Trans. Inst. Indian Geographers
Vol. 6, No.1, January 1984

ANALYSIS OF SETTLEMENTS IN A SYSTEM : A Case Study of Mahesana District

Anjana P. Desai, Ahmedabad

ABSTRACT : This study analyses rural settlements in a system through the concepts of Population Potential and Nearest Neighbour Analysis with the help of Computer-aided mapping. These concepts measure settlements in terms of mass distance and relative location in a spatial context. Population potential measures the sum of the influences, on a centre, in proportion to the populations of others and divided by its respective distances from them. Nearest Neighbour Analysis measures the reandomness of pattern of settlements on space. In this study, the impact of one settlement on others has been brought out over time (1951-1981) and space in a comparative analysis within a system.

In the study area of the southern six talukas of Mahesana district in the Narmada Command area of North Gujarat, the physical environment varies from the east with higher rainfall, irrigation and better soil, to the west with low rainfall and little irrigated land with infertile (saline and alkaline) soils. In response to such differential environmental quality, human beings have settled in large and densely populated villages with higher cropping intensity and more job opportunities in the east, and in small settlements with low density with low cropping intensity in the drier parts of the west.

The above contrasting situation is clearly depicted through the analysis of population potential over time and space, while the distribution of settlements is brought out with the help of nearest neighbour analysis. Taking mass (population) and distance as major factors, population potential is found to be high in the east with large villages which are closely spaced in a uniform pattern; while those in the western side have low potential with small size and are widely spaced in a random manner.

Population potential is a macro spatial concept which is helpful in regional planning as it brings our the hierarchical system, depicting accessibility and socio-economic interaction potential of settlements.

INTRODUCTION

Systems approach provides us a method of explanation of the complexity of the relationship that exists between phenomena in the real world. It conceptualises the existence of dynamic relationship between objects in totality and emphasizes how the relationship changes over time and space. The method is typology-oriented and aims at prediction of growth and development of a system, based on relative condition of elements in it.

Traditionally, in Geography, settlements were viewed as a fundamental expression of a system of non-land relationship. But the explanation of a pattern cannot be only physical - it has to be comprehensive, encompassing the history, culture, technology and socio-economic aspects of settlements along with their physical attributes.

Each settlement is a system by itself - in its landuse pattern, socio-cultural layout, population density and distribution, economic activities, transport and communication system.

Environmental resources and technology for the development of settlement are not equal on space so settlements do not grow or develop in a similar fashion by size and by function. Interactions of goods, people and information, based on the principles of complementarity, intervening opportunity and friction of distance, make each settlement system as a part of a larger system of settlements in a hierarchical fashion. Settlements are tied up together in a form of a spatial organisation based on the principles of movement-minimisation. Settlements take the advantage of accessibility, agglomeration and scale economy in such a manner that a change in one will affect the other. Various models have been used to measure different aspects of settlement systems, e.g. measurement of pattern of distribution of nodes and hierarchy, optimisation of connectivity, flow and interactions of the network pattern, determination of the zone of influence or market area of nodes, classification of settlements by functions, availability of amenities with a regional context. Thus spatial pattern and its relation to mutual interaction, is an important area of study.

OBJECTIVES OF THIS STUDY

The main objective of this paper is to analyse the spatial pattern of rural settlements in a system as an aid to regional planning. This obviously includes the issues of relative location, spacing and direction, of each settlement with respect to other, such that the pattern can be understood in totality in a particular environment. There are various concepts by which settlements can be analysed in a system. This paper has focussed mainly on the two concepts: (a) Population Potential and (b)) Nearest Neighbour Analysis. Population Potential is based on the concept that, the influence of all other settlements on one centre depends on the relative size of population and the distance separating them; while the Nearest Neighbour Analysis deals with the concept of how randomly settlements are distributed over space. Both the notions deal with the theoretical concept of relative position and can be mapped geographically for visual analysis. Generally, the absolute location of settlements does not change the change takes place mainly in size and density of population. This paper focusses in depicting the change of population potential of settlements over time (1951-1981) as their populations change in different settlement at a differential rate in the whole system.

