CHAPTER-X

CHAPTER - X ROLE OF PHYSICAL FACTORS IN THE DISTRIBUTION OF LEPROSY

10.1 Importance of Environment

Among the several disciplines which study the health of the people in one form or another, geography is one. Medical geographic tradition, which was almost abandoned during the 19th century, was revived again in the first half of this century when it was realised that to understand a disease, a study of relationships between the pathological factors or "Pathogens", which cause the disease, and the geographical factors or "Geogens" which give rise to pathological conditions (May, 1958), is very essential. May's concept of geogens incorporate all these factors of the environment that may be related to disease causation.

Environment means different things to different people. To a traditional geographer it is synonymous with natural environment; to a sociologist it means only social envirnoment; and to an anthropologist it is largely a cultural milieu. In medical geography it consists of all the physical and cultural elements which combine to from a total environment in which man and all other animate beings live together. Studies made on relationships between natural environment and human life on scientific lines, are not many. Apparently and cultural traits of people. But there is no denying the fact that man is so inexricably linked with the land he inhibits, that he cannot escape from the natural pattern existing on, above and below it. This being the case, man's health, at least in part, is determined by this very natural environment. And the natural environment can be considered as the matrix of physical, biological and related cultural circumstance surrounding man and affecting his well-being.

The agent, the host, the vectors and the reservioirs which are so closely related to human disease and hence to human health are parts of the overall geographical environment. Plant and animals of all sorts are bound together by interdependence. They cannot lead a mutually independent existance. They live in ecological balance with in the overall context of the natural environment and cultural pattern. A change in either the natural environment or the socio-cultural pattern disturbs the balance. This concept, basic in plant and animal ecological (usually related with both organic and inorganic factors, does not usually enter, the medical professional mind. They are more restricted in discussing the disease within the body **while medical geographer's stress that there is a great urgency to mo ve out of the body to understand the real geographical environment of disease by incorporating all physical, social and cultural milieu.**

Medical geographical studies have, to a large extent, to be cartographic and statistical in nature. The data available on various aspects of disease have to be plotted on map and then correlated with various geographical and cultural factors. Mapping of the distribution of disease and ill-health and the factors causing them leads to the question; why a real difference if any ? To answer this question, it is necessary to try to seek causative factors by correlating the health data with the environmental factors.

Diseases are found to be associated with sex and the age-group as well as locality. Some of them are found more in urban than in rural areas. Certain areas and countries are immune to certain diseases even if they turn out to be pandemic. Some diseases are peculiar to certain type of topography, climate, flora and fauna. Here an attempt is being made to correlate the disease leprosy with various types of factors associated with it by incorporating latest technology. viz., Remote sensing technique and statistical analysis, together with the geographer's traditiuonal tool, viz., Cartographic representation.

10.2 Tracing Physical Features by Satellite Technology

Now a days a application of remote sensing for studing physical biological and chemical parameters of public health importance like temperature, humidity, turbity, plankton, surface water and vegetation cover, has proved to be an importance tool which can directly or indirectly be used by epidemiologists and other allied researchers in public health programmes. A brief review of the studied using this technique in other types of diseases can be undertaken in order to know the importance of this technique in public health system. Courserum et al (1969) showed a correlation between the various types of plant communities in southern France and the mosquito egg and larval habits and indicated the value of that approach for mosquito control. More or less similar findings were reported by Pautou (1973). Similarly Jolivet et al (1985) on Wido islands of the republic of Korea, Pravost in eastern USA, and Maire in Canada reported on plant associations and mapping of different vegetation associated with mosquito larval habits. Barnes and Abula (1979) described the use of aerial photography and satellite multi-spectral scanner imaginery for classifying vegetation and terrains that had implicit public health and insect control significance.

