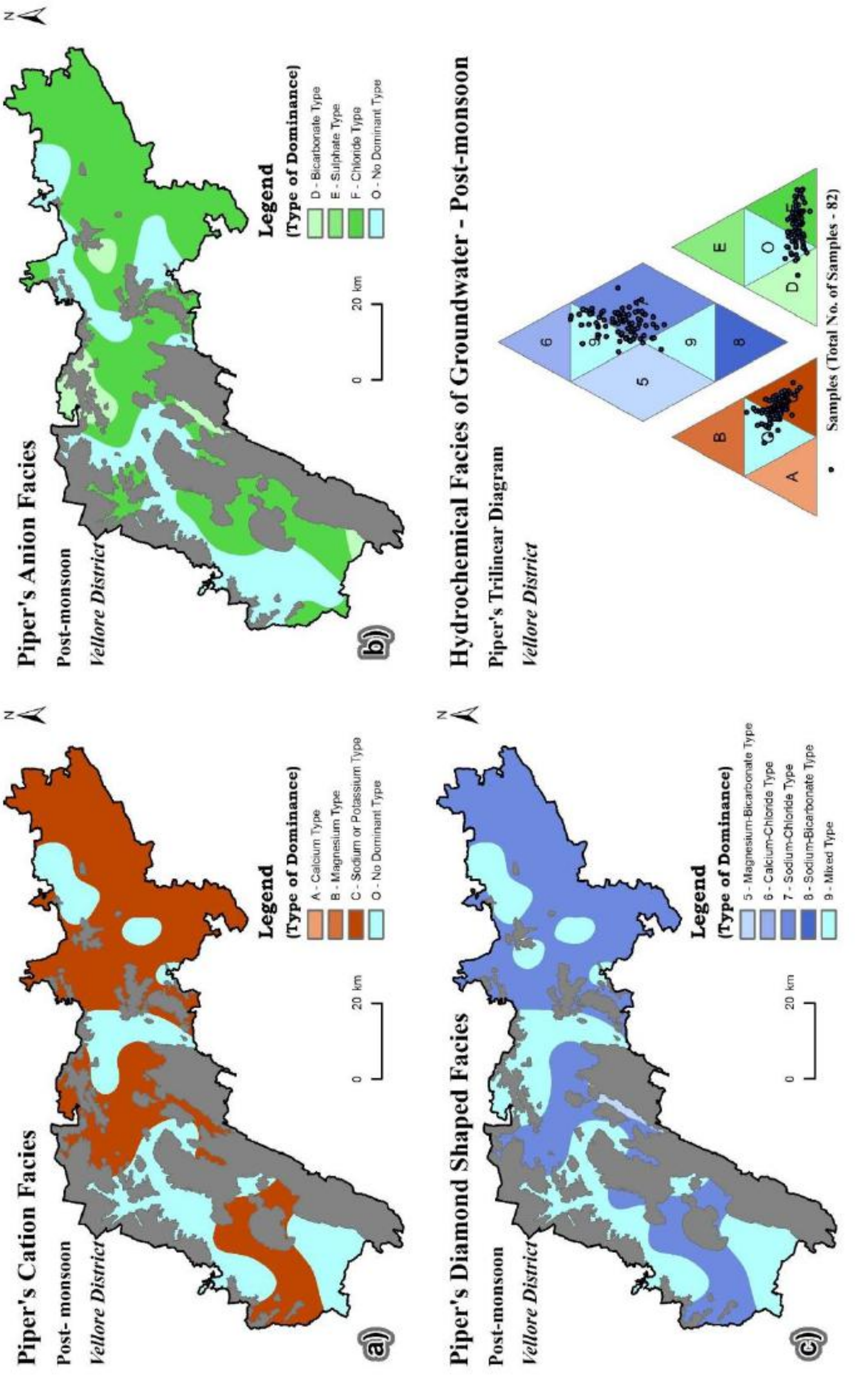

Fig. 18. a) Piper's Cation Facies; b) Piper's Anion Facies; and Piper's Diamond Shaped Facies - Post-monsoon Season

Conclusion

The hydrogeochemical characteristics of groundwater in the study area are evaluated for its suitability to various purposes by analysing 82 groundwater samples to understand the concentrations of major cations and anions. The sequences of abundance of the major ions are in the following order: $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+} = Cl^{-} > HCO_3^{-} > SO_4^{2-} > CO_3^{2-} > NO_3^{-}$ during both the seasons. The Gibbs diagrams show that the mechanisms controlling groundwater chemistry in majority of samples are influenced by rock dominance during both the seasons. The outputs of Chloro Alkaline Indices explain that there were no major variations found in the results and similar kind of results were reflected in both the seasons with negative and positive ratios (discharge and recharge zones). The interpolated raster surfaces of Schoeller's water types explain that the entire study area is dominated by Type IV water compared to Type I and Type III waters during pre- and post-monsoon seasons. These results indicate the increasing trend of concentrations with older waters. The triangular fields of Piper's diagram explain that sodium and potassium type among cations and chloride type among anions are dominating in cation and anion facies respectively. The diamond shaped facies explain that the groundwater is dominated by alkalies exceed alkaline earths; strong acids exceed weak acids and sodium-chloride type during both the seasons.

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HUMAN ECOLOGY OF VARANASI METROPOLITAN CITY IN UTTAR PRADESH

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Abstract

Human Ecology deals with the population aspects of any region which are essential for the location/allocation of resources. In this research paper, the study dealt with the population and demographic characteristics of Varanasi city since the first known census of India. Population characteristics include study of population distribution, density, growth rate, social compositions, occupational structure etc. For the present study, secondary sources of data were collected and its spatial and temporal variation was assessed. The problem faced by the city due to the unexpected overgrowth of population, haphazard sprawl of the housing structures of the city were discussed in this study. Relevant as well as pragmatic solution to the urban problems was derived from the discussion.

Keywords: Human Ecology, Population Characteristics, Demographic Characteristics, Urban Migration, Human Habitation.

Introduction

The study of population aspects are essential as it forms base for understanding the disease ecology all over the world specifically in urban areas of third world cities. The census of India 2001, being the first census of the 21st century, reveals the state of abundant human resources available in the country. The census of India indicates the population of India as 1,027 million in 2001. India constitutes 16.87 percent of the world population and 2.4 percent of the global land area. Since the Varanasi city could not expand eastern side due to the presence of the river, the western side is found with high density of population. The middle part of the western side is called as Kashi. This can be called as the C.B.D the commercial centre of the city. The wholesale market of all products with residences is distributed in the area. Very old buildings and gullies (narrow lanes), are the common features of the region.

A comprehensive assessment of human resource and related aspects are very essential. It influences the environment in general and urban environment specifically. The economic conditions of the area are also regarded as the resultant of nature of people residing in that particular place. It determines the income structure, expenditure pattern and standard of living etc.

Therefore in the present study it is very essential to pay due attention to the human resource aspect in the city. The pattern of population distribution, growth and density of the people, sex composition, occupational structure, literacy, fertility rate, mortality rate etc., play an important role in determining the quality of urban environment and the future improvements/developments thereof. The objectives of the present study are to analyse the population characteristics and it impact on human habitation and to assess the health aspects of population for certain diseases.

Database and Methodology

The required data was collected from the secondary sources of Census Data of various decadal census of India, Varanasi Development Authority, Kutchery, Varanasi, Varanasi Municipal Corporation, Sigra, Varanasi. Some other important information were collected from published research papers and journals. Online published materials were also considered for this study

Study Area

Varanasi is one of the world's oldest living city. Very famous educational hub, religious, cultural centre of the world. It is situated in a subtropical region of the middle Ganga plain. It has a recent deposition of Pleistocene period, underlies by Gangetic alluvium. It extends between 25° 18' North Latitude and 83° 01' East Longitude. It is well known for its spiritualism and pilgrimages.

Population Growth

a) Causes of Growth

The following are the main reason for the growth of population of Varanasi

- Educational facilities
- Health Care facilities
- Commercial and Business activities
- Migrants from surrounding areas
- Employment opportunities
- Cultural and Age old mythological aspects.

Varanasi city being head quarter of the region has become an important centre for education and health care. There are number of permanent and semi-permanent migrants found as managers and uses of these infrastructural facilities. The migration is also due to various employment opportunities available as a result of increasing commercial activities. Shopping complexes are increasing and other infrastructure facilities like hotels, travel and transport agencies etc. are adding to cater the needs of the growing population. All these factors govern the growth of population. Varanasi city plays an important role as a tourist, recreational and religious centre. To cater the needs of the floating population infrastructural facilities are established.

b) The Trend of Population Growth till 1951

Varanasi is one among the largest cities in Uttar Pradesh. It is well known for its tourist attraction and attracts population from other states of India and from all over the world. The population of Varanasi had increased six times from 1901 to 2001 (Table 1). According to the first known census of 1800 A.D which was mentioned in the "Travels of India" there were (about) 30,000 houses and 5,82,000 inhabitants. The first dependable census was conducted in 1881 A.D; In that it was revealed that there were 2, 18,573 people. The census of 1901, had stated the population of the city as 2, 15,523 with male population of 1, 11,857 and female population of 1, 03,366. The trend, between 1800 and 1901 indicated that the population was decreasing. The following table shows the decadal growth and variations of growth.

Table 1. Growth of Population in Varanasi City.

Census Year	Total Population	Male	Female	Decennial variation	Percentage Dec. Var.
1901	215,523	111,857	103,366	-	-
1911	205, 420	106,651	98,767	9,803	-4.55
1921	200,022	107,088	93,014	5,358	-2.62
1931	203,372	112,894	90,475	3,350	+1.67
1941	258,646	143,902	115,554	55,272	+27.18
1951	341, 923	186,546	155,377	83,277	+32.20
1961	471,258	257,831	213,427	129,336	+37.83
1971	583,856	377,402	266,454	112,598	+23.89
1981	716,779	385,731	331,048	132,928	+20.71
1991	1,017,995	548,073	469,922	301,216	+42.02
2001	1,100,748	584,574	576,254	82,753	+8.13

Source: *Kayastha, S. L. (2004)*

In the period of 1901-1921 population growth recorded decreasing trend and from 1921 to 1951, the increasing trend is very slow. The variation is less comparative to other decades. From 1951 onwards i.e. after independence, the city population had started increasing. In 1961 the population had increased to 4,71,258. The growth of population was –2.62% during 1911-21 and the decline was mainly due to epidemics and famines. During the first few decades of 20th century there were high fluctuations resulting from high birth rates and death rates.

Lack of health care facilities, outbreak of epidemics, crop failures, low literacy level, lack of awareness are responsible for the negative growth rate slow pace of growth. Since 1931 the population started increasing, there has been a steady and somewhat rapid growth till 2001. The population of 1931 marks the 'Demographic Divide' showing an era of two-digit increase of 27.18%. After 1931, it has been a phase of early expansion because of a significant decline in mortality and morbidity rates, natural increase and heavy influx of immigrants from rural areas.

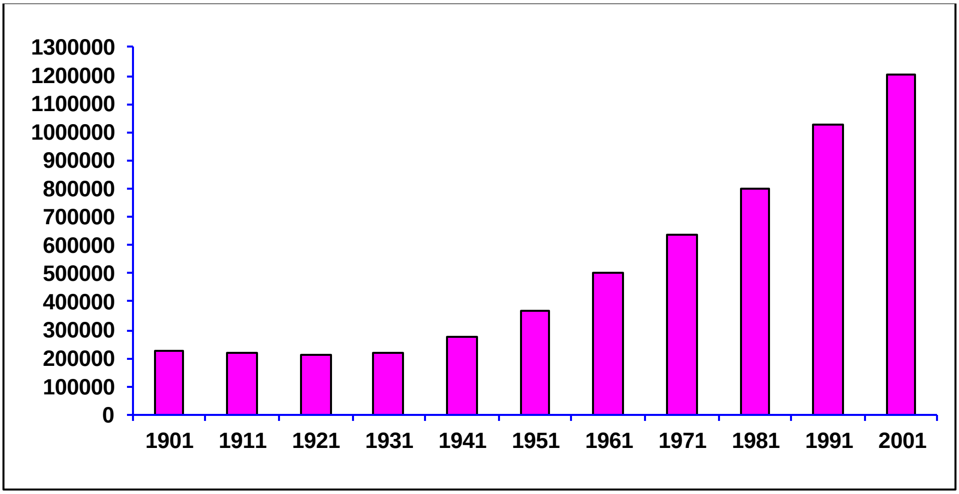

Fig. 1. Varanasi City - Population (1901 - 2001)

The increase in the post 1931 period had been mainly due to better medical knowledge, which controlled epidemics like plague, cholera and small-pox. Till 1951 there had been a steady increase of population due to improved means of trade and commerce. The Figure 1 shows the trend from 1901 to 2001.

c) The Trend of Population Growth in Recent Few Decades

There has been a period of 'quick gains' and a period of steady high growth of urban population since 1961 till 2001. Expansion of employment opportunities in the non-farm sectors (increasing number of industries e.g. Diesel Locomotive Works in 1961) in and around the city, improvement in transport and communication network, better provision of educational and health facilities, and, above all, the lack of development and poverty in the rural areas, have added to the cause of high population growth rate.

After 1991, Varanasi suffers from high congestion and uncontrolled population growth. In 2001, it had increased to 1.2 million and decadal percentage increase had changed to 42.02% from 8%. It is observed that there is a deep decline in the growth rate in the last decade. If the present trend continues, this will pose a great threat to the carrying capacity of the land, following the degradation of environment and huge congestions in different infrastructural facilities.