THE STUDY AREA

The study area includes the southern six talukas Sami, Harij, Chanasma, Mahesana

Kadi and Kalol of Mahesana district of North Gujarat, with a total area of 4912 km and total population of 12,18,014 in 1981. The area extends from 71° 33'E to 72° 55'E and 23° 05'N to 23° 52'N bordered by Radhanpur, Patan and Visnagar talukas in the North, Surendranagar and Ahmedabad districts in the South, Vijapur, Visnagar of Mahesana district and Gandhinagar district in the east, the Little Rann of Kutch and Ahmedabad district in the west. (Map No. 1).

The general slope of the land is from the north-east to south-west. The area is largely a flat area except for a few hillocks around Balol, Kadi and south-east of Mahesana. The area is drained by four rivers, the Sabarmati, the Rupen, the Saraswati and the Banas, following the slope of the land. The river Sabarmati is the only perennial river; it flows through Kalol taluka.

The average annual rainfall decreases from the east (75 cm.) to the west (45 cm.). The State Committee has classified the western talukas, Sami and Harij, as chronically drought prone areas. Soils in Sami area are highly saline and alkaline in nature, and often are not suitable for agriculture. In the east, soils are sandy loam suited to the cultivation of cereals, pulses, cotton, spices and fodder crops. In Sami area, an additional problem is that of dust storms that bring wind-blown sand particles from the Rann, making the quality of soils poorer. The vegetation is of xerophytic type with thorny leaves, deep roots and stunted in size in the west, while vegetation cover is thicker in the eastern side.

The socio-economic profile of the area somewhat matches with the physical background. In general, the western talukas, Sami and Harij, are relatively poor in terms of education and medical facilities, transport and communication, and electricity facilities. The situation is much better in the east in Mahesana and Kalol, while it is in intermediate condition in Chanasma and Kadi talukas. Similarly, the percentage of non-primary workers is higher in the east compared to that in the west. On the western side, Sami taluka has low rainfall, low irrigation and low land use efficiency compared to those in the eastern talukas of Kalol and Mahesana. The relevance of studying this area with such marked environmental variations within a short distance of a hundred km. lies from the point of view of regional planning, and understanding of demography, economic situation and infrastructural facilities.

METHODOLOGY

The measurement of randomness of the pattern of settlements with the help of Nearest Neighbour Analysis is as follows:

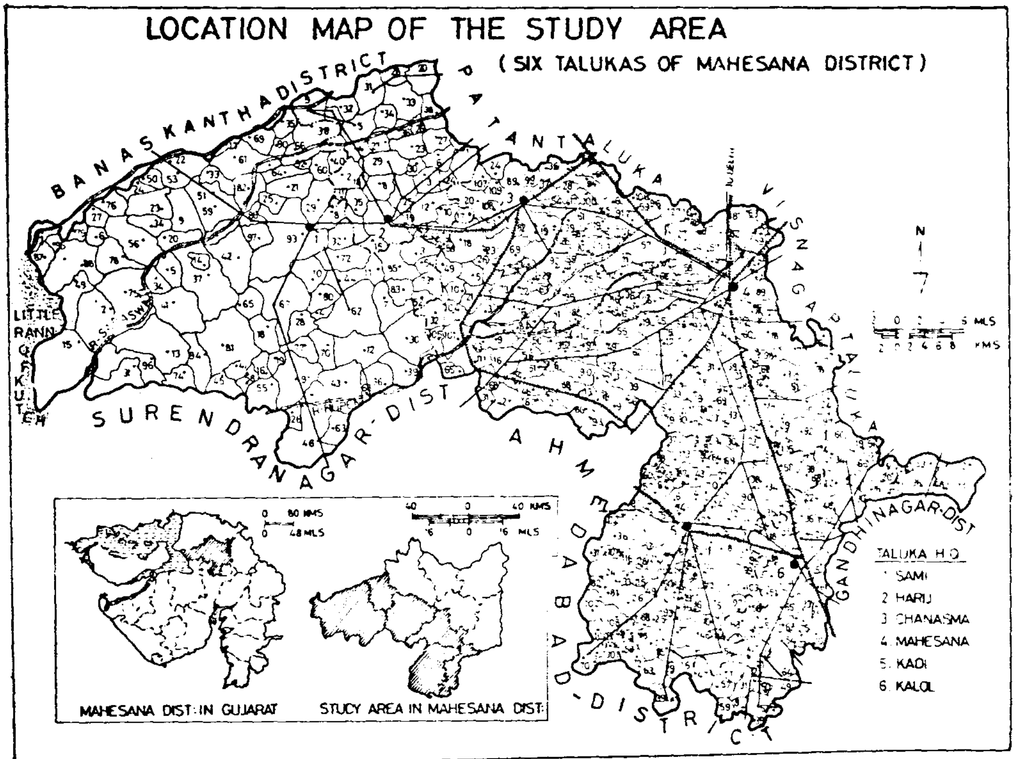
$$\bar{D} = \frac{1}{2\cdot\sqrt{\frac{N}{A}}}$$

where $\bar{D}$ = Mean distance of a centre from its nearest neighbour in k.m. measured linearly for simplicity.