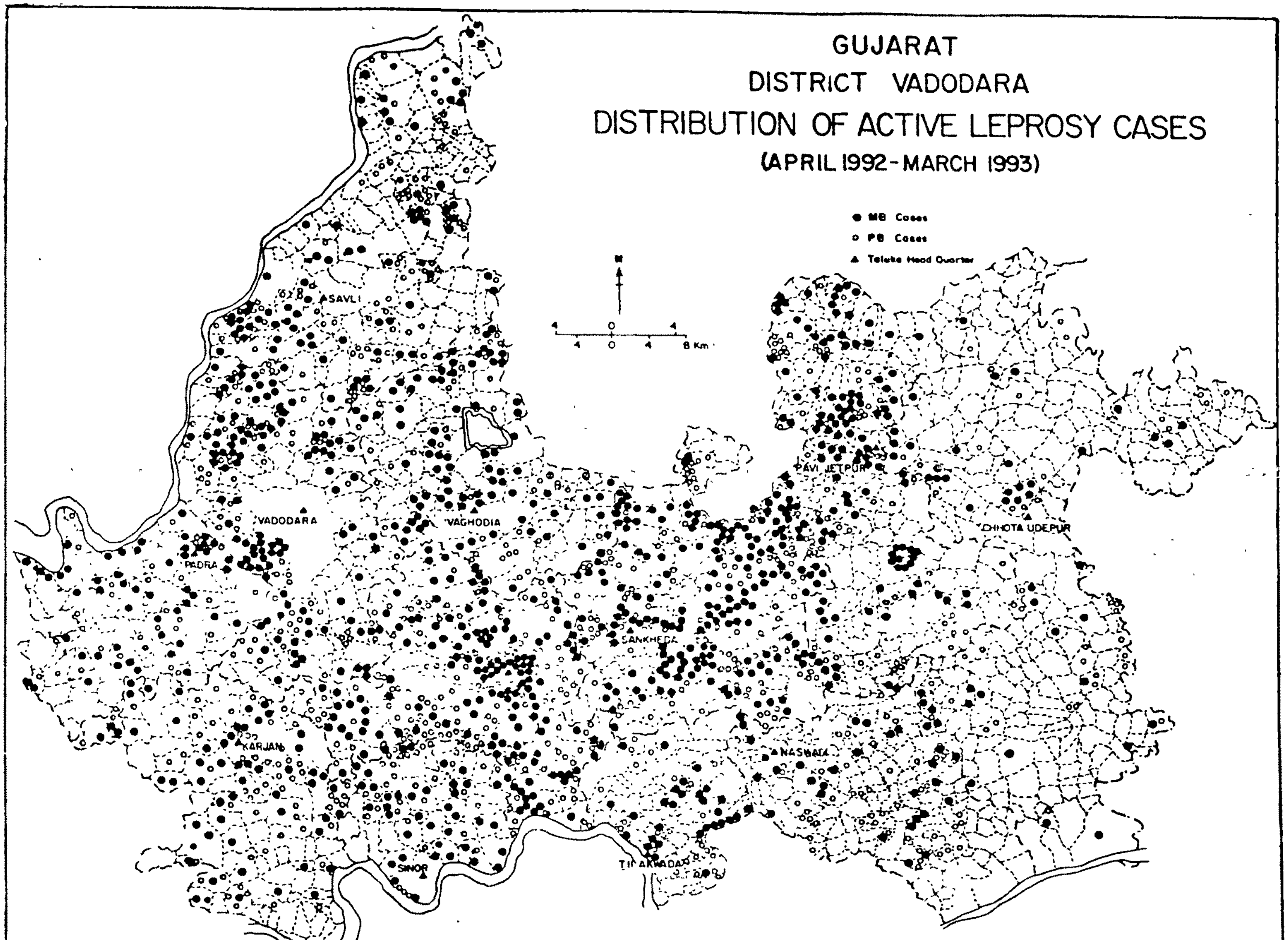
Haytel et al (1985) studied mosquito larval habitats associated with fresh water plant communities, wetland and other aquatic habitats at Lewis and Clark lakes in the state of Nebraska and south Dakota, USA, using Landsat multispectral scanner (MSS) data. They have observed wetland periodically flooded and transitional habitat classes were generally associated with mosquito breeding grounds. Moreover they have reported that additional information on soil moisture will be quite useful in locating the mosquito larval habitat. Narain et al (1989) studied malaria endimicity in Kheda district of Gujarat using satellite data. This study reveals that the monitoring of the change in landuse/landcover from satellite data can very well help in not only forecasting the malaria incidence but also in planning the control measures.

No work has been done in public health, using remote sensing technology, for identification of endemic area for leprosy. **As it is not possible to see the bacilla directly, it is necessary to approach indirectl;y through the visible part of its biological cycle or chain as the indicator of its real or potential presence in the environment (Jovanovic, 1985).** A similar type of task has been undertaken using this technology in showing the association between the natural environmental factors and the incidence and prevalence of leprosy in Vadodara district.

10.3 Preparation of Maps

A villagewise distribution map was prepared for the active cases found on 1st April 1992 to 31st March 1993 as shown in figure 10.1.

A base map of Vadodara district was prepared from the topsheets No: 46B, 46F, 46C and 46K on 1:250000 scale. This map was later superimposed on the image of multidata false colour composite satellite data (IRS-IA) (FCC as 1:1M - 9th April, 1992) by Large Format Optical Enlarger (LFOE)



GUJARAT
DISTRICT VADODARA
DISTRIBUTION OF ACTIVE LEPROSY CASES
(APRIL 1992 - MARCH 1993)
MB Cases
PB Cases
Taluka Head Quarter
N
4 0 4 8 Km
SAVLI
VADODARA
PADRA
VAGHODIA
PAVI JETPUR
CHHOTA UDEPUR
SANKHEDA
KARJAN
NASWADI
SINOR