During the period of 1951 to 1981, the city showed a rapid increase of population. If we compare the growth of population of Varanasi with other large cities of U.P and of middle Ganga valley, the growth rate of Varanasi was higher than Kanpur but lower than other Kaval cities. In 1991-2001 the decadal growth of Varanasi city was lower than other Kaval cities, but the same is lesser than Kanpur and Allahabad.

d) Natural Increase

From 1994 to 2004, decadal births were assessed. The registered births in the city were fluctuating, between 22,000 and 25,000. In 1994, there were 22,720 births which had increased to 24,543 in 1995. In 2003 it decreased to 22,047 births. The birth rate had been somewhat remained constant over the decade. (Table: 3).

Table 2. Population of Kaval* Cities

KAVAL Cities	1951	1981	1991	2001	Growth Rate	
					1981 - 91	91-01
Kanpur	7,05,383	1,639,064	2,029,889	2,555,811	23.84	25.91
Lucknow	4,96,861	1,007,604	1,669,204	2,185,927	65.66	30.96
Agra	3,75,665	7,41,318	9,48,063	1,275,134	26.86	34.50
Varanasi	3,55,777	773,865	1,030,863	1,202,443	33.00	17.09
Allahabad	3,32,295	650,070	8,44,546	1,081,622	29.92	28.04

Source: *Use and Misuse of Land in the KAVAL Towns (U.P.), K.K. Dube (1976). UP Census Handbook, 1991 and Census of India, 2001 * KAVAL stands for the first names of the 5 important cities of U.P found in the middle Ganga Plains.*

Table 3. Varanasi city - No. of Births and No. of Registration

Year	Registered births	Named birth certift. issued	Unnamed birth cer.issued
1994	22720	2135	20585
1995	24543	2718	21825
1996	23588	2405	21183
1997	22110	2124	19986
1998	23248	2297	20951
1999	23961	2306	21655
2000	23204	2611	20641
2001	23302	2563	20739
2002	22791	2443	20348
2003	22047	3306	18741

Source: *Varanasi Nagar Nigam, Varanasi*

Birth rate was a single major indicator, of natural increase of population. The following table shows the actual Birth and Death rates of Varanasi city. The total annual number of births and deaths from 2000 to 2005 shows that there was natural fluctuations in Birth rate. In 2000, there were 23,204 births and it was decreased to 22,047 in 2003. Again the trend was increasing, since 2003. The (Table 4) reveals the fact that the deaths were recorded as per information of the hospitals and the relatives of the victim. The number of deaths varied since 2000 till 2004. This shows the increasing trend. Number of male deaths was more comparing to the female deaths. Altogether, the number of births were very high and death rates were very low and thus high population growth through natural increase was noticed. As per the study, the increasing migration was also keeping pace with the natural growth.

e) Deaths Due to Diseases

The Table 5 shows the death due to various diseases. From the data, it is clear that more deaths were due to circulatory disorders and other miscellaneous disorders and diseases.

Table 4. Crude death rates Registered

Year	Govt. Hospitals	Private Hospitals	Without medical treat.	Total
2000	267	751	4303	5321
2001	289	873	4756	5918
2003	1214	725	4078	6017
2004	612	907	5324	6843

Source : *Varanasi Nagar Nigam (Varanasi Municipal Corporation)*

Table 5. Deaths due to diseases

Diseases		2000	2001	2003	2004
Circulatory diseases	(M)	438	340	606	623
	(F)	284	434	438	382
Infection	(M)	37	55	231	99
Parasite	(F)	30	29	159	68
Undefined	(M)	61	22	129	40
Conditions	(F)	40	19	110	25
Injury	(M)	0	191	140	72
Poison	(F)	0	34	111	16
Respiratory	(M)	11	20	372	112
System	(F)	10	11	319	82
Others	(M)	2752	2679	1950	2993
	(F)	1658	2084	1463	2331
Total	(M)	3299	3307	3429	3939
	(F)	2022	2611	2600	2904
Over All Total		5,321	5,918	6,029	6,843

Source: *Varanasi Nagar Nigam (Varanasi Municipal Corporation)*

f) Migration

The migration of population from the adjoining districts to the Urban Centres has been most common feature in India since 1920, especially after world war I (Dubey, 1976). It is very interesting to note that the increase in population is not solely attributed to the natural growth of population of the city, the heavy influx of migrant population from neighbouring districts, especially from Bihar and Jharkhand have a tremendous impact on the demographic structure of the city. Not only the industries and educational facilities attracted the immigrants but also the increasing economic and commercial activities to boost the local tourism as well as foreign tourism attracts in migrants for catering the needs of the tourists. People are largely attracted, most of them are age old people and staying in the Kasi expecting death and salvation.

g) Population Projection

Population projection is an important for planning and providing basic services and revenue realization. It is projected using past decadal population and growth rate. Different population projection methods like incremental increase, geometric method have been used to calculate future population. (Table 7).

Table 7. Varanasi city, Population projection by different methods

Methods	2011	2021	2031
Geometric	1,489,931	1,846,154	2,287,544
Incremental	1,995,366	3,311,161	5,494,624
Exponential	1,576,734	2,067,531	1,711,102
Average population	1,687,344	2,408,282	3,497,757

Varanasi city had joined million plus cities in 1991 where it crossed 1 million population in the demographic history

Population Density

Population Density is one among the typical characteristics of India's population composition, which carry wide range political, social and economic implications, both at national and international levels (Chandana,2004). Population density in the city is governed by physical conditions; land use, infrastructure facilities etc. In the study area the population is seen along the river Ganga and Varuna as well along the Assi River. The south ward extension of population is seen in and around the Banaras Hindu University. The population distribution of the city correlates with the population density. In Varanasi city, population density in the city varies very much from one ward to another. The overall population density of the city is 15,070 persons per Sq.km (Census, 2001). During the early stages of an urban growth, the highest density of population was found in the central area with a steep gradient towards the periphery.

In the course of expansion, the increasing density is shifting towards the peripheral region. Gibbs (1961), states that the highly concentrated population is not necessarily a highly centralized one and that is what found in Varanasi. In the city the high concentration of population is seen in the middle part of Ganges which flows along the city. However the pheripheral units may cluster on the center in due course of time. Nevertheless, Varanasi suffers from congestion ranging from 80,000 persons/Sq.km. in the central zone, to decreasing trends outwards. B.H.U has the lowest density of 1780 persons/Sq.Km. (According to 2001, Census). Clark (1951) generalize that the density decreases exponentially away from the city centre. In Indian cities, the central wards show continuous increase in density, and the decrease towards the periphery, which is some times gradual and some times abrupt. Varanasi is not an exception to this rule. An analysis of the density of population in different census decades shows that the density of population is very high in the centre of the city. The density pattern in 1971 exhibits that the central parts of the city with 81,356 persons per sq.km.

The minimum density in the peripheral region was 1482 persons per Sq.km. In 1981, the pattern shows significant deviations mainly because of the faster growth of population over the decade and partly because of the reorganisation of the ward boundaries. In 1981 the number of wards had become 40 although the total area remains almost the same. The maximum density of this Central region, was 1,10,066 persons per sq.km in ward number 19 (Kazipurkalan). The minimum population density was 1,815 persons per Sq.km. which was observed in ward number 38 (Sarnath) (Singh, 1990).

In 1991, the no. of wards having more than 1,00,000 persons per Sq.km has gone up to 4 and peripheral wards continue to have population density of less than 10,000 persons per Sq.km. The comparative analysis of the three maps may reveal some notable characteristics of the pattern of population density. There is an inner zone of very high density, which was very much constricted in 1961 and 1971 and got much more enlarged in 1981 and 1991. There is an outer zone of low population density, which constitute a larger proportion of the total urban areas. The population density is less than 10,000 persons per Sq.km. in most of the wards included in this zone. (Seema, 1992). The Figure 2 shows density of population, according to 2001 census. It is apparent from the map that the density decreases exponentially outwards. Distance decay principle operates more significantly in Varanasi city.

Sex Composition

While analysing human resources, it becomes quite essential to look into the sex-ratio as one of the important elements affecting the socio-economic structures. Variation in the age and sex composition reflects the socio-economic characteristics of the region. The sex composition is highly fluctuating since 1961. The decadal variation shows negative values and positive values in the same decades. The sex ratio exercises greater influence in determining the number of workers and dependents. The Table 7 shows the sex ratio from 1961 as well as child ratio. This Table shows that the child sex ratio tremendously decreased since 1961.

Table 8. India - Trend in Sex Ratio (Females per 1000 males) 1961-2001

Year	Sex ratio	Variation	0-6 population	Variation
1961	941	-	976	-
1971	930	-11	964	-12
1981	934	+4	962	-2
1991	927	-7	945	-17
2001	933	+6	927	-18

It is high in 1961 and 2001. If the present trend of child sex ratio persists, there will be a very less no. of females in the future which affects the social life and cultural aspects of the urban population in India. Sex ratio shows the declining trend from 1901 to 1941. In 1901 the sex ratio is 924 and in 1941 it had decreased to 783. Again it shows the increasing trend from 1951 to 2001. In 1951 it was 833 and increased to 881. In 2001.

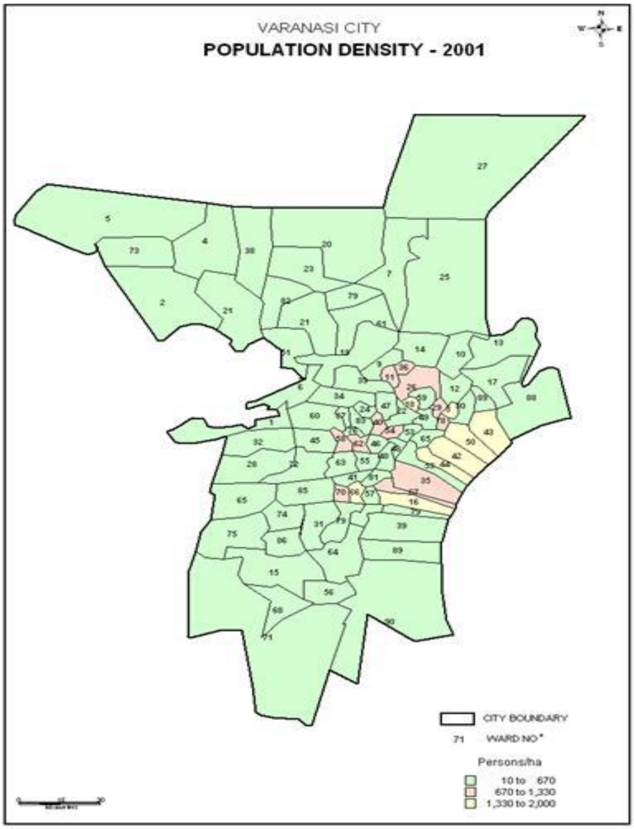

Fig. 2. The Density of Population, Varanasi,2001

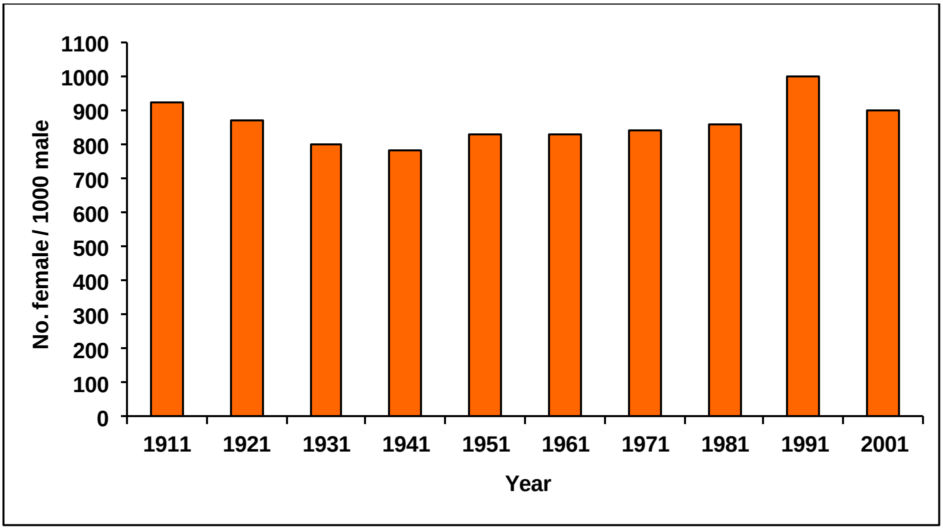

Fig. 3. Sex Ratio Trends - of Varanasi

Table 9. Sex Ratio Trends - Comparison of Varanasi with India

Year	Sex ratio city	India Sex ratio
1901	924	972
1911	927	964
1921	869	955
1931	802	950
1941	783	945
1951	833	946
1961	828	941
1971	842	930
1981	858	934
1991	860	927
2001	881	933

As per the census 2001, the current sex ratio in Varanasi city is 876, which is lower than the state urban average of 885 and national urban average of 901. Besides the city has experienced excessive migration of males from the surrounding rural areas and neighboring districts. Comparing to the national sex ratio of 933 in 2001 and 926 in 1991 and 934 in 1981 the city had continued to show low sex ratio. The low sex ratio is partly attributed to rural male migrants who keep their families in their villages.