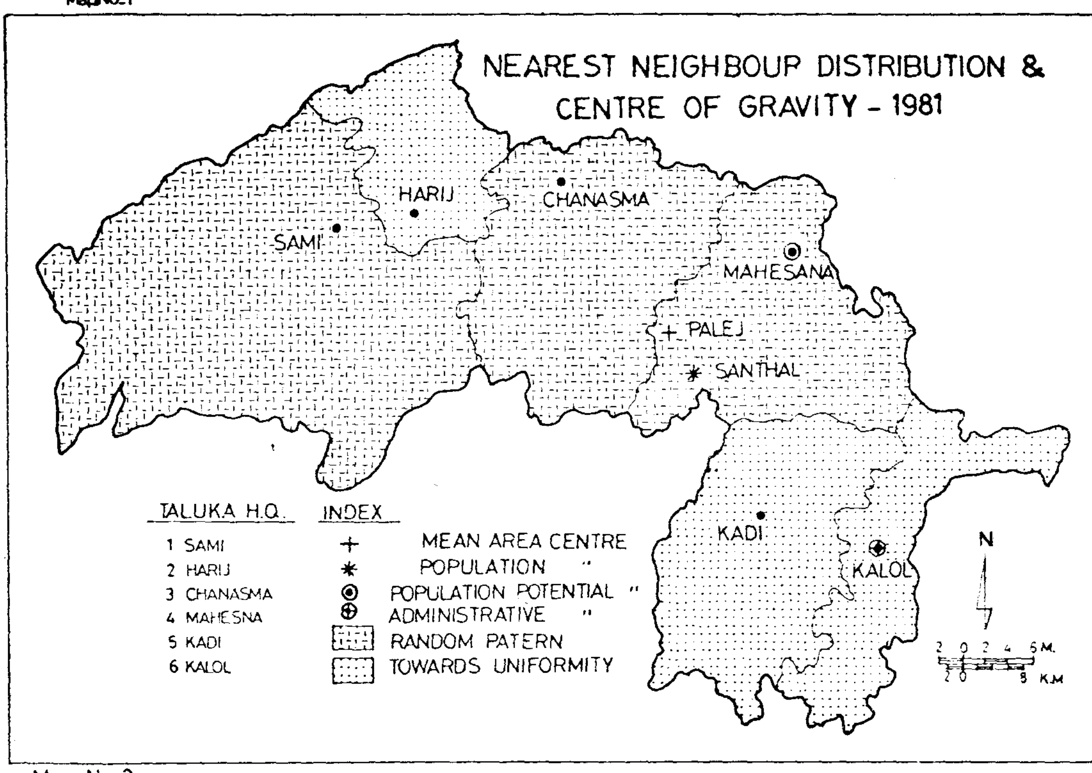
$$R = \frac{\bar{D}_{obs}}{1 \div 2\sqrt{\frac{N}{A}}}$$

N = No. of Settlements (Centres)

A = Area under consideration; (here it is a taluka)



MapNo_1



Map. No. 2

i.e. $R = 2\,\bar{D}_{obs} \cdot \sqrt{\frac{N}{A}}$. where $R = \frac{\text{Measured mean distance}}{\text{Expected mean distance}}$

(based on random distribution)

The mean centre of settlements has been calculated in the following manner:

$$\frac{\sum_{i=1}^{N} x_i}{N}, \quad \frac{\sum_{i=1}^{N} y_i}{N}$$

Using x and y co-ordinates of locations of all settlements.

Similarly, population centre of settlements has been calculated:

$$\frac{\sum_{i=1}^{N} P_i x_i}{\sum_{i=1}^{N} P_i} \quad \frac{\sum_{i=1}^{N} P_i y_i}{\sum_{i=1}^{N} P_i}$$

Where P is the population of Settlements.