Fig. 10·1

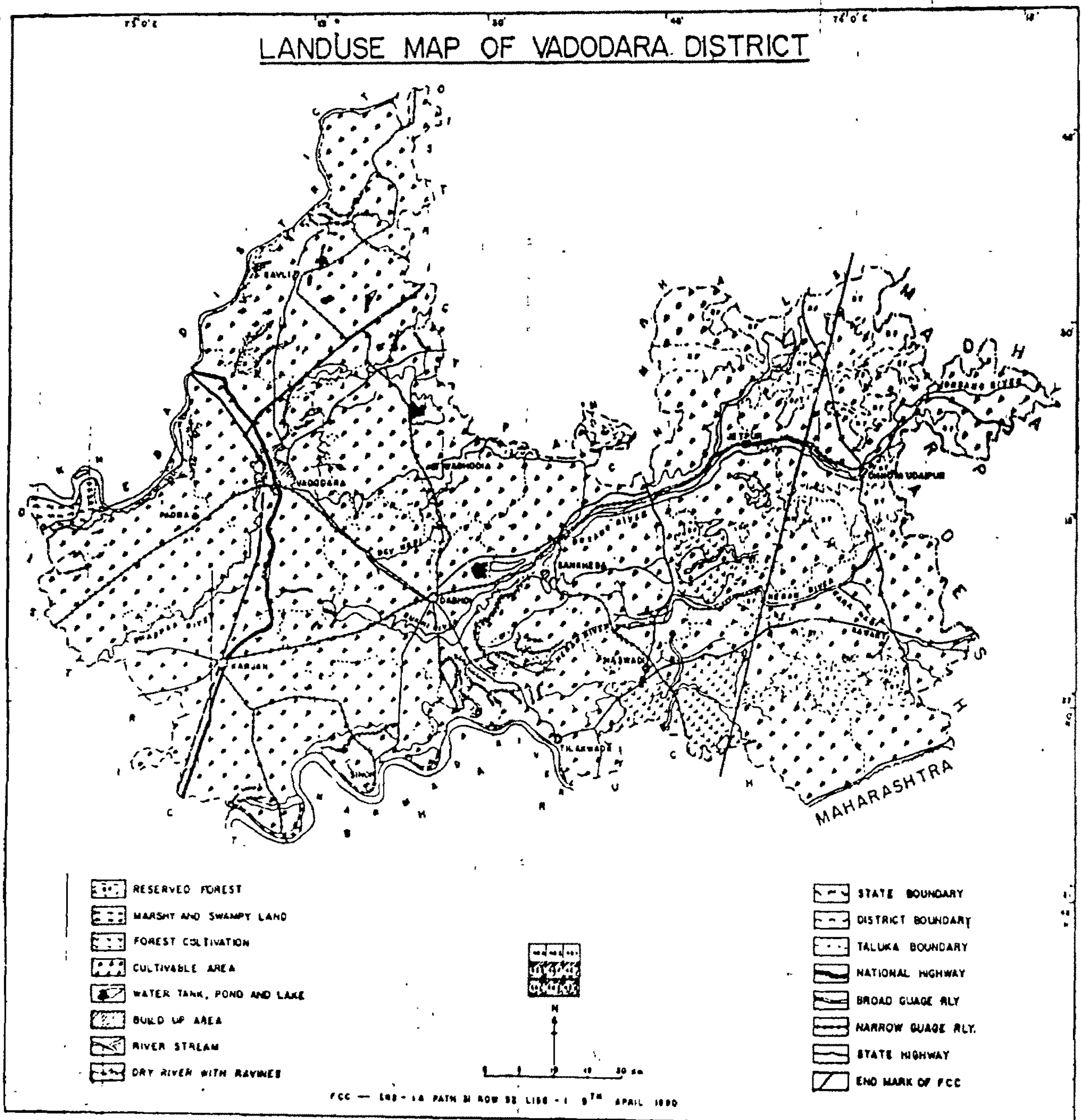

LANDUSE MAP OF VADODARA DISTRICT
MAHARASHTRA
RESERVED FOREST
MARSHY AND SWAMPY LAND
FOREST CULTIVATION
CULTIVABLE AREA
WATER TANK, POND AND LAKE
BUILD UP AREA
RIVER STREAM
DRY RIVER WITH RAVINES
STATE BOUNDARY
DISTRICT BOUNDARY
TALUKA BOUNDARY
NATIONAL HIGHWAY
BROAD GUAGE RLY
NARROW GUAGE RLY.
STATE HIGHWAY
END MARK OF FCC
N

Fig.10·2

of Vadodara district in order to produce landuse map of Vadodara district as shown in figure 10.2 which gives the dynamic ground details of Vadodara district.

A ground elevation map of Vadodara district was also prepared as shown in figure 10.3 from the above mentioned topsheets.