In 1911 it touched the maximum of 927, since then it had been a continuous decline in the following four decades. There had been steep fall in 1921 to 915 (Figure 3). Whenever, there is an outbreak of some epidemic, the female population was affected more and a decline in female ratio was the result. The epidemics of cholera and influenza of 1911-21 claimed a big toll of the female population. The Famine, the plague and malaria in 1901-11 (Tiwari, 1971) also contributed to declining sex ratio..

Literacy

Education is a life long process, which takes place from the womb to the tomb. It is the mirror of the modern society and essential for human emancipation and social development (Sharma, 2003). Literacy is one of the prime indicators to measure Human Development Index (HDI) at regional, national and international levels. Literacy rate plays an important role in determining the socio-economic condition of the people. At District level the Literacy rate of Varanasi District is considered to be moderate which is 67.2% as per 2001 census. Current literacy rate is high as 72% as compared to State Urban average of 56.3% and National Urban Average of 70.1%. It is low as compared to the prevailing literacy rates in the other Kaval cities (Table 10).

Occupational Structure

The various commercial units and other basic infrastructure facilities govern occupational Structure of the city. No doubt most of the people in Varanasi are engaged in tertiary occupations. These are white-collar jobs. In the city till 1931, population was based on rural based activities. The economy of the urban inhabitants was dependent on surrounding rural areas. The Table 11 shows the progressive change in the occupational structure of Varanasi city. The primary activities show a slight increase. The percentage of employment in household industries reveals a remarkable fall while the growth of trade and commerce exhibits upward trend. The census of 1981 reveals that only 3.21% of total workers are engaged in agriculture and cultivation. At present the city has become city of multifunctional character. The city had remarkable advancement in industrial sector during the last four decades. In 1981 out of the total active population 22.30% was engaged in house hold industries. About 23.96% of the active population engaged in transportation. Due to establishments of four Universities and other institutions, a significant number of persons are engaged in professional jobs. A comparative study of the occupational structure of Varanasi city in the last two census years indicates some minor changes. However, the most striking feature had been the decrease in the percentage of total main workers in 2001, as compared to 1991. There has been a decline in the number of male workers in the farm sector while the number of female workers in this sector has increased. The number of workers in the livestock and other allied activities has increased during the decade. Similarly, there has been significant increase in the number of workers (both males and females) in the household industry and manufacturing sector, as well as construction, transport, trade and commerce. The number of female workers in all the occupations had increased during the decade.

Table 10. Total Literacy Rates in Kaval Cities

City	1991	2001
Kanpur	62.03	78.8
Agra	50.93	70
Varanasi	53.04	**72.0**
Allahabad	61.64	80.9
Lucknow	61.60	77.1

Human Habitation

Overcrowding in urban areas pose various environmental problems such as shortage of land, high cost of land price, housing congestion, pollution etc. The unplanned development of housings and commercial establishments cause shortage of amenities and deteriorating environment and human health. The increasing population has caused pollution, development of slums, starvation, diseases and physical malfunctioning etc., along with many of the social problems which are worst in urban areas (Singh et, al. 1988).

The urban areas are subjected to the high rate of enteric diseases as cholera, typhoid, dysentery and the diarrheal diseases and viral diseases hepatitis are more. Hence development of urban centre and its impact on environment at local level have become major issues of research (Ramachandran, 1989).

Table 11. Varanasi City, Occupational Structure

Occupations	1991				2001			
	Male	Female	Percent of Total Population	Percent to Total Main Workers	Male	Female	Percent of Total Population	Percent to Total Main Workers
Cultivators	3825	137	0.54	1.88	2896	557	0.37	1.37
Agri-Labourers	2486	285	0.38	1.31	1786	314	0.22	0.83
Livestock and allied activities	1307	1	0.18	0.62	2831	151	0.31	1.18
Mining & Quarrying	113	-	0.01	0.05	76	1	0.008	0.03
House Hold Industry	43833	3073	6.50	22.30	55083	7911	6.75	25.02
Manufacturing	40144	936	5.69	19.53	37094	1780	4.16	15.44
Construction	4479	75	0.63	2.16	5796	102	0.63	2.34
Trade & Commerce	49333	1049	6.99	23.99	68659	2205	7.60	28.14
Transport, Storage & Communication	14007	118	1.95	6.72	14322	164	1.55	5.75
Other Services	40558	5421	6.37	21.86	42294	7741	5.36	19.87
			29.24					

***Source**: District Census Data: 1951, 1981, 1991, 2001*

a) Housing

Housing, one of the basic services, which is to be provided for better quality of life. The increasing level of urbanization had created the stress in housing sector in Varanasi. In the last two decades there is a high increase of 33% population from 1981-1991 while it came down to 17% in next decade, but the increasing in housing cannot catch the pace of increasing population hence resulting in the housing gap. The average housing density is approximately 2167 HH/Sq.km. The core area of the city is very congested, which is highly identified. As the city is growing, new extension areas has low housing densities, as some of the people are shifting from old area to these areas in search of better living conditions.

b) Housing Shortages

The city faces an acute housing shortage. As per the study conducted by ICRA, there is a huge gap between housing supply and demand. The housing demand is increasing at the rate of 16% (approximately) yearly. According to the data there is nearly shortage of 90,000 houses in year 2001, which is expected to be 119, 954 in 2011 and further to 1,39,657 in 2025. Due to acute shortage of housing Varanasi city faces the problem of overcrowding. With the average household size of Varanasi being 7.3, the condition of the people is very bad and overcrowded. There are 47% of the households, who live in one room or two rooms. Five and six dwelling rooms are found in only 7% and 14% of the households respectively.

Conclusion

From the above description, it may be noted that the human landscape of the city has vast potentialities for the development of infrastructure facilities. The balanced and rational development in this context is achieved with the promotion and maintenance of the cordial relationships with the residents in the city. No doubt, increasing population in the city increases the socio-economic activities thus increases the chances of many communicable as well non-communicable diseases. Varanasi Development Authority should take various initiatives and create new policies to cope with the problems related with city and its surroundings.

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AN ECONOMIC ANALYSIS OF MANGO PROCESSING IN DHARMAPURI DISTRICT, TAMIL NADU

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Abstract

Market imperfection is one of the most severe problems faced by the agricultural sector in India. There are frequent price fluctuations in the agricultural market in India. This problem could be minimized if the surplus production is processed and stored without loss of quality. Food processing plays an important role in loss prevention, price stabilization and value addition of food products. Moreover, it provides the crucial farm-industry linkage, which helps to accelerate economic development in general and agricultural development in particular. The study has considered the available information gathered from various groups of stakeholders of fruit processing namely farmers, entrepreneurs of processing units, retailers, consumers and the promotional agents. Significant increase in the fruit processing activity is clearly observed in the study region, through increase in the number of MPUs, installed capacity and the proportion of mangoes processed. This increase is mainly attributed to the increase in the volume of fruit pulp exported to foreign countries through merchant-exporters; but the share of local market appears to be very little and dormant. MPUs have helped the mango growers to some extent to find market for their produce. The MPUs are also able to do some business. The processing has really lengthened the life of mangoes in the form of pulp. The pulp processed and tinned is said to be safe with normal temperature for consumption even for three year period from the date of processing. If the MPUs could find some way of packing the fruit pulp in smaller quantities (now minimum quantity tin is 3.1 kg), they may be able to enlarge their market by capturing domestic market and small consumers too. If the fear of food-poisoning is removed from the consumers' mind, the scope for processing could be still increased. If bio-technological researchers could make some efforts to lengthen the shelf-life of the mangoes and lengthen the fruit-season, more mangoes could be processed and consumed for longer period of time in a year. Finally, if all the above three propositions are brought into action, all the stakeholders of the mango processing are expected to reap still more benefits from the mango cultivation.

Keywords: Market imperfection, Fruit processing, Post-harvest technology, Promotional agencies, Entrepreneurs

Introduction

Agriculture is one of the most important sectors, which provides basic and necessary goods and employment for vast majority of the people in India. The agricultural development of a nation depends not only on the volume of production but also on the quality of marketing of agricultural commodities. The market imperfection is one of the most severe problems faced by the agricultural sector in India. There are frequent price fluctuations in the agricultural market in India. This problem could be minimized, if the surplus production is processed and stored without loss of quality. Food processing plays an important role in loss prevention, price stabilization and value addition of agricultural commodities. Moreover, it provides the crucial farm-industry linkage, which helps to accelerate agricultural development (Iyyampillai and Balamurugan, 2005). The studies conducted in national and international level have emphasized the crucial role of post-harvest technology in the marketing of agricultural commodities. However, there is an argument that compared with production research, adequate attention is yet to be given to post-harvest research by the national and international research centers (Johnson, 2001).

In India, when compared with developed countries, the investment in food processing industry (FPI) is very low. India is one of the major suppliers of raw materials to the food industries in the world. Even then, the food industry itself is extremely under developed in India. In India only 0.5 to 1.0 per cent of the total fruits and vegetables produced are processed as against 83 per cent in Malaysia, 80 per cent in South Africa, 78 per cent in the Philippines, 70 per cent in Brazil and 65 per cent in the United States of America (U.S.A) (Singhal, 1999). Moreover, Indian food products are not in the international standards set by the Codex Alimentarius Commission (CAC) (Deodhar, 2001 & Iyyampillai and Balamurugan, 2006). For instance, the requirement for aflatoxin content in groundnut is set at 15 parts per billion (ppb) by CAC. Indian laws permit 30 ppb. In India, 0.2 parts per million (ppm) lead content in milk is considered safe. However, international requirements are fixed at 0.02 ppm. The CAC standard for sulphur content in sugar is set at a maximum of 20 ppm. However, Indian standard permits 75 ppm (Balamurugan and Iyyampillai, 2005). In addition, the foreign collaborations in the Indian food industry are very low when compared with other industries (Singh, 1988). The FPI receives very low level of foreign direct investment (FDI), which is less than five per cent in the total foreign direct investment in the country (Balamurugan P, 2007). These observations reveal the fact that this sector has received very little and inadequate attention in India. India's share in the world production of processed foods is meager (0.79 per cent) but the unexploited potential for value added processed food production and export is substantial (Singh, 1988)

India has very poor post-harvest infrastructure facilities. This has been highlighted in many studies. For instance, Kaul (1997) has mentioned in his study that the important constraints of the horticulture sector in India are the lack of infrastructure and post-harvest technology to the required level. Singh (1999) has remarked in his study that the cold storage industries in India still have not played their complete role in agricultural development. Saigal (2001) has observed in his study that Indian horticulture sector has the problem of low level of processing and the non-availability of post-harvest infrastructure. Iyyampillai and Balamurugan (2007) have found that there are no adequate infrastructural facilities like road, transportation, cold storage, etc for the efficient marketing of grapes in Theni District of Tamil Nadu.

India has not developed its post-harvest technology up to the mark. Hence, India has to face the problem of huge post-harvest losses on the one side and price fluctuation (within a year and within a season) on the other side. In India, there are many commodities in which price variations across seasons are very large (Singh, 1999). The Group on Perishable Agriculture Commodities, headed by M.S. Swaminathan, has estimated that the actual post-harvest losses are as high as 25 to 30 per cent of the value of produce depending on the perishability of the product. At this scale, the post-harvest losses are estimated to be Rs. 3,000 cores to Rs. 4,000 crore per annum (cited in Patnaik, 1995).

As per another study viz., Technology Information for Costing and Assessment Council (TIFAC) of the Department of Science and Technology published in 1996, wastage in certain fruits is as high as 30 per cent and in case of vegetables the losses are up to 20 to 30 per cent at the post-harvest stages due to poor storage, transportation, lack of infrastructure and the inadequacy of the marketing (cited in Saigal, 2001). In addition, the All India Coordinated Research Project on Post-harvest Technology of Horticultural Crops has estimated the annual loss of fruits and vegetables at 30 per cent in 1993-94 due to poor infrastructure and post-harvest handling (cited in Singhal, 1999). For instance, annual fruit wastage in India is equivalent to annual consumption in the countries like United Kingdom (U.K.). The minimization of post-harvest loss and the inter-seasonal price stability can be achieved only by an appropriate post-harvest technology (Balamurugan and Iyyampillai, 2005).

It is observed that the post-harvest technology like storage and processing for horticultural crops has not developed to its optimum level in India. For instance, the production of fruits and vegetable in India is about 1,492 lakh million tonnes in the year 1999-2000, whereas the installed capacity of fruit and vegetable processing industry and the installed capacity of the cold storage units are accounted for only 21 lakh million tonnes and 103 lakh million tonnes respectively in the same year. It shows that there is a wide mismatch between the production of horticultural crops and the existing capacity of processing and storage units. It is likely to adversely affect the profitability of the farmers and to reduce the bargaining power of the farmers in the market.

Due to the poor post-harvest technology, Indian farmers are forced to distress sales and receive only 20 to 30 per cent of the retail price of their products. It would also affect the consumers by making the market uncertain and unstable. Moreover, it affects the economic development in general and agricultural development in particular. Hence, it is important to develop the post-harvest technology to achieve the full-fledged development of agriculture. It is of a timely requirement to study the problems and prospects concerned with the development of post-harvest technology in India. The present study is one of such efforts to understand the reasons for the slow growth in food processing industries in India.

In 1999-2000, the total area under the cultivation of horticultural crops in Tamil Nadu was 5.12 lakh hectares, in which undivided Dharmapuri District (hereafter Dharmapuri District) constituted 62 thousand hectares (12 per cent). This District was bifurcated in the year 2004.