The population potential model using population and distance in a system has been used as follows:

$$P_{ix} = \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{M_j}{d_{ij}}$$

where P_{ix} = Population potential of *ith* centre exclusive of the centre itself.

M_j = Population of j ("Mass" of j)

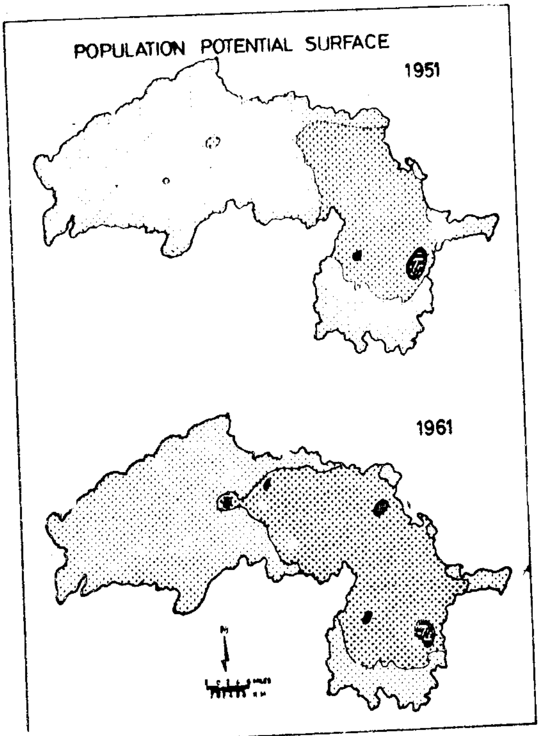
d_{ij} = Distance between i and j in k.m., in a linear form for simplicity.

In the above, N is the total number of settlements in the system under consideration, i.e. in the study area. (External influences from outside the area are ignored.)

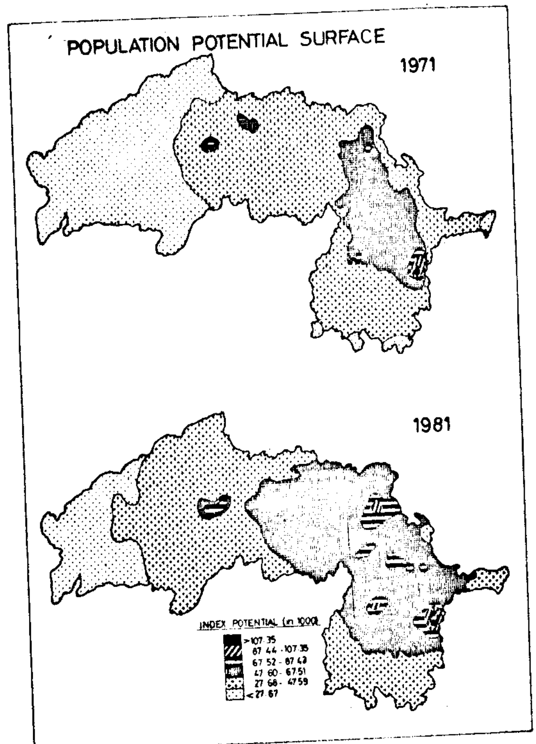
$$P_i = P_{ix} + \frac{M_i}{D}$$

Where P_i = Population Potential of i, inclusive of the centre's own influence.

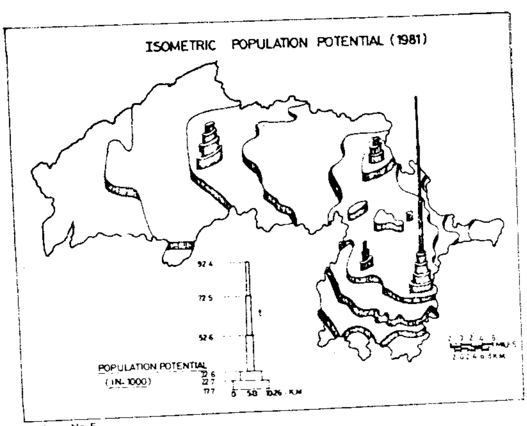
D = ½ of nearest neighbour distance from the centre i.