During the course of survey village-wise information on leprosy active cases was collected from the affected villages of Vadodara district from 1st April 1992 to 31st March 1993 at an interval of three months. Later on village-wise prevalence rate (P.R.) was calculated and four groups of PR were made by using standarad deviation method. Later these information were depicted on maps as shown in figures 7.1, 7.2, 7.3 and 7.4.

Apart from these, a village-wise population density map of Vadodara district was prepared as shown in figure 10.4. This map was based on data from the 1981 census handbook of Vadodara district.

10.4 Interpretation of Map

Based on map 10.2 and 10.3 and some secondary information obtained from the district census handbook and

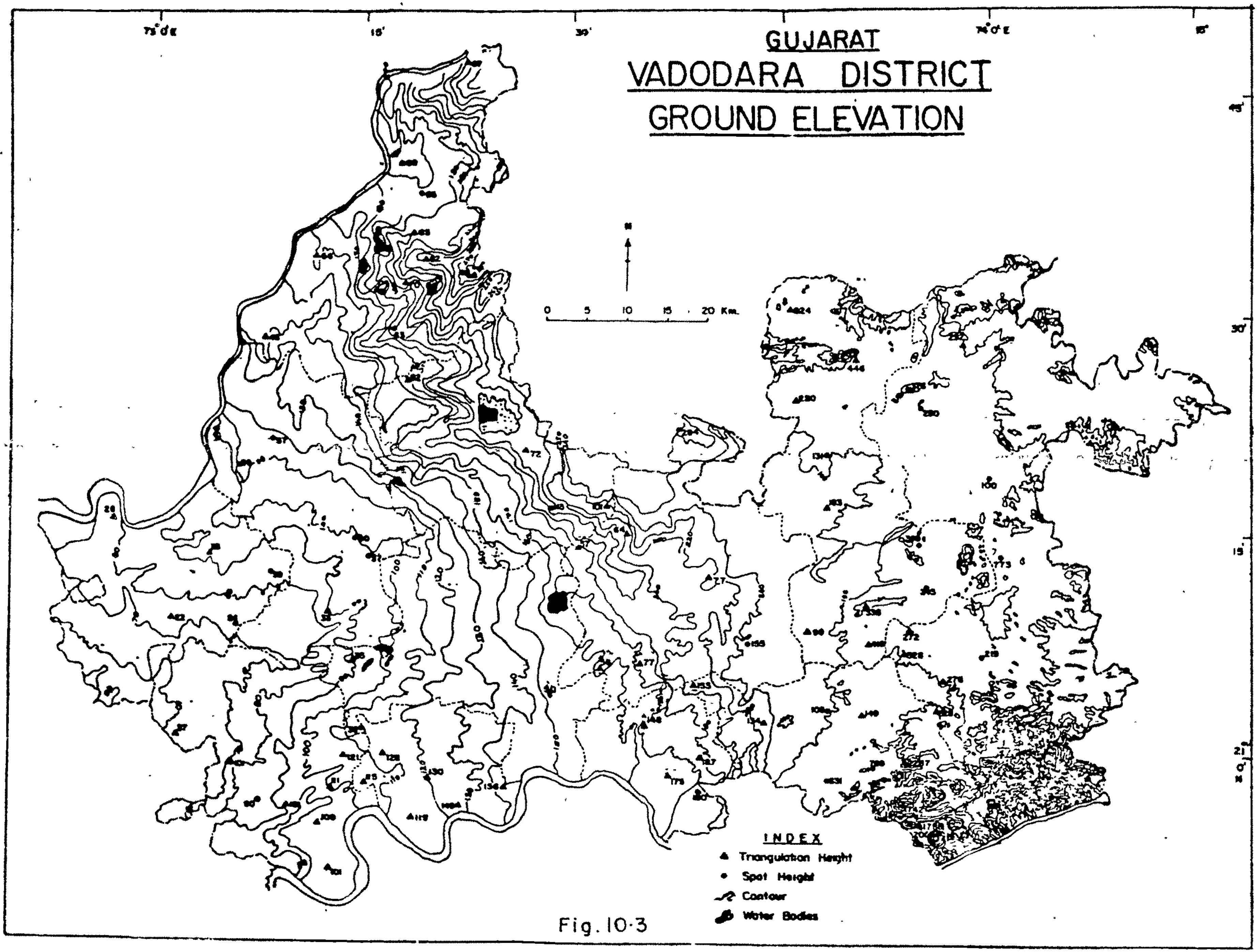

GUJARAT
VADODARA DISTRICT
GROUND ELEVATION
73°0'E
15'
30'
74°0'E
45'
21°0'N
N
0 5 10 15 20 Km.
INDEX
Triangulation Height
Spot Height
Contour
Water Bodies