Now Krishnagiri has been formed as a separate district, where actually larger proportion of area under fruits and fruit processing units are found. Dharmapuri District ranks first in terms of area under cultivation and production of major horticultural crops and number of fruit (mango) processing units in Tamil Nadu. Hence, Dharmapuri District has been purposively selected for the present study. Since mango, called *"king of fruits",* is the major fruit item in terms of the area under cultivation in the study region, the mango processing has become major focus of the study. The objectives of the study are to understand the structure and growth of fruit and vegetable processing units and activities in Dharmapuri District of Tamil Nadu, and to identify the factors that hinder / promote the growth of processing activities, ii. to trace the public, private and cooperative efforts taken so far for the development of post-harvest technology and iii. to enlist the problems faced by the farmers and processing units in the processing of agricultural commodities.

As per the statistics given by the Department of Horticulture and Plantation Crops, the production of fruits and vegetables in Dharmapuri District for the agricultural year 2001-2002 was 8,88,878 tonnes. According to the statistics given by the Dharmapuri District Fruit and Vegetables Processors Federation on an average 35,000 tonnes of fruits (mostly mangoes) and vegetables are processed in the district in a year. The percentage of fruits and vegetables processed in the district is only about four per cent of the total harvest in the district. It is clear from the statistics that only small quantity of fruits and vegetables are processed in the district. A large proportion of fruits go for direct sale. The district appears to have a huge unexploited potential for the development of processing of fruits and vegetables. The main research question of the present study is: what are the factors that are responsible for the lack of development of processing units in the district?

Database and Methodology

The problem of post-harvest loss and the problem of price instability are common to all the agricultural produces. However, the degree and the extent of these problems are higher in horticultural crops, as they are highly perishable in nature and hence require the appropriate post-harvest technology. In order to understand the problem in a holistic manner, detailed field survey has been conducted in Dharmapuri district in Tamil Nadu. The primary data have been collected from the owners of the processing units, both mango and non-mango cultivators, fruit retailers, fruit consumers and the officials in the promotional agencies - major stakeholders of the development of horticulture in the study region. At the time of field survey, there were 40 FPO (Fruit Product Order) licensed fruit processing units in the study region. The list of these units was collected from the District Industries Centre (DIC) in Dharmapuri and Krishnagiri. By adopting the census method, the primary data were collected from all these units. It was found out at the time of field work that five new units were under construction. However, the present analysis relates to only the 40 units which are right now functioning. These 40 units are located in 33 different villages. From these 33 villages, the required data have been collected from both mango and non-mango cultivators. These cultivators are with different size of landholdings with mango cultivation.

Hence, it was decided to have sample farmers from different categories on the basis of area under mango cultivation. The farmers with less than five acres of mango orchard are treated as small farmers. The farmers with more than five acres but less than 10 acres of mango orchard are treated as medium farmers. The farmers with more than 10 acres of mango orchard are treated as large farmers. The operated landholding of these farmers would be slightly less than what they own, for many of these farmers have leased out their lands to the wholesale mango merchants. By taking one farmer from each of these three groups, 99 (3 X 33) mango cultivating farmers from 33 villages were contacted for collecting relevant information. Apart from these sample mango cultivators, 33 non-mango cultivators (1 X 33) were also selected as sample respondents irrespective of the land-holding size. The sample farmers were selected by conducting focused group discussions (FGD) with the village people.

In Dharmapuri District, there were 10 taluks. From these 10 taluk head-quarters, 50 fruit retailers and 50 consumers at the rate of five fruit retailers as well as five consumers per taluk were selected as sample respondents. The sample fruit retailers were identified by conducting FGD with the available fruit retailers at the time of field survey. The first consumer who buys fruits from the sample retailer at the time of interview was selected as sample consumer respondent. Thereby one sample consumer respondent was selected to one retailer. In total, 50 consumers were selected as sample consumer-respondents. In order to understand the role of promotional agencies in the overall development of the horticulture sector in the study region, the Assistant Directors of Horticulture were interviewed in the present Dharmapuri and Krishnagiri districts. The president of the Fruit Processors Federation was also interviewed. Some of the presidents of the Horticulture Self Help Groups were interviewed to know their role in the promotion of horticulture in the study region. One agricultural economist, who works in Agricultural Research Extension Centre of Tamil Nadu Agricultural University (TNAU) in Paiyur in Krishnagiri district, was also interviewed.

Secondary Data Base

The secondary data have been collected from various official reports of different agencies of the government, including the Ministry of Food Processing Industries (MFPI), National Horticulture Board (NHB), Agricultural Processed Foods Export Development Authority (APEDA), Tamil Nadu Season and Crop Reports, District Handbook, Economic Survey and others.

Limitations of the Study

The study has purposively chosen only one district (of Tamil Nadu), which has larger proportion of land under fruit crops, mango and mango processing units (MPU). Hence, the results of the study can be generalized to a limited extent only. The present study has purposively chosen mango alone, which has occupied dominant position among the fruit crops in the selected district. Hence, the results could not be generalised to other fruit-crops or for the other crops in general.

Results and Discussion

Farmers have got weaker bargaining power in the market, for they are unable to control the natural forces which largely determine both the quantity and quality of the produces they harvest. One way of regulating quantity and quality of the produces they supply is through developing appropriate post-harvest technology that could lengthen shelf-value of the produce. The present study has taken up this issue for the analysis. The available empirical evidences indicate that only very low proportion of total harvest is being put into post-harvest processing. This is much lower (around five per cent) for fruits. As a result, the fruit crop growers are bound to lose their income through wastage of fruits and non- remunerative prices for fruits. Consumers also get less supply of fruits (due to wastage of fruits). In this context, the present study has chosen mango, the king of fruits, for the analysis.

Mango is similar to the other fruits in the following sense: one, seasonal supply - only for about three months in a year. Mango is a long term crop. Hence, the research on developing new mango varieties will take longer duration of time. But, the researchers and funding agencies are interested in getting quicker results. Hence, researchers are reluctant to take up mango for research. The success rate for the mango research already done is also very little. However, it is felt that if the shelf-value of the mangoes is enhanced or if mangoes are made to be all- season crop, then the supply and demand for mango would further increase. However, adequate research has not been done in this line. Two, mango has got a very narrow shelf-value, say about one week. This is also one of the reasons why cold storage for mango has not come up. Mango is cultivated in larger area in Dharmapuri District (Tamil Nadu) wherein the mango processing units are also concentrated. Hence, Dharmapuri District has been chosen as an empirical context for the study. Dharmapuri District was bifurcated and Krishnagiri district was then carved out in the year 2004. Hence, now larger proportion of area under mango as well as larger proportion of mango processing units is found in the new Krishnagiri district. The field work was done in these two districts namely Dharmapuri and Krishnagiri in the mid-2007 i.e. after the mango harvest and processing season was over in the year 2007.

Mango Processing Units and Farmers

Mango processing in the study area (Dharmapuri and Krishnagiri districts now) was started in the year 1985. The farmers report that the mango sales have become easier now due to the emergence of mango processing units (MPUs) around Krishnagiri town. Between 1985 and 2004, the area under mango in the dry area has expanded four times thanks to the efforts made by both central and State governments, and MPUs. Though there are some deficiencies being reported by the farmers and entrepreneurs of the MPUs, financial assistances received by them from both the Central and State governments are also reported to be substantial and significant. Also, there is substantial increase in the number of MPUs and in the volume of mangoes processed.

Suitable varieties of mango are purchased from neighbouring districts and States for processing and are also sold to other States. Now, tonnes and tonnes of mangoes are processed within three months period in a year in the study region and mostly exported to other States and other countries. Besides this, mangoes are also exported to other countries as table-fruit, thanks to relaxation of phyto-sanitary norms in foreign countries like USA and Japan. Langra, Dussehri, Hapus and Begnmpuri are now being exported to USA and Japan (The Hindu, 2007, 'Good Response for Indian Mangoes in US', Tiruchirappalli edition, 17th June, p. 9), Japan has recently agreed to allow the import of six mango varieties- Alphonso, Banginapalle, Chausa, Kesar, Langra and Mallika (Sandeep Joshi, 2007, The Indian Mangoes now go to Japan, The Hindu, Tiruchirappalli edition, 22nd May, p. 20).

Of the total fruits processed by the processing units, mangoes top the list. The processing units have tried to process other fruits (guava, pine apple, apple, papaya, pears, banana, mixed fruits, chilies and tomato) also; however, this proportion is very small as compared to the processing capacity of the units; and the volume of harvest of those fruits is also stagnant over the period. Of the mango varieties, the bangalora tops the list. The type of mango processed is largely determined by the demand from export-merchants. Barring a few, majority MPUs are involved in producing mango pulp for the merchant- exporters. The entrepreneurs report that they are not prepared to directly export the pulp to other countries, for they are yet to develop contact. Thus the risk borne by them is very little, for they do only job work for the merchant-exporters. While some MPUs directly buy the required mangoes, some other units do not do even that work; the mangoes are supplied by the buyer of the pulp. It is observed that those units with the long history, larger assets, land under mangoes, large infrastructure and contacts with foreign countries are able to grow faster. The horizontal and vertical integration of the activities have really helped the MPUs. The MPUs with little activity struggle to survive.

The links between farmers and MPUs on the one hand and the MPUs and export-merchants on the other hand have to be well established and formalized for the success in this business. In the absence of this, there come many failures, violation of contracts and uncertainties in payments leading to loss of trust and rise in risk levels. The payments at all the stages are usually delayed with uncertainty. In one case, a farmer was waiting for many hours in a processing unit to get the payment (on 27-11-2007) for the mangoes supplied four months ago, ie., during July 2007. The farmer was requesting the owner of the unit to give at least Rs. 5,000, so that he could apply pesticide to save the mango trees from the pests. However, the owner of the unit simply kept mum. The MPUs, after having invested large amount on fixed assets, are unable to make full use of them. It is reported that the MPUs are unable to carry out the processing even for 90 days in a year. Most of the time, the fixed assets are idle. Hence, MPUs are unwilling to invest more on updating the technology and enhancement of the fixed assets. On the contrary, during the busy season, for about 90 days, the stress on the fixed assets is too much, causing larger wear and tear loss.

Mobilizing fund and large number of labourers for very short period is also another tough task for the MPUs. (One can easily find mangoes and workers everywhere there). However, no effort seems to have been made to minimize the above uncertainties. It is in this situation, the units with long trend of good records, wealth and contacts are able to survive, and get profit from this business and also enhance the business. Whereas, the other units, who are unable to cope with these uncertainties and who depend on the borrowed money (for which interest amount will compound with cascading effect) for running their business, find it difficult to survive in this business. Thus, the existing informal arrangements and consequent violation of contracts at every stage work as hindrances for the utilization of full potential. As a result, only less quantity of mango is processed, causing loss to all the stakeholders of this business.

In some cases there is a nexus among the farmers, processers, merchants and exporters. Some do more than one of the activities namely, farming, processing, purchasing and exporting. Some are merchant-cum-farmers. They either own or lease-in mango garden. Some MPUs also own mango gardens in this region. They express their happiness over the present situation for, the earlier situation was much worse. Earlier, in the 1980s, they used to take the mangoes to the market in Salem and Bangalore. After reaching these market places, the price would be fixed by the merchants, which would always be less than what the farmers had expected; even then, the farmers were to sell away the mangoes, for the re-transportation of the mangoes back to their places, would not only raise the cost of transport but also add to uncertainty and risk. The payment was not certain in earlier years also. However, now the situation is slightly better, for the farmers are closer to the MPUs and even the delay in payment could be easily managed. Besides these benefits, both the Central and State governments are also taking promotional measures. As a result, the area under mango trees has increased four times in this region. However, the total production of mangoes has not increased to that extent due to the following reasons: a) trees have started yielding less (diminishing marginal rate of return) while the new trees are yet to pick up, b) in order to utilize the government assistance, less suitable sub-marginal lands are also brought under mango cultivation. Even now mangoes are exported to Bangalore and other nearby markets as table-variety and for processing as well. Generally the prices, the farmers get from outside market are slightly higher; but, the late payment is more likely and the levels risk and uncertainty are also higher.

Retailers

The retailers' economic background is very poor; most of them have taken up this business as the last resort. They buy fresh mangoes from nearby market places. They report frequent wastages of mango. On an average the wastage per seller per day is around three kilo grams of mango; and they do not seem to have attempted to reduce this loss except sprinkling some water on the fruits then and there. There is no significantly visible difference in the socio-economic background among their customers. The customers in Hosur town have somewhat better economic background; many of them are found to be regular and assured income earners.

Consumers

The consumers clearly indicate their preference for fresh fruits over the processed fruit pulp (PFP). They are afraid of consuming PFP. They feel that there may be food poisoning due to the use of chemical preservatives in the fruit processing. Local market for PFP is very little. The PFP is heated, tinned and exported mostly to West-Asian countries. Heating and packing are done by the workers of the units after the processing season is over.

Promotional Agencies

Central and State level promotional agencies are functioning in this region to enhance area under fruits and also to encourage setting up of processing units. Almost all the MPUs have obtained funds with subsidies from the promotional agencies. However, among the farmers very few have benefited, for the information on promotional efforts have not reached the farmers. There appears to be a principal - agent problem - both groups namely, departmental officials and farmers find fault with each other. There is also Federation of MPUs to organize and regulate the activities of the MPUs and disseminate the relevant information. The President of the Federation [Mr. G. Venkatasamy B. Sc (Ag.), an owner of one of the largest and busiest unit], appears to be complacent with the development; though some of his dreams are yet to be materialized.