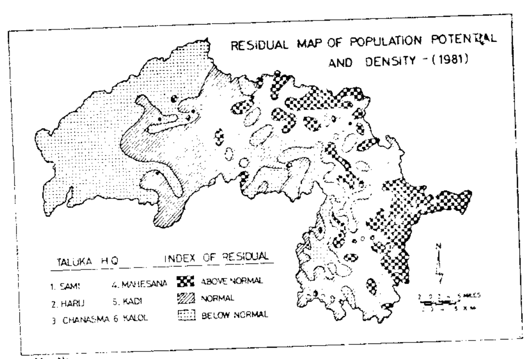
Map.No. 3



Map.No. 4



Map _ No.5



Map.No 6

Population potential exercise has been carried out for 1951, 1961, 1971 and 1981 in the form of surface of isopleths with the help of computer mapping so that the impact to size can be depicted, keeping distance as constant. An isometric map of population potential brings out clearly the three dimensional effect of the potential surfaces of proportionate height. Finally, the residual map based on the regression analysis of population potential and density of population has been depicted in an isopleth map to demarcate the areas of higher and lower density than that expected by model based on population potential.

ANALYSIS AND FINDINGS

a) *In the Nearest Neighbour Analysis*, the ratio (R) of the observed mean distance and the expected mean distance between settlements, varies in principle from R=0, indicating clustering, R=1, suggesting randomness and R=2.15, indicating uniformity. In general, any pattern may not have a value exactly 0, 1 or 2.15 so an approximate range of R = below .71 (clustering) .71 to 1.42 (random and R = above 1.42 (uniformity) has been used to categoriese the talukas, which have been taken as units of area in this Nearest Neighbour Analysis. 'R' value of these six talukas varies between 1.23 (Mahesana) to 1.54 (Kalol). In the study area Sami (R = 1.33), Chanasma (R = 1.27) and Mahesana (R = 1.23) have a pattern of randomness, while Harij (R = 1.45), Kadi (R = 1.43) and Kalol (R = 1.54) have shown a pattern towards uniformity (Map No.1).

The implication of random distribution is that, there is no definite force or process that has controlled the pattern, whereas homogeneous environmental conditions give rise to a pattern towards uniformity, while clustering takes place where there are unique facilities, found together at a few nodes in the midst of an area. In the study area, Kalol with higher percentage of irrigated land and homogeneous soil and better rainfall, has more uniform pattern of settlements than any other taluka.

b) *The Centre of Gravity* of the area is Palaj whereas mean population centre is at Santhal (Map No. 2). Both the villages are in Mahesana district. The district headquarters, Mahesana, is not at the centre, the point of equal accessibility, as the study area only consists of the southern six talukas out of total eleven talukas in the district. The mean centres of each decade can be helpful to know the direction of the advance of population.

c) *Population Potential*, based on the concept of gravity, is expected to be high, if a settlement is surrounded with large settlements and distance between them is small. Here the aggregate influence implies socio-economic interactions and the degree of accessibility in the hierarchical system of settlements in an area. The sum of all influence of mass and distance has been depicted as a continuous spatial variable in the form of isopleths of potential surfaces.

Theoretically, it is expected that in a system of settlements, interaction will be proportionally high if the mass is large in centres and it will be inversely low with increasing distance between centres. If any one of these two variables changes, interaction changes in the system. These elements in a set of settlements exert their influence simultaneously. Each centre is simultaneously under the influence of other centres and similarly exerts an influence on all other centres. In the study area, since the distance is constant, the impact of mass or population on potential of each village has been analysed over a period of three decades (1951 to 1981), with the help of computer programming (Map Nos. 3 and 4). As mass changes by decade, so does the population potential value of the village.

In 1951, a large portion of the study area had population potential value less than 27,000 and it was between 27,000 to 47,000 in Mahesana and Kalol talukas. The value was very high, forming a loop near the town of Kalol. The minimum potential was 8,349 at Adagam village in Sami and the maximum was 1,29,626 at Kalol (Map No. 3). In 1961, the population potential value increased in the west in Chanasma taluka, ranging between 27,000 to 47,000 and the high loop was still existing near Kalol. A few other loops of high potential values varying between 47,000 to 67,000 were visible around Kadi, Mahesana, Dhinoj and Chanasma. In 1971, the extension of the potential was mainly in the value ranging from 27,000 to 47,000 and the spread took place westward in Harij and Chanasma talukas (Map No. 4). The potential surface of 47,000 to 67,000 came in the limelight in Mahesana and Kalol talukas. Finally, in 1981 the potential value lower than 27,000 was not visible in the east. It was only seen in western Sami, near Little Rann of Kutch. The loops of potential got strengthened with higher values of 67,000 to 104,000 in Kalol, Mahesana and Chanasma talukas. Even Sami taluka had a higher potential value of 27,000 to 47,000 in 1981.