Fig. 10·3

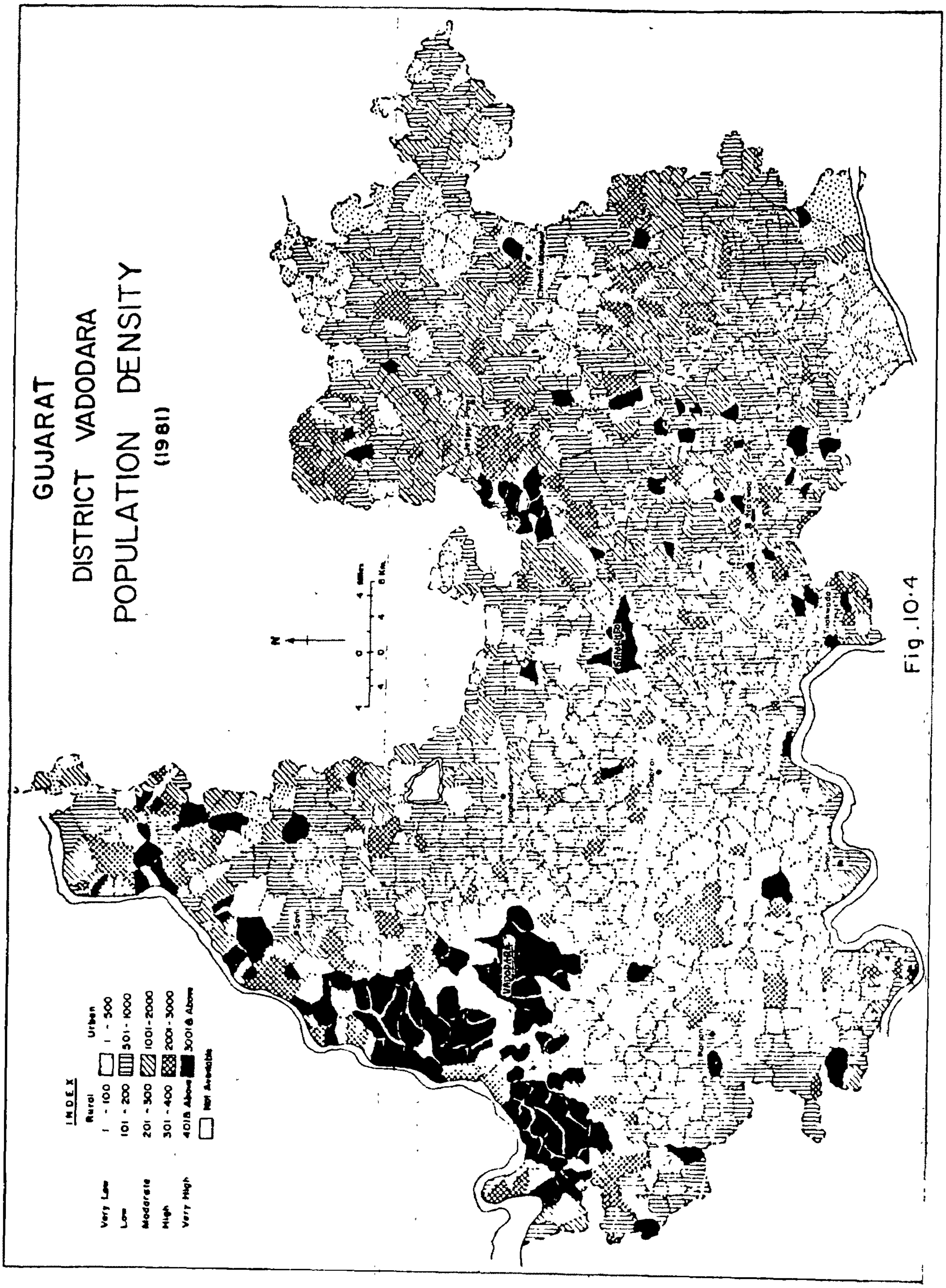

GUJARAT
DISTRICT VADODARA
POPULATION DENSITY
(1981)
INDEX
Rural
Urban
Very Low 1 - 100 1 - 500
Low 101 - 200 501 - 1000
Moderate 201 - 300 1001 - 2000
High 301 - 400 2001 - 3000
Very High 401 & Above 3001 & Above
Not Available
N
VADODARA

Fig. 10.4

depending on the height above sea level, the surface slope and the ruggdness of relief, the entire district has been divided into four physiographic units.

10.4.1 The Hills : The hills of Chhota Udepur, eastern Pavi Jetpur and southern Nasvadi are the offshoots of the Vindhyan mountains, known locally as the Vanmala hills. They are highly eroded and reduced to a number of isolated hillocks.