Conclusion

The study has considered the available information gathered from various groups of stakeholders of fruit processing namely farmers, entrepreneurs of processing units, retailers, consumers and the promotional agents. Significant increase in the fruit processing activity is clearly observed in the study region, through increase in the number of MPUs, installed capacity and the proportion of mangoes processed. This increase is mainly attributed to the increase in the volume of fruit pulp exported to foreign countries through merchant exporters; but the share of local market appears to be very little and dormant. MPUs have helped the mango growers to some extent to find market for their produce. The MPUs are also able to do some business. The processing has really lengthened the life of mangoes in the form of pulp. The pulp processed and tinned is said to be safe with normal temperature for consumption even for three year period from the date of processing.

If the MPUs could find some way of packing the fruit pulp in smaller quantities (now minimum quantity tin is 3.1 kg), they may be able to enlarge their market by capturing domestic market and small consumers too. If the fear of food-poisoning is removed from the consumers' mind, the scope for processing could be still increased. If bio-technological researchers could make some efforts to lengthen the shelf-life of the mangoes and lengthen the fruit-season, more mangoes could be processed and consumed for longer period of time in a year. Finally, if all the above three propositions are brought into action, all the stakeholders of the mango fruit processing are expected to reap still more benefits from the mango cultivation..

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THE POOR AND FINANCIAL INCLUSION: A PANEL QUANTILE REGRESSION ANALYSIS OF BANKING SERVICES IN INDIAN STATES

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Abstract

With the aim of making the services of the financial sector available to the poor too, the RBI and the Government of India have initiated many strategies. In this financial inclusion effort, the banking sector has been entrusted to bank the unbanked. Though the concept and meaning of financial inclusion is clear, there is no consensus on how to measure financial inclusion. Indicators of banking performance do not necessarily include financial inclusion. As financial inclusion is influenced both by demand side and supply side factors, the measure of financial inclusion should consider the depth of the financial reach. This paper considers one such measure, the index of financial inclusion constructed over three dimensions of financial inclusiveness viz. banking penetration, availability and usage of banking services. Using the state level banking sector data for 29 states of India for the period 1996-2008, this paper measures the financial inclusion index for the states and analyses the effects of each dimensions on IFI applying the quantile regression method. The calculated IFI for states show that there are wide variations in financial inclusion across the states of India. The quantile regression estimates show that the each dimension of IFI has differential effects across quantiles of the distribution of IFI. The low income states are at the lower quantiles of IFI and the effects of the variables on IFI are also low compared to the high income states. Also, basic infrastructure in states of India impacts financial inclusion.

Keywords: Financial inclusion, Commercial banks, States, Index of financial inclusion, Quantile regression

Introduction

Financial inclusion aims at drawing the unbanked population into the formal financial system so that they have the opportunity to access financial services ranging from savings, payments, credit and transfers to credit and insurance from formal service providers. The term financial inclusion can be simply understood as having the access to basic banking services and easy credit at an affordable cost from a formal financial institution which allows an individual to store money in a safe place, access credit, insurance products and managing risks. Access to financial services enables in the improvement of living standards especially for the poor.

Simple services such as a savings bank account, an insurance policy and access to cheap credit would enable low income households to counter the fluctuations in income, face uncertainty and have increased opportunities at entrepreneurial activities. These factors would enable the increased expenditure on other basic needs leading to a better standard of living and more importantly provide greater opportunities in enabling low income households to rise above poverty.

The necessity of financial inclusion needs policies focused on an inclusive banking sector with the capacity to reach to all the population groups in the country. Though at its core financial inclusion is a policy for social development, it involves the development of the banking sector in the delivery of its services across geographies and households of various income groups. In fact, "financial services for poor people have been treated exclusively as part of social policy, distinct from the rest of the financial sector. Extending financial services to poor people is also part of policy for economic growth and financial sector development" (United Nations, 2006a, p.6). Thus, it needs to be understood that financial inclusion as a policy measure can be achieved only through the efficient structuring of the banking services that meet the needs of different sections of the population.

The Committee on Financial Inclusion defines financial inclusion as the "process of ensuring access to financial services and timely and adequate credit where needed by vulnerable groups such as weaker sections and low income groups at an affordable cost" (Rangarajan Committee, 2008, p. 35). Since most of the financial services are coordinated through banks, we can approximate financial inclusion by banking inclusion. In this sense, Leeladhar defines financial inclusion as "delivery of banking services at an affordable cost to the vast sections of disadvantaged and low income groups" (Leeladhar, 2005, p.1).

Despite the growth in the banking sector witnessed in the country, the lack of access of its services to a large percentage of the population causes social imbalance. Though holding a bank account and availing its services may be elementary in urban India, an access to one with the bare minimum of services of the banking sector is vital for the rural population especially those without any income, assets or collateral surety ordinarily required by the banks. While defining financial inclusion in the context of the larger issue of social inclusion, it can be defined as the inclusion of the excluded population groups into the mainstream financial sector to give them better opportunities at attaining health, education, economic activities and break-free from poverty. In fact, one of the rationales of the nationalisation drive of commercial banks in late 1960s in India was to restrain the banking sector from concentrating in the profitable regions and services, and instead spread its reach in order to be made accessible to the entire population of the country inclusive of those living in remote and rural areas. In 2006, towards greater financial inclusion, the RBI introduced the business correspondents model, allowing banks to appoint business correspondents as intermediaries in providing financial and banking services on their behalf.

Understanding the distancing between the banks and the unbanked population requires an understanding of the services that are demanded and the supply side barriers that prevent the delivery of banking services. The financial services that are demanded by low income households are simple in nature like saving accounts to safely park their meager savings, small, short-term credits, repeat loans and freedom of unrestricted use, payment services for non-cash businesses, and an insurance-like saving account that enables smoothing consumption expenditure against an inconsistent income. The supply side constraints in banking the unbanked population could be remote areas, low population density, lack of the needed infrastructure to service a viable bank branch, lack of demand of financial services, amount of savings too low, lack of human resources to man the operations, and security concerns. Further, factors like lack of document, poor collateral surety, high transaction costs, lack of trust, and lack of financial education are some of the demand side issues that keep the poor section of the population away from the banking sector. Therefore, on an overall perspective, it can be understood that people are either infrastructurally excluded or self-excluded from the financial services. In order to understand the pattern and progress made in financial inclusion, the extent to which people are excluded from the banking system need to be understood. Unbanked population can be defined as the section of population which has no access to the services of the banking sector. All financial inclusion initiatives at its core are focused at enabling this population group has access to banking services. Tables 1 and 2 present the level of financial inclusion in the country in terms of the number of persons in the country having a credit or a savings account in scheduled commercial banks in India.

Table 1. Savings Accounts with Scheduled Commercial Banks in India

Location	Description	1971	1981	1991	2001	2007
Rural	No. of accounts (millions)	-	56.9	153.8	169.8	213.8
	Accounts per 100 persons	-	10.9	24.5	22.9	26.2
	Accounts per 100 adults	-	17.9	39.2	35	38.8
Urban	No. of accounts (millions)	-	40.9	99.2	110.2	159.7
	Accounts per 100 persons	-	25.7	45.6	38.5	50.7
	Accounts per 100 adults	-	42.3	73.1	58.9	75.2
Total	No. of accounts (millions)	23.6	97.8	253	280	373.5
	Accounts per 100 persons	4.3	14.3	29.9	27.2	33
	Accounts per 100 adults	7.1	22.9	46.8	41.5	48.9

Source: *RBI: Basic Statistical Returns of Scheduled Commercial Banks*

Table 2. Credit Accounts with Scheduled Commercial Banks in India

Location	Description	1971	1981	1991	2001	2007
Rural	No. of accounts (millions)	-	16.4	49.9	36.6	53.1
	Accounts per 100 persons	-	3.1	7.9	4.9	6.5
	Accounts per 100 adults	-	5.2	12.7	7.5	9.6
Urban	No. of accounts (millions)	-	4.4	12.1	15.8	41.3
	Accounts per 100 persons	-	2.7	5.5	5.5	13.1
	Accounts per 100 adults	-	4.5	8.9	8.4	19.5
Total	No. of accounts (millions)	4.3	20.7	61.9	52.4	94.4
	Accounts per 100 persons	0.8	3	7.3	5.1	8.3
	Accounts per 100 adults	1.3	5	11.7	7.9	12.4

Source: *RBI: Basic Statistical Returns of Scheduled Commercial Banks*

It is evident from Tables 1 and 2 that less than 40 percent of adults have a savings account in rural areas, whereas about 75 percent of the urban adults are banked. Though there appears to be an improvement in the access to savings account since 1981, there is a significant lag in rural areas when compared to urban areas. The growth of the number of credit accounts has been even pathetic; the figure of only 9.6 percent and 19.5 of the adults in rural and urban areas respectively having credit accounts explains the need for greater dependence of rural population on non-formal sources of credit (Mohan, 2009).

To understand the efforts of the banking sector in achieving financial integration, the growth of the banking sector need to emphasised. Since nationalisation, the banking infrastructure has increased from 8262 bank offices in 1969 to 82408 bank offices in 2009. The annual average compound growth rate of the banking sector in India presented in Table 3 indicates that the growth in business conducted by the banks in the country has far exceeded the growth in the number of bank offices.

The Figure 1 shows the total deposits with the scheduled commercial banks has increased from Rs.4,646 crores in 1969 to Rs. 38,34,110 crores in 2009 and the total credit that has been delivered by the banking system has been increased from Rs.3,599 crores in 1969 to Rs.27,75,549 crores in 2009.As on 2009, on an average, every banking office in the country did business of Rs. 46.5 crores in total deposits and Rs.33.6 crores in total credit (Figure 2). However, the significant growth in the volume of business conducted by the banking industry, when analysed from the credit-deposit ratio, the percentage of loan assets created out of the total deposits collected by the banks, shows a picture of fluctuations in the efficiency of its operations.

As shown in Figure 3, the credit-deposit ratio has declined from 77.5 in 1969 to a low of 51.6 in 1994, thereafter registering an improvement in 2009 to 73.9. From the sub-period growth analysis presented in Table 4, it is observed that the credit-deposit ratio has registered negative growth rate, except for the last decade, with -0.12 for the period 1969-2009.

Table 3. Annual Average Compound Growth Rate of Commercial Banks in India (percent)

Description	1969-79	1979-89	1989-99	1999-2009	1969-2009
Bank offices	13.84	6.69	1.19	2.41	5.92
Total deposits	19.96	17.83	17.05	18.30	18.28
Total credit	18.17	16.64	15.27	22.36	18.08

Source: *RBI: Basic Statistical Returns of Scheduled Commercial Banks, 2009*

Table 4. Annual Average Compound Growth Rate of Deposits and Credits and Credit-Deposit Ratio of Commercial Banks in India (percent)

Description	1969-79	1979-89	1989-99	1999-2009	1969-2009
Average deposits per bank office	5.38	10.44	15.68	15.52	11.67
Average credit per bank office	3.81	9.33	13.91	19.48	11.48
Credit-deposit ratio	-1.49	-1.00	-1.53	3.64	-0.12

Source*: RBI: Basic Statistical Returns of Scheduled Commercial Banks.*

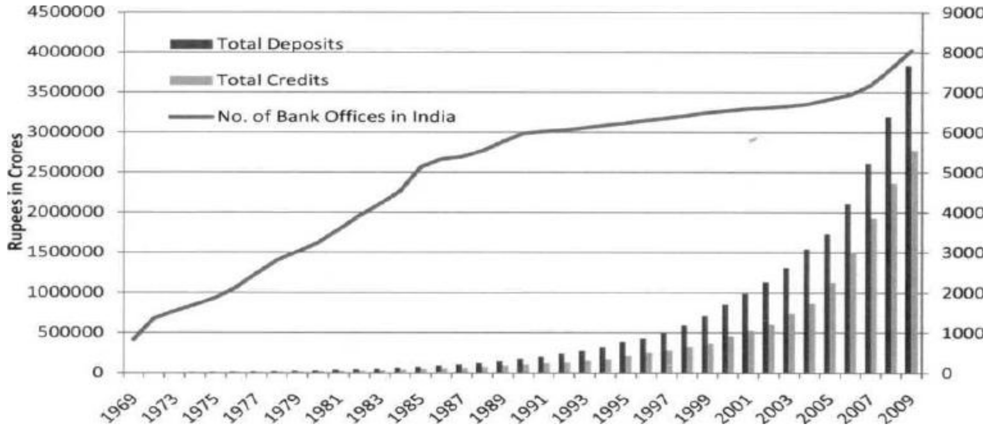

Fig. 1. Growth of Deposits and Credits of Commercial Banks in India
Source: RBI: Basic Statistical Returns of Scheduled Commercial Banks, 2009.

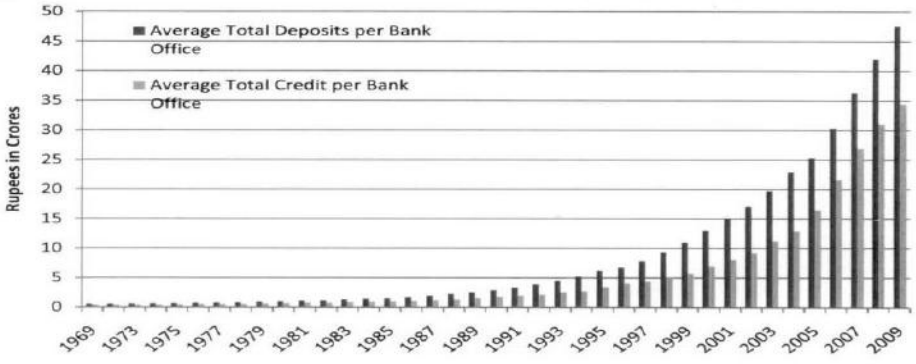

Fig. 2. Growth of Average Deposits and Credit per Commercial Bank Office in India
Source: RBI: Basic Statistical Returns of Scheduled Commercial Banks.