It is to be noticed that, the western side of Sami has remained in the low population potential category, while other areas, in the east, have shown a much increased population potential. This dynamic pattern of population potential indicates how the impact of population is gradually spreading from the east to the west over a period of thirty years, indicating a spread of socio-economic interaction from the east to the west. However, the extreme west, near the Rann of Kutch, has not yet felt this influence.

The isometric map of population potential of 1981 gives a three dimensional depiction of it in terms of height (Map No.5) The importance of Kalol is clear in relation to Mahesana which is the District Headquarters. Being closer to large urban centres of Ahmedabad and Gandhinagar, Kalol has superceded Mahesana in its interaction, in an indirect manner.

Density of population in 1981 has been regressed with population potential of 1981, and residuals have been mapped to show the departure between the two (Map No. 6). The correlation coefficient is "r" = .43, and half a standard deviation is considered as normal one. The residual map brings our clearly the same picture with below normal density in Semi-Harij area and also the southern and western parts of Chanasma, Mahesana and Kadi talukas, while the density above normal, is visible in the north and eastern parts of Mahesana and Kalol talukas. This indicates the influence of other factors on density, such as, connectivity, accessibility and pull of urban centres which are located outside the study area.

CONCLUSIONS AND REFLECTIONS

These mathematical models of Nearest Neighbour Analysis and Population Potential Surfaces are based on certain abstraction from complex reality, and have been mapped for geographical analysis. They are helpful in understanding the overall spatial pattern or structure, and the interaction based on the impact of size and distance of a settlement with respect to all other settlements in a system. The analyses of population potential and of density residuals indirectly indicate the areas of accessibility, flow of people and commodity, and organisational pattern or hierarchical systems of settlements of an area. This information is very much helpful, in monitoring the process of growth for mobilising resources in the context of regional planning in a systems approach.

FUTURE SCOPE OF STUDY

There is much scope in using the broad concept of population potential. First of all, the model can be made realistic with variable factor of distance as in the case of mass. In other words, distance can be made a variable by measuring it with actual travel time or cost. Moreover, actual road distance can also be used in case of linear distance measured by co-ordinates. Instead of population, mass can be measured as total workers, retail sales, value added for manufacturing goods, median income or any other factors like agricultural tractors, to measure market potential, economic potential or farm potential which can be of much help for the purpose of planning on a regional or national scale. The neglect of external influences would in fact be more justified in a national scale. The concept of centrography or mean centre is useful for regional planning as one can compare the mean centres of many phenomena on a single map over time or of one phenomenon over different points of time. The standard distance around mean centre is helpful in knowing the differential rate of dispersion of various activities, say commercial activities from the Central Business District. An analysis of a pattern on space leads to an understanding of processes behind it, and eventually planning and monitoring of such process depend on the value and judgement of the society. In the context of the present study, an issue before planners is, whether to develop further the already developed areas of the east which have higher potential, or to redirect resources to the west to bring about a spatial equilibrium.

ACKNOWLEDGEMENTS

The author is very much thankful to the Narmada Planning Group (NPG) of Gandhinagar for providing the opportunity to use the information from her research project on 'A Study of Settlement Pattern', sponsored by the NPG. The author is thankful to Shri V.D. Thakkar for assistance in programming, to Smt. Smita Sen Gupta and Miss Damayanti Patel for cartographic help.

REFERENCES

Abler, R., J.S. Adams and P. Gould (1971) : *Spatial Organization : The Geographer's View of the World*, Prentice Hall, New Jersey.

Chorley, R.J. and P. Haggett (1967) : *Models in Geography*, Methuen, London.

Coffey, W.J. (1981) : *Geography : Towards a General Spatial Systems Approach*, Methuen, London.

Haggett, P. (1972) : *Geography : A Modern Synthesis*, Harper and Row, New York.

Taylor, P.J. (1977) : *Quantitative Methods in Geography*, Houghton Miffin Co., Boston.

ADDRESS OF THE AUTHOR

Dr. (Mrs.) Anjana Desai
Head, Department of Geography
Gujarat University
Ahmedabad - 380 009