10.4.2 The Piedmount Zone : This is a narrow zone of intermediate relief lying approximately between 75m and 150m, contour and comprising the lower reaches of the hill slopes and upper part of the plains. Lying between the transitional belt between the hills and the plains, this presents a sloping surface and stands in sharp contrast to the flat plains. It included the eastern parts of Sankheda and Tilakwada and western parts of Pavi Jetpur and Naswadi talukas. The sloping and dissected surface of this zone does not allow much soil to be formed and retained with the result that only sandy and gravelly shallow soils are found.

10.4.3 The Plains : The plains or the Mahi-Narmada Doab are remarkably flat and are flanked by the coastal marshes in the south-west (along the Gulf of Khambhat) and a rature of slope in the east rising up sharply to the hills. They appears as tectonic depressions filled with alluvium. They include the talukas of Savli, Padra, Vadodara, Dabhoi, Karjan, Vaghodia, Sinor, West Sankheda and West Tilakwada. At its widest, it is 125 km from Padra to Sankheda.

10.4.4 The Badlands : The stretch of land along the rivers Narmada, Orsang, Dhadhar, Mahi, Viswamitri, Jambuva, Bhukhi, Mesri, Goma, Khar, Heran, unch Sukhi and Men has been subjected to deep and extensive gully erosion which has given rise to be varigated ravines (Kotar). They are marked by suggedness of relief and steady increase through headward erosion. The depths of the raviness may sometimes range between 5 and 25 metres. They can be seen on either side of the river in their plain reaches.

10.4.5 Drainage : Figure 10.2 & 10.3 give the details of drainage. Three major river-systems drain the district. They are Narmada in the south, Mahi in the north and

Dhadhar in-between. All the other rivers form part of one or the other of these river systems. Narmada, forming and southerns boundary of the district is entrenched in a rift valley and forms an estuary at the confluence with the Gulf of Khambhat. The Dhadhar system of rivers almost dry out during the summer seasons. The other two systems also carry very little water during the dry season.

From Figure 10.1 it was found that the major part of the district is affected by the disease leprosy. Both types of patterns of distribution of the disease, viz., clustered and scattered, are observed with-in the district. In order to know the significance of the distribution of the disease with physical features Map 10.1 is superimposed on Map 10.2 and 10.3 or By visual intrepretation it was found that the highest percentage of active leprosy cases (76%) are found in the plains and rest are distributed in the peidmont zone (16%) and the hills (8%). It is quite amazing to note that among the cases found in the plains, 70% are from those village areas which are located beside rivers or water bodies as shown in appendix-6. Thus the final picture of the distribution of active leprosy cases according to physical features is shown in Table 10.1.

Table 10.1 : Distribution of cases according to physical features.

Sr.No.	Physical Features	Active cases	Percentage
1.	The Hills	122	8
2.	The Piedmont zone	240	16
3.	The Plains		
	a) Beside river	812	54
	b) Other plain areas	341	22
	Total	1515	100

Thus this suggests that more than half of the leprosy active cases are found besides rivers or water bodies. Taking various parameters of the disease it is now possible to group them in the above mentioned physical setting (See appendix 7, 8.1 & 8.2) by differentiating the conditions along water bodies and those elsewhere in the district. The summary of the picture that emerges is shown in Table 10.2.

From table 10.2 it is evident that riverine areas cover 32% the total area of the district in which 23% of the population resides in 30% of the villages and 48% of Urban areas. The calculated rates of various parameter of leprosy shows that prevalance and incidence rates are greater besides rivers as compared to the total district position, while MB and new MB detection rates are almost the same besides river and in the total district.

Table 10.2: Basic information on Area, Population and Leprosy in Vadodara district.

Sr. No.		Total District	Beside river Actual	Beside river % of total district
1.	Total Area (Sq. Km)	7794	2475.4	32
2.	Total Population	2543783	595501	23
3.	Total a) Villages	1655	482	29
	b) Town	19	7	37
4.	Leprosy affected a) Village	818	243	30
	b) Towns	15	7	48
5.	Total Active Cases (No.)	1515	812	54
6.	Prevalence Rate/10000 pop.	5.9	13.6	Greater
7.	New Active Cases (No.)	1410	709	50
8.	Incidence Rate/10000 pop.	5.5	12.0	Greater
9.	Total MB cases (No.)	911	454	50
10.	MB cases Rate/100 total cases	60.1	56.0	Almost equali
11.	New MB detection (No.)	403	199	49
12.	New MB detection Rate (per 100 new cases)	28.6	28.0	Almost equali

Thus this technique (RST) if applied in different seasons can help to identify presence of water bodies in different points of time and can thereby more accurately locate the constant sources of spread of infection. Unfortunately, satellite imageries for all the time periods under study could not be availabe as a result of which more detailed seasional analysis could not be attempted. Therefore, to further substantiate the findings, other physical factors such as climate, soil and vegetation conditions of these areas have also been investigated.