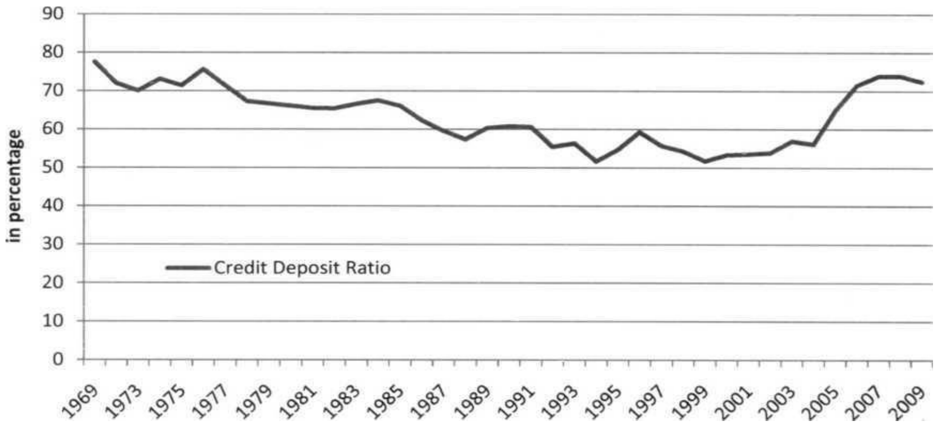

Fig. 3. Trend in Credit-Deposit Ratio of Commercial Banks in India
Source: RBI: Basic Statistical Returns of Scheduled Commercial Banks.

Though there has been a considerable improvement in the delivery of financial services as the growth in total deposits and total credit show, there also exists significant regional and sectoral imbalances. Despite the initial emphasis on rural banking leading to an increased concentration of banks in rural areas, recent inclination of growth in banking infrastructure has been towards urban and metropolitan areas. Also, greater volume of businesses are being conducted by banks in metropolitan and urban areas as result of significant growth of economic activity in urban India. Similarly, the deposits growth registered by the banking sector had been driven by metropolitan and urban areas due to increasing corporate businesses and higher income levels in urban areas. Further, the growth of the credit delivery by the banking system in the country can be attributed to the change in the consumption and investment patterns that have witnessed parallel movement along with economic growth, not due to the inclusive banking system across the regions of India.

Therefore, given the significant and sustained efforts and the uneven progress towards financial integration through the banking sector, this paper aims to analyse the effects of the performance of the banking sector on financial inclusion in India. This paper adopts a multi-dimensional index of financial inclusion (IFI) defined over banking penetration, availability of the banking services and usage of the banking system, and its distribution across the states of India. Empirically the RBI data on the banking indicators for 29 states of India for the period 1996-2008 has been used applying the quantile regression method.

A Brief Review of Literature

The literature on the relationship between financial development and economic growth is vast and growing. Also, many studies examine the effect of financial development on social development. However, there has not been much discussion on whether financial development implies financial inclusion. Some studies focus on the role of financial sector as an intermediary for economic development and equitable distribution of income. Beck et al. (2007a), using a broad sample of 52 developing and developed countries data over the period 1960 to 1999, assess whether there is a direct relationship between financial intermediary development and changes in income distribution. The results indicate the income of the poorest quintile grows faster than average GDP per capita in countries with better-developed financial intermediaries. Income inequality, measured both by the Gini coefficient and the standard deviation, falls more rapidly in countries with higher levels of financial intermediary development. Beck et al. (2007b) study the proximity of the access to financial services and the use of them in 99 countries comprising of financially and economically developed economies as well as emerging markets and transition economies. The access to financial services is defined as the geographic and demographic penetration of the banking system and is measured by the number of branches and ATMs relative to population and area.

The actual use of financial services is defined as the use of deposit and credit services of the banking system and is measured by the number of loan and deposit accounts relative to population and average loan and deposit size relative to GDP per capita. The results show that loan and deposit indicators are good predictors of the share of households with bank accounts and the share of small firms with bank loans. Correlation and regression results indicate that larger economies enjoy greater levels of outreach, suggesting scale economies in banking service provision. Also, banking system structure, quality of the institutional framework supporting the financial system, and physical infrastructure explain cross-country variation in outreach.

Index of Financial Inclusion

The literature that investigates the determinants of financial penetration is scanty and is hampered by the lack of a suitable measure of financial inclusion. Some studies generally use some dimensions of the financial system as indicators of financial penetration to assess the extent of financial inclusion. The most commonly used indicator has been the number of bank accounts. Some other indicators are number of bank branches, number of ATMs, amount of bank credit and amount of bank deposit. Such indicators, while used individually, provide only partial information on the inclusiveness of the financial system of an economy. Using individual indicators can lead to misleading understanding of the extent of financial inclusion in an economy. What is needed is a comprehensive multidimensional measure of financial depth that takes into account the demand and supply side factors of the financial system, especially the cross geographical comparisons.

Towards this end, Sarma (2008) propose a comprehensive measure of an index for financial inclusion which can be used to compare the levels of financial inclusion across economies as well as across states/provinces within countries. Similar to some of the well-known indices like HDI, HPI and GDI, the financial inclusion index considers some basic dimensions of an inclusive financial system like banking penetration, availability of banking services and usage of banking system. This multidimensional index of financial inclusion (IFI) is computed by first calculating a dimension index for each of the three dimensions of financial inclusion. The dimension index for the i-th dimension, di, is computed by:

$$d_i^j = \frac{A_i - m_i}{M_i - m_i} \quad (1)$$

where i represents the financial penetration dimensions like banking penetration, availability of banking services and usage of banking system, j represents the level of financial inclusion desired, such as the geographical divisions like the states in the present case, and n is the number of dimensions considered. Ai is the actual value of dimension i, mi is the minimum value of dimension i, Mi is the maximum value of dimension i, so the equation ensures that 0<di<1 for each of the dimension index. Higher the value of di, higher the achievement in dimension i. In the n-dimensional space, the point 0 = (0,0,0,..,0) represents the point indicating the worst situation while the point I = (1,1,1,...,1) represents the highest achievement in all dimensions.

The index of financial inclusion, IFIj for the j-th state, then, is measured by the normalised inverse Euclidean distance of the point Dj from the ideal point I = (1,1,1,....,1) as:

$$IFI^j = 1 - \frac{\sqrt{(1-d_i)^2}}{\sqrt{n}} \quad (2)$$

the numerator of the second component is the Euclidean distance of Dj from the ideal point I, normalising it by $\sqrt{n}$ and subtracting by 1 gives the inverse normalised distance. The normalisation is done in order to make the value lie between 0 and 1 and the inverse distance is considered so that higher value of the IFI corresponds to higher financial inclusion.

Following Sarma (2008), this paper also considers three basic dimensions of an inclusive financial system: banking penetration, availability of banking services and usage of banking system:

Banking penetration (pi): An inclusive financial system should have as many users as possible, that is, an inclusive financial system should penetrate widely amongst its users. The size of the banked population i.e. number of people having a bank account is a measure of the banking penetration of the system. Thus, if every individual in an economy has a bank account, then the value of this measure would be 1. Since, the data on banked population is not available, this paper uses number of bank accounts as a proportion to the total population as an indicator of the banking penetration dimension.

Availability of banking services (ai): The services of an inclusive financial system should be easily available to its users. Availability of services is indicated by the number of bank branches (per 1000 population) to measure the availability dimension.

Usage of banking services (uj): Having a bank account is not enough for an inclusive financial system. It is also important that the banking services are adequately utilised. In incorporating the usage dimension in the financial inclusion index, this paper considers two basic services of the banking system, credit and deposit. Accordingly, the volume of credit and deposit as proportion of GDP has been used to measure the usage of banking services dimension.

Thus, considering the above three dimensions, IFI for a state i can be measured by:

$$IFI^j = 1 - \frac{\sqrt{(1-p_i)^2+(1-a_i)^2+(1-u_i)^2}}{\sqrt{n}}$$

(3)

The computed index of financial inclusion for the states and union territories of India the year 2008 are presented in Table 5. Maharashtra tops the list with an IFI of 0.606, while Chandigargh has the least IFI with 0.014.

The State of Uttar Pradesh has achieved a full banking penetration, Sikkim has zero banking penetration. The availability of banking services is only moderate in most parts of India, with Goa achieving a score of one and Manipur zero. The usage of banking services is high in Delhi, the index being one, and lowest in Manipur with zero usage of banking services.

Table 5. Index of Financial Inclusion India for 2008

State	Banking penetration	Availability of banking services	Usage of banking services	Index of financial inclusion	Rank
Maharashtra	0.790	0.172	0.527	0.606	1
Uttar Pradesh	1.000	0.089	0.098	0.522	2
West Bengal	0.519	0.126	0.123	0.433	3
Tamil Nadu	0.564	0.252	0.209	0.420	4
Andhra Pradesh	0.626	0.205	0.130	0.416	5
Karnataka	0.487	0.305	0.247	0.395	6
Bihar	0.286	0.050	0.068	0.382	7
Madhya Pradesh	0.275	0.118	0.103	0.347	8
Gujarat	0.410	0.200	0.081	0.334	9
Jharkhand	0.137	0.115	0.087	0.287	10
Kerala	0.341	0.392	0.140	0.283	11
Orissa	0.180	0.158	0.056	0.264	12
Chhattisgarh	0.079	0.089	0.029	0.249	13
Nagaland	0.097	0.008	0.026	0.221	14
Manipur	0.087	0.000	0.000	0.218	15
Rajasthan	0.297	0.137	0.066	0.217	16
Uttarakhand	0.074	0.357	0.188	0.217	17
Tripura	0.014	0.127	0.029	0.200	18
A & N Islands	0.103	0.239	0.051	0.199	19
Assam	0.119	0.077	0.036	0.192	20
Sikkim	0.000	0.401	0.198	0.182	21
Puducherry	0.010	0.289	0.049	0.149	22
Goa	0.035	1.000	0.209	0.146	23
Punjab	0.302	0.376	0.157	0.144	24
Haryana	0.186	0.245	0.071	0.141	25
Mizoram	0.170	0.247	0.050	0.135	26
Delhi	0.278	0.419	1.000	0.130	27
Arunachal Pradesh	0.002	0.144	0.093	0.114	28
Jammu & Kashmir	0.079	0.243	0.173	0.106	29
Meghalaya	0.007	0.209	0.057	0.091	30
Himachal Pradesh	0.059	0.449	0.089	0.059	31
Chandigarh	0.035	0.931	0.613	0.014	32

Data and Econometric Methodology

In this paper the data for 29 states of India for the time period 1996-2008 has been used to analyse the financial inclusion in India. The data relating to the banking indicators have been sourced from the Basic Statistical Returns of Scheduled Commercial Banks of various years published by the Reserve Bank of India. The data on the population and the state gross domestic product have been sourced from the CSO data.

The data for the newly created states of Jharkhand, Chhattisgarh and Uttarkhand have been summed to the states of Bihar, Madhya Pradesh and Uttar Pradesh respectively in order to nullify the effect of bifurcation of the states. The variable banking penetration is measured by the number of bank deposit accounts, providing the access component of the index of financial inclusion. The availability of banking services is measured by the number of bank offices per thousand population. The dimension of usage of banking services is measured by the ratio of the amounts of deposits and credits over the respective state and union territory gross domestic product.

Quantile Regression Method

The linear regression model on the causal relationship between a set of independent variables and a dependent variable focuses on the conditional mean response of the dependent variable to each fixed value of the independent variables. However, the conditional-mean model cannot be extended to non-central locations, especially for skewness, outliers, and heavy tailed distributions.

Alternatively, when a distribution is highly skewed, conditional median instead of mean is highly informative. The median is a quantile, one that describes the central location of a distribution. In other words, quantiles can be used to describe non-central positions of a distribution. The θ-th quantile denotes the value of the response below which the proportion of the population is p and above which the proportion of population is (1-p).

As the median is the middle value of a set ranked data, a set of equally spaced conditional quantiles can characterise the shape change of the conditional distribution in addition to its central location. Just like the sample mean is the solution to the problem of minimising a sum of squared residuals, the median is the solution to the problem of minimising a sum of absolute residuals.Since the symmetry of the absolute values yields the median, minimising a sum of asymmetrically weighted absolute residuals, by giving differing weights to positive and negative residuals would yield the quantiles.

The θ-th unconditional quantile is obtained by optimizing:

$$min \sum \rho_{\theta}(y_i - u_{\vartheta}) \qquad (4)$$

where the function ρθ(.) is the absolute value function. The conditional quantiles are obtained, analogous to the least squares model, as a solution to the optimisation problem. Given a random sample of yi observations, estimates of conditional quantile functions are obtained by solving:

$$min \sum \rho_{\theta}[y_i - u(x, \beta)] \qquad (5)$$

The resulting minimisation problem is formulated as a linear function of the parameters and is solved by linear programming methods (Koenkar and Hallock, 2001).

Following Koenker and Bassett (1978), let {yi: i = 1,…n}be a random sample on a random variable y having distribution function Φ. Then, the θ-th quantile, 0<θ<1 may be defined as any solution to the minimisation problem:

$$Qy_\theta = min[\sum \theta|y_i - u_\theta| + \sum(1-\theta)|y_i - u_\theta|] = min \sum \rho_\theta(y_i - u_\vartheta) \quad (6)$$

with $\rho_\theta = \phi(x) = \begin{cases} \theta u & u \geq 0 \\ (\theta - 1)u & u < 0 \end{cases}$

If the median (θ = 0.5) is taken, equation (8.3) can be expressed as:

$$Qy_{0.5} = min \sum |y_i - u_{0.5}| \quad (7)$$

Assuming that y is linearly dependent on a vector of exogenous variables x, the conditional quantile function can be specified as:

$$Qy_{\theta|x} = min[\sum \theta|y_i - u_\theta| + \sum(1-\theta)|y_i - u_\theta|] \quad (8)$$

Empirical Analysis

In the empirical analysis of financial inclusion, the effect of the various dimensions on IFI at different quantiles of the IFI distribution is estimated by the quantile regression method. The dimension variables are banking penetration, availability and usage of banking services. The summary statistics presented in Table 6 shows the differences between the mean and median values of the variables. As can be observed, the mean and median values differ substantially for all the variables, justifying the use of quantile regression on the basis of median values. Further, the variations in the variables in terms of standard deviations are also to be noticed.

Table 6. Descriptive Statistics of the Variables in Index of Financial Inclusion

Variable	Description	Mean	Median	Std. dev.	Min.	Max.
BP	Banking penetration	0.203	0.167	0.184	0	1
BSA	Availability of banking services	0.250	0.209	0.201	0	1
BSU	Usage of banking services	0.142	0.098	0.155	0	1
IFI	Index of financial inclusion	0.182	0.167	0.096	0.033	0.469
States	15					
Years	7					
Observations	377					

Empirically, the estimating equation is specified as,

IFIi = β0 + β1 BP + β2 BSA + β3 BSU + ui (9)

The Table 7 presents the quantile regression estimates, along with the OLS estimates for comparison. It is to be noted that the estimators of the least squares regression are around the mean, while those of the quantile regression are around the median. The OLS estimates show that effects of all the independent variables on IFI are positive and statistically significant. A one unit increase in banking penetration increases IFI by 0.279 units. An increase in the availability of banking services increases IFI by 0.230 units, while the usage of banking services increases IFI value by 0.306 units.

Table 7. OLS and Quantile Regression Estimates of Financial Inclusion Dependent variable: Index of Financial Inclusion

Variable	OLS	Quantile Regression				
		5%	25%	50%	75%	95%
Banking penetration	0.279* (54.66)	0.242* (21.32)	0.308* (16.83)	0.316* (78.96)	0.329* (98.39)	0.327* (44.83)
Availability of banking services	0.230* (41.6)	0.209* (25.33)	0.265* (10.40)	0.278* (19.47)	0.320* (45.94)	0.317* (108.19)
Usage of banking services	0.307* (43.67)	0 294* (10.36)	0.276* (11.23)	0.283* (28.56)	0.318* (42.30)	0.348* (27.14)
Constant	0.025* (13.38)	0.012* (4.86)	0.011* (4.08)	0.012* (3.61)	0.003*** (1.77)	0.002* (4.86)
R2	0.970	0.750	0.804	0.861	0.902	0.943

Note: Absolute t-values in parentheses. * significant at 1 percent level. ** significant at 5 percent level. * significant at 10 percent level.

The quantile regression estimates that analyses the conditional distribution of the IFI variable are presented for 5 different quantiles. The states that figure in the lower 5th quantile, are the low income states like Himachal Pradesh, Meghalaya and Jammu and Kashmir. The low levels of financial inclusion in these states can be attributed to the infrastructure constrains and the geographical terrain where large parts of these states are inaccessible. The 25th quantile is represented by states such as Haryana and Punjab and the low level of financial inclusion in these states is due to the poor usage of banking facilities resulting from a low ratio of banking deposits and credits over states gross products. The 50th quantile is represented by the states such as Orissa and Rajasthan.

The low level of financial inclusion in these states are due to the low level of infrastructural facilities that enable connectivity and penetration of the banking services and the very low volume of banking transactions as a ratio of state gross products. The 75th quantile includes the states of Gujarat, Madhya Pradesh, and the southern states of Andhra Pradesh, Karnataka and Tamil Nadu. The high level of financial inclusion is largely enabled by the large number of account holders and the high usage of the banking services resulting from a high ratio of banking deposits and credits over state gross products. The 95th quantile is represented by the states of Maharashtra and Uttar Pradesh. The high financial inclusion is enabled by the large population in these states and the resultant large number of bank account holders in these states ensuring high banking penetration.

It can be observed from Table 7 that the effects of banking penetration, availability and usage of banking services on the index of financial inclusion differ markedly at different quantiles of the IFI distribution, and all variables are positive and statistically significant. Further, the effects increase with the level of quantiles in the distribution. Also, the effects of the variables at the median quantile are not the same as that of the mean effects. In fact, banking penetration and availability of banking services have higher effects at the median quantile than the mean effects, while the effect of usage of banking services is lower at the median quantile than that of in the mean level.

The quantile regression estimate at the 5 percent quantile indicates that when the banking penetration dimension increases by 1 unit, IFI value increases by 0.242, while the same is 0.327 at the 95th quantile. A unit change in the availability of banking services causes an increase in the IFI value by 0.209 at the 5th quantile, compared to 0.317 at the 95th quantile. Similarly, a unit change in usage causes an increase in the IFI value is by 0.294 units at the 5th quantile, but the effect is 0.348 at the 95th quantile. The effects of the variables on IFI at other quantiles are interpreted in the same way.

A more comprehensive presentation of the effects of variables on IFI at each quantile is through graphical presentation. Figures 4, 5 and 6 display the estimated response of the variables for all 99 quantiles. The 95 percent confidence bands from bootstrapped estimation errors are also shown on either side of the line representing the coefficients. At first sight, it can be noted that the effect of the variables are different on the performance of the index at various quantiles. Further, the graphical presentations indicate that at lower quantiles a change in the unit of the variables leads to much wider change in the IFI value. At quantiles above the median, the effects almost converge, suggesting the complementarity among the variables. Moreover, the non-linear effect of the variables on the index of financial inclusion at various quantiles thus signifies that quantile regression which provides its estimates as a measure around the median rather than the mean as in ordinary least squares provide greater insights on the effects of the variables over the complete distribution.

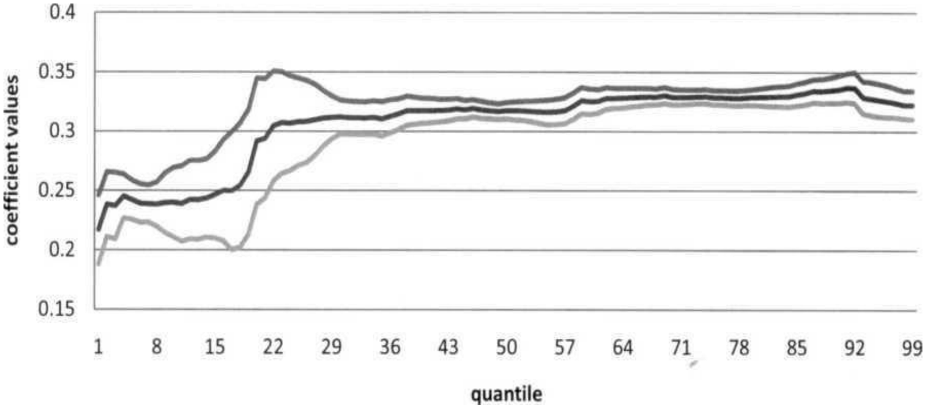

Fig. 4. Effect of Banking Penetration on Index of Financial Inclusion

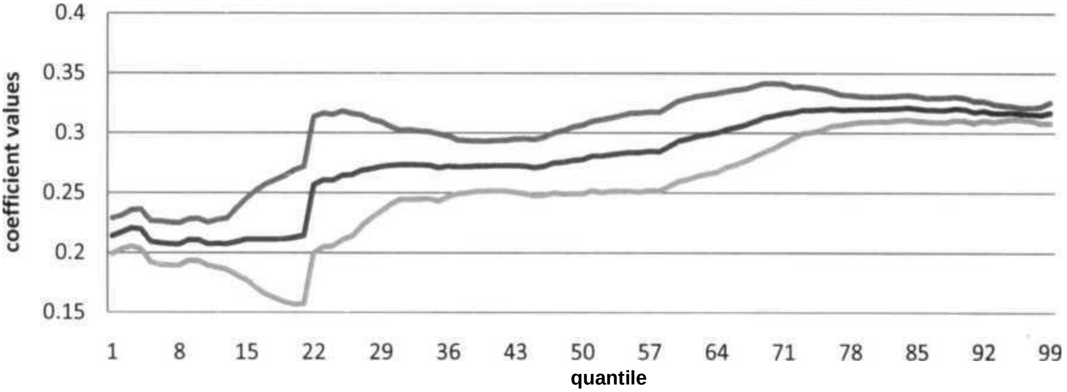

Fig. 5. Effect of Availability of Banking Services on Index of Financial Inclusion

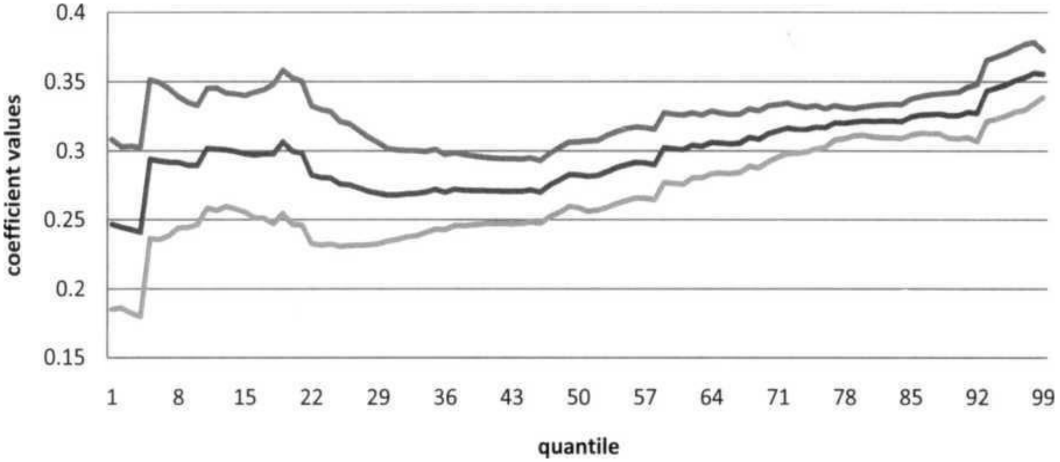

Fig. 6. Effect of Usage of Banking Services on Index of Financial Inclusion

The above quantile regression analysis considered the response of IFI to banking sector related variables that are measured by a scale of banking and financial performance only. However, financial inclusion is influenced by some infrastructure and economy wide variables also. Therefore, it is imperative to consider the effects these other external variables on financial inclusion. One of such important variables that affect the level of financial inclusion in a particular area is the level of infrastructure that decides the extent to which the penetration of banking services is enabled.

In this paper, length of roads (in sq.km) of each state is used as an infrastructure variable. The quantile estimates with added variable are presented in Table 8. The estimated results indicate that the states at the lower quantiles have a higher response of IFI with every one percent increase in the road length. Also, addition of road length variable increases the effects of other variables on IFI. These results imply that that the basic infrastructure is necessary to enable any improvement in financial inclusion in the states of India.

Table 8. Quantile Regression Estimates of Financial Inclusion with Infrastructure Dependent variable: Index of Financial Inclusion

Variable	OLS	Quantiles				
		5%	25%	50%	75%	95%
Banking penetration	0.263* (24.38)	0.217* (10.34)	0 299* (8.94)	0.320* (28.94)	0.323* (35.71)	0.336* (48.61)
Availability of banking services	0.236* (23.78)	0.214* (22.56)	0.227* (6.60)	0.285* (9.68)	0.343* (16.70)	0.329* (31.33)
Usage of banking services	0.293* (25.98)	0.298* (24.56)	0.280* (11.36)	0.264* (19.13)	0.271* (23.97)	0.315* (15.92)
In (road length)	0.007** (2.28)	0.009* (3.12)	0.002 (0.23)	0.000 (0.04)	0.003** (1.96)	0.000 (0.35)
Constant	-0.004 (0.29)	-0.028** (2.03)	0.008 (0.25)	0.013 (0.95)	-0.007 (1.03)	0.000 (0.06)
R2	0.970	0.750	0.804	0.861	0.902	0.943

Note: Absolute t-values in parentheses. *significant at 1 percent level. ** significant at 5 percent level. * significant at 10 percent level.

Conclusions

With an aim to improve the services of the financial sector available to the poor also, the RBI and the Government of India have initiated many financial inclusion strategies. In the financial inclusion efforts, the banking sector, which has registered a significant growth, has been included as a major player to bank the unbanked population. Though the concept and meaning of financial inclusion is clear, there is no consensus on how to measure financial inclusion. Generally, the banking performance is assessed with certain financial indicators that do not necessarily include financial inclusion as an indicator of performance. As financial inclusion is influenced by both demand side and supply side factors, any indicator or a measure of financial inclusion should consider the depth of financial reach. This paper considers one such measure, the index of financial inclusion constructed over three dimensions of financial inclusiveness viz. banking penetration, availability and usage of banking services. Being an index, the IFI is between 0 and 1 and is useful for comparison at different levels. Using the state level banking sector data for 29 states of India for the period 1996-2008, this paper calculate the IFI index for the states of India and analyses the effects of each dimension on IFI, applying the quantile regression method.