10.5 Climate :

The district enjoys a semi-humid tropical monsoonal type of climate, characterized by seasonal rainfall brought by the south-west monsoon during the period mid-June to september. A hot dry summer before and cool dry winter season after the monsoon, are the other features (Sinha 1992). An analysis of the data of temperature, rainfall and humidity for eight years (1985-92) has been attempted here to probe into their relationship with the incidence of leprosy during the study period.

From Figure 10.5 it is quite clear that the period from March to middle of June coinciding with the summer months is one of continous increase in temperatures. Here annual avereage or maximum and minimum temperature along with rainfall was taken from 1985-1992. The temperature (See Appendix - 9) during this season may reach its peak 42° C - 44° C mark. After that the temperature starts dropping with the onset of the monsoon by middle of June. But, it starts rising again with the withdrawal of the monsoon by the end of September and October, and may show the second maximum of day temperature, though night temprature continues the downward trend. During the past eight years the highest temperature recorded in the month of May was 44° C and the lowest in the month of December was 5.6° C.

During the past eight years the average annual rainfall (See Appendix - 10) in the district was 84.7 cm varying between 47.6 cm to 108.1 cm. About 95 percent of this is received during the south-west monsoon period from June to September July being the rainiest month. Most of the rains of this period are associated with the depression from the southern part of the Arabian sea, moving west or south-westward towards Gujarat. Consequently there is more

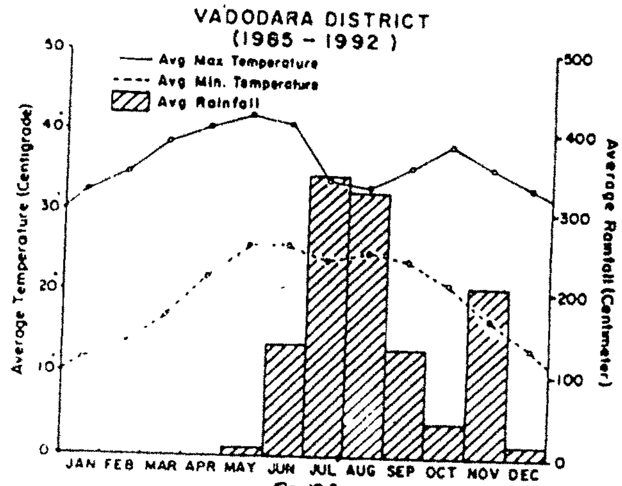


Fig 10 5

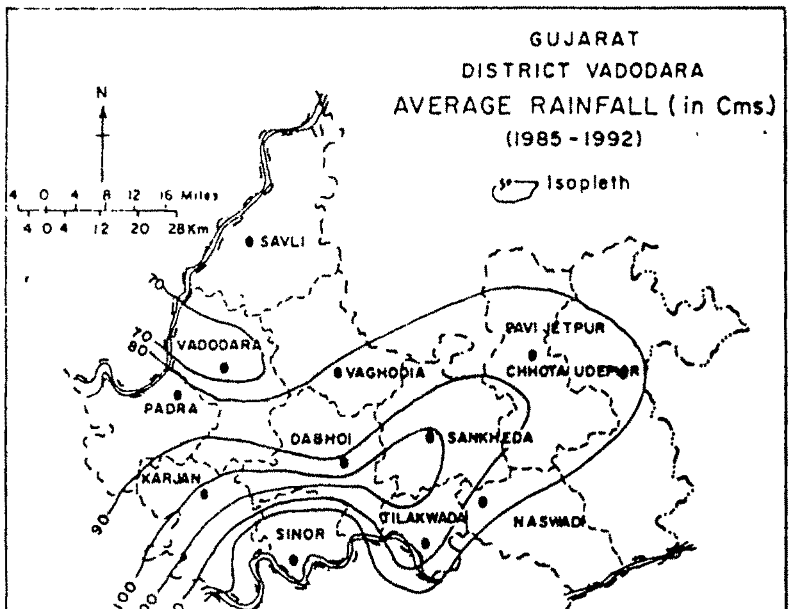


Fig 10 6

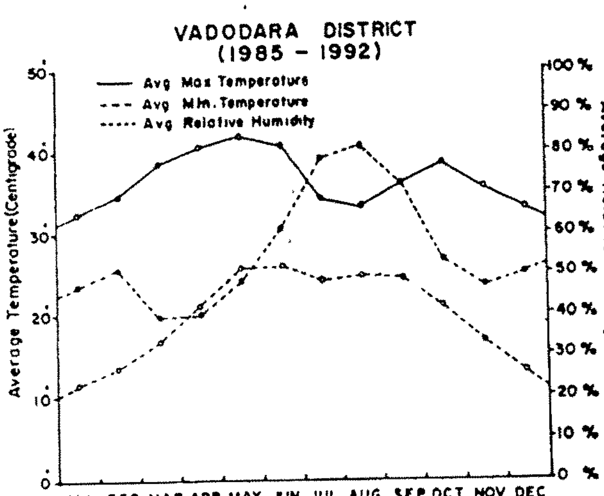


Fig 10 7

rainfall in the southern talukas (Karjan, Naswadi, Sinor, Tilakwada, etc.) of the district and also in the hilly areas of Naswadi, Chhota Udepur and Pavi-Jetpur. The amount gradually decreases from south-west towards the northern side as shown in Figure 10.6.