The calculated IFI for states show that there are wide variations in financial inclusion across the states of India. The quantile regression estimates show that the effects vary across quantiles over the distribution of IFI. The low income states are generally at the lower quantiles and therefore the effects of the variables on IFI is also low compared to the high income states. Also, basic infrastructure impacts the financial inclusion in states of India. The estimated results highlight the need that policy initiatives on improving the financial inclusion in the country have to be region specific and concentrate on the demand and supply dimensions of the financial sector that regions lack.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 005

Announcement

Conduct of 1st Talent Test - 2011 for Geography Students on 07th March, 2011

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The General Body meeting of Indian Geographical Society has decided to organise the **Talent Test-Young Geographer-2011 for final year UG and PG students of the Department of Geography** in Tamil Nadu. The EC has identified the following coordinators to organise this event successfully with HOD's of Geography Departments.

Regional Coordinators

1**. Dr. G. Bhaskaran (Chennai Region),**
Assistant Professor, Department of Geography, University of Madras,
Chennai - 600 005, ***Mobile:*** *94444 14688,* ***E-mail****: grbhaskaran@gmail.com*

2. **Dr. K. Balasubramani (Rest of Tamil Nadu)**
Assistant Professor, Department of Geography, Bharathidasan University,
Tiruchirappalli - 620 024, ***Mobile****: 99440 60319,* ***E-mail:*** *geobalas@gmail.com*

3. **Dr. S.R. Nagarathinam (Coimbatore Region)**
Professor and Head, Department of Geography, Government Arts College (Autonomous), Coimbatore - 641 018, ***Mobile:*** *98941 10585*

4. **Dr. P. Ilangovan (Madurai Region)**
Professor and Head, Department of Environmental Remote Sensing and Cartography, Madurai Kamaraj University, Palkalai Nagar, Madurai - 625 021, ***Mobile:*** *94426 43430*

5. **Prof. G. Jagadeesan (Salem Region)**
Professor and Head, Department of Geography, Government Arts College (Autonomous), Salem- 636 007, ***Mobile:*** *94432 02011*

(a) All the coordinators to contact the HOD's of nearby Geography Departments to conduct the Talent Test and (b) Request the HOD's of the Geography Departments to contact the coordinators and conduct the Talent Test successfully.

TALENT TEST-YOUNG GEOGRAPHER-2011

Instructions for Talent Test

****

1. Talent Test will be for 1.30 hours and consists of 100 questions without any choice.
2. Syllabi for UG and PG talent tests are provided in Annexure I & II
3. Final year UG and PG students of Geography are eligible for Talent Test.
4. Filled-in Application forms should be submitted to the Head of the Geography Department concerned on or before 05th March, 2011.
5. The coordinators will (a) contact the HOD's of nearby Geography Departments and (b) send the representatives for conducting Test.
6. The Head of the Departments of Geography will (a) collect the filled-in Application forms from students with registration fee and (b) contact the coordinators and conduct the Talent Test.
7. Talent Test is scheduled on 07th March, 2011between 11.00 AM to 12.30 PM.
8. Registration fee for UG Students Rs.50/- and for PG Students Rs.75/-. Only Cash should be collected from the candidates.

Details of Awards and Prizes

Prize	Award and Prize Amount	
	UG The IGS Founder Prof. N. Subrahmanyam Award	PG Prof. A. Ramesh Award
I	Rs. 5,000/-	Rs. 7,000/-
II	Rs. 3,000/-	Rs. 5,000/-
III	Rs. 2,000/-	Rs. 3,000/-

Prizes will be awarded during International Conference / IGS Annual Meeting. All other participants will be given certificates of Participation. Please visit our website for further information: http://www.igschennai.org/

Dates to Remember

Last date for the Enrolment : 05th March, 2011
Date of the Talent Test : 07th March, 2011

APPLICATION FORM FOR TALENT TEST - YOUNG GEOGRAPHER (UG/PG) - 2011

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1. Name of the Student :
2. Date of Birth and Age :
3. Programme and Subject :
4. Department / College Address :
5. Residential Address :
6. Phone / Mobile Number/email :
7. Particulars of Payment :
8. Signature of the Student :

Signature of the HOD

Annexure – I

TALENT TEST-YOUNG GEOGRAPHER-2011

Syllabus for Under Graduate Students

Geomorphology: Fundamental concepts; Factors controlling landform development; Endogenetic and Exogenetic forces; Continental drift and plate tectonics - Denudation process: weathering, mass movement and erosion - Landforms associated with fluvial, glacial, arid, coastal and karst.

Climatology: Composition and structure of the atmosphere; Insolation; Heat budget of the earth; Distribution of temperature, atmospheric pressure and general circulation of winds; Monsoons and jet streams; Air-masses; Fronts, temperate and tropical cyclones; Types and distribution of precipitation; Classification of world climates; Koppen's and Thornthwaite's schemes; Global warming.

Oceanography: Bottom relief of Indian, Atlantic and Pacific Oceans; Ocean deposits; Coral reefs; Temperature and salinity of the Oceans; Density of sea water; Tides and ocean currents; Sea-level changes.

Settlement Geography: Site, situation, types, size, rural and urban settlements; Settlement systems.

Economic Geography: Sectors of Economy: primary, secondary, tertiary and quaternary; Natural resources -.Renewable and non-renewable; Conservation of resources; Classification of industries; Modes of transportation.

Geography of India: Physiographic divisions; Climate : Its regional variations; Vegetation types and vegetation regions; Major soil types; Coastal and Marine resources; Water resources; Irrigation; Agriculture; Agro-climatic regions; Mineral and power resources; Major industries and industrial regions; Population distribution and growth; Settlement patterns.

Cartography: Types of maps – Projections – Scale; Types - General purpose and Thematic maps; Choropleth, Isopleth and Chorochromatic maps and pie diagrams; Accessibility and flow maps; Remote Sensing - Geographic Information System (GIS) - Global Positioning System (GPS).

Statistical Methods: Data sources and types of data; Statistical diagrams; study of frequency distribution and cumulative frequency; Measures of central tendency; Selection of class intervals for mapping; Measures of dispersion; Standard deviation.

Annexure – II

TALENT TEST-YOUNG GEOGRAPHER-2011

Syllabus for Post Graduate Students

Geomorphology: Fundamental concepts; Factors controlling landform development; Endogenetic and Exogenetic forces; Denudation process: weathering, mass movements and erosion, Geosynclines, mountain building, continental drift and plate tectonics; Concept of Geomorphic Cycle; Landforms associated with fluvial, glacial, arid, coastal and karst cycles, Slope forms and processes; Environmental and Applied Geomorphology.

Climatology: Composition and structure of the atmosphere; Insolation; Heat budget of the earth; Distribution of temperature, atmospheric pressure and general circulation of winds; Monsoons and jet streams; Stability and instability of the atmosphere; Air-masses; Fronts, temperate and tropical cyclones; Types and distribution of precipitation; Classification of world climates; Koppen's and Thornthwaite's schemes; Hydrological Cycle; Global warming.

Oceanography: Origin of ocean basins; Bottom relief of Indian, Atlantic and Pacific Oceans; Ocean deposits; Coral reefs; Temperature and salinity of the Oceans; Density of sea water; Tides and ocean currents; Sea-level changes.

Bio-Geography: Physical factors influencing world distribution of plants and animals; Forms and functions of ecosystem: Forest, grassland, marine and mountain ecosystem; Bio-diversity and its depletion through natural and man induced causes; Conservation and management of ecosystems; Environmental hazards and problems of pollution; Ozone depletion.

Geographic Thought : General character of Geographic knowledge during the ancient and medieval period; Foundations of Modern Geography: Contribution of German, French, British and American schools; Conceptual and methodological developments during the 20th century; Changing paradigms; Man and Environment, Determinism and possibilism, areal differentiation and spatial organization; Quantitative revolution; Impact of positivism, humanism, radicalism and behaviouralism in Geography.

Population Geography: Nature, scope, subject matter and recent trends; Patterns of world distribution, Growth and density of population; Policy issues; Patterns and processes of migration; Demographic transition; Population-resource regions.

Settlement Geography: Site, situation, types, size, spacing and internal morphology of rural and urban settlements; Ecological processes of urban growth; Urban fringe; City region; Settlement systems; Primate city; Rank-Size rule; Settlement hierarchy; Christaller's Central Place theory; August Losch's theory of market centres.

Economic Geography: Location of economic activities and spatial organization of economies; Classification of economies; Sectors of Economy: primary, secondary, tertiary and quaternary; Natural resources -.Renewable and non-renewable; Conservation of resources.

Agricultural Geography: Concept and techniques of delimitation of agricultural regions; Measurement of agricultural productivity and efficiency; Crop combinations and diversification; Von Thunen's Model; Agricultural systems of the world.

Industrial Geography: Classification of industries: Weber's and Losch's approaches; Resource based and footloose industries.

Geography of Transport and Trade: Modes of transportation and transport cost; Accessibility and connectivity: Inter-regional and Intra-regional: Comparative cost advantages.

Political Geography: Definition and scope of Political Geography; Geopolitics; Global strategic views (Heartland and Rimland theories);-Concept of nation, state and Nation-State; Boundaries and frontiers; Politics of world resources; Geography and Federalism.

Social Geography: Nature and scope of social geography; Social structure and social processes; Elements of Social Geography-: ethnicity, tribe, dialect, language, caste and religion; Concept of Social well-being.

Cultural Geography: Nature and scope of Cultural Geography; Environment and culture; Concept of culture-areas and cultural regions; Theories of tribal groups; Dwelling places as cultural expressions.

Regional Planning: Regional concept in Geography; its application to planning; Concept of planning region; Regional hierarchy; Types of regions and methods of regional delineation; Conceptual and theoretical framework of regional planning; Regional planning in India: Concept of development; Indicators of development; Regional imbalances.

Geography of India: Physiographic divisions; Climate : Its regional variations; Vegetation types and vegetation regions; Major soil types; Coastal and Marine resources; Water resources; Irrigation; Agriculture; Agro-climatic regions; Mineral and power resources; Major industries and industrial regions; Population distribution and growth; Settlement patterns; Regional disparities in social and economic development.

Cartography: Map as a tool in Geographical studies ; Types of maps: Techniques for the study of spatial patterns of distribution; Single purpose and composite maps; Choropleth, Isopleth and Chorochromatic maps and pie diagrams; Mapping of location specific data; Accessibility and flow maps. Remote Sensing and computer application in mapping; Digital mapping; Geographic Information System (GIS) Global Positioning System (GPS): Thematic maps.

Statistical Methods: Data sources and types of data; Statistical diagrams; study of frequency distribution and cumulative frequency;. Measures of central tendency; Selection of class intervals for mapping; Measures of dispersion and concentration; Standard deviation; Lorenz curve; Methods of measuring association among different attributes; Simple and multiple correlation; Regression. Measurement of spatial patterns of distribution; Nearest-neighbour analysis; Scaling techniques, rank score, weighted score; Sampling techniques for geographical analysis.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 005

Minutes of the Executive Meeting Held on 30.12.2010 at the Department of Geography, Bharathidasan University, Tiruchirappalli at 2.30 p.m.

Members Present:

1. Thiru. K. Devaraj, President
2. Dr. R. Jaganathan, General Secretary
3. Dr. K. Kumaraswamy, Editor
4. Dr. V. Madha Suresh, Treasurer
5. Dr. G. Baskaran, Member
6. Dr. R. Bhavani , Member
7. Dr. T. Lakshmanasamy, Special Invitee

Resolutions:

1. Resolved to send invitations for GB/ECE meeting to the concerned members well in advance.
2. Resolved to conduct Talent Test-Young Geographer-2011 for final year UG students in the Geography Departments including the Bharathidasan University Ill year students of M.Sc Geo- Sciences.
3. Resolved to conduct dissemination of Innovative Technology Workshop to the School Teachers of Geography in the month of March 2011.
4. Resolved to request the Former Secretary Prof. T. Yasantha Kumaran to submit all the documents to the present secretary Dr. R. Jaganathan on or before 20th January 2011.
5. Resolved to request the Former Treasurer Dr. R. Bhavani to handover all the documents to the present treasurer Dr. V. Madha Suresh on or before 20th January 2011.
6. Resolved to request the Former Editor Prof. S. Subbiah to handover all the records and other relevant documents to the present editor Dr. K. Kumaraswamy on or before 20th January 2011.

The Indian Geographical Society, General Body Meeting

Date: 27 March 2011 Venue: Department of Geography, Bharathidasan, Tiruchirappalli

Sitting (L – R): Dr. R. Jaganathan (General Secretary), Dr.K.Kumaraswamy (Editor), Dr.N.Sivagnanam, Mr.K.Devarajan (President), Dr.A.Santhakumarai, & Dr.S.Aruchamy
Standing(L – R): Dr. Dr. M. Sakthivel, Dr. G. Bhaskaran, Dr.R.Shyamala (Joint Secretary), Dr. V.Madha Suresh (Treasurer), Mr. R.Jegankumar (Joint Secretary) & Ms. M.Sumathi

Statement about ownership and other particulars about

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I, K. Kumaraswamy, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Dr. K. Kumaraswamy
Editor, The Indian Geographical Journal