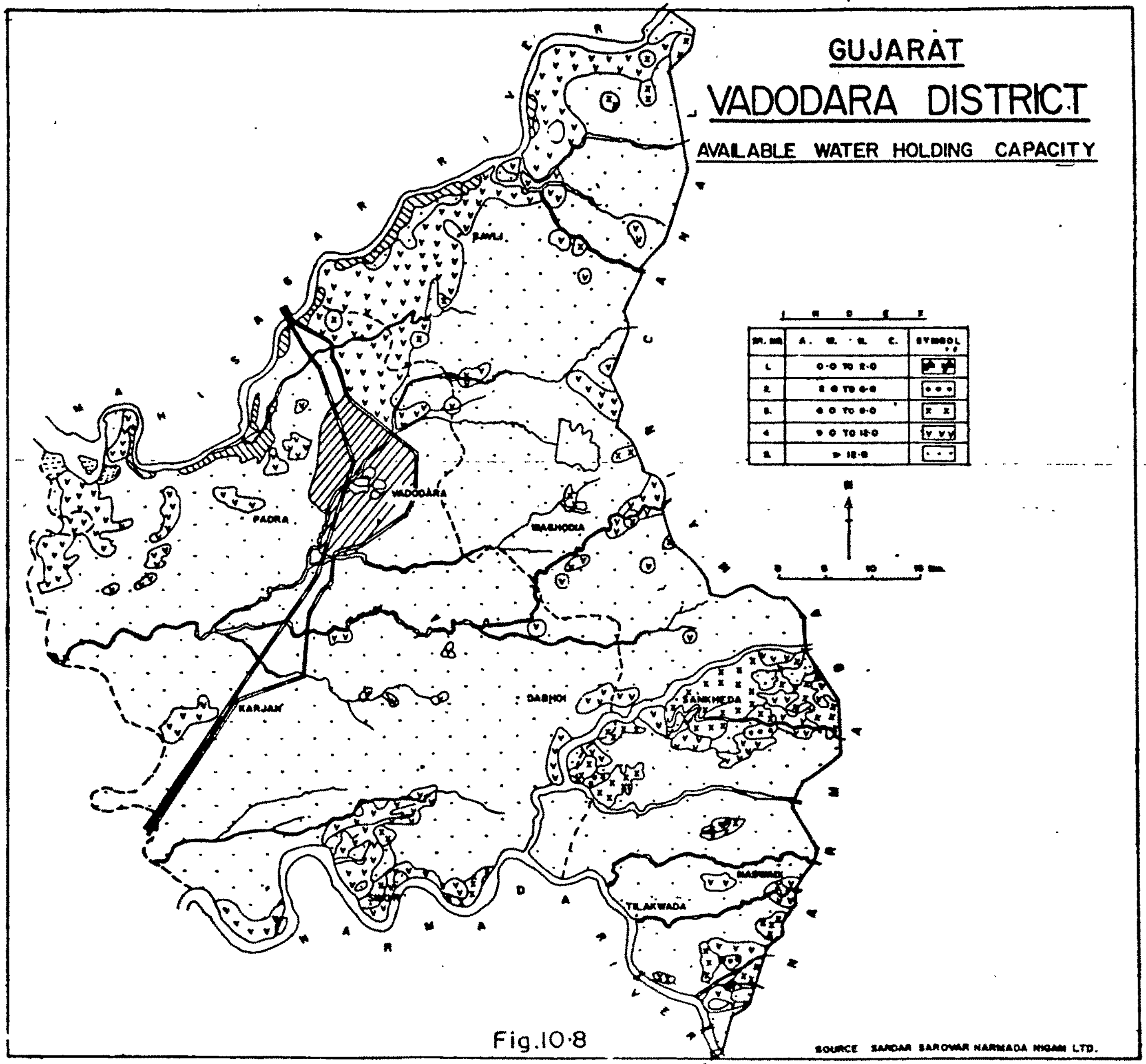
Figure 10.7 shows average relative humidity (See Appendix - 11) along with the maximum and minimum temperature. It is high during the south-west monsoon period when it may exceed 80%. The remaining part of the year experience dry air. The period between February to April is the driest part of the year when the relative humidity may go down to 40% or below it in the afternoon session of the day.

10.6 Soil :

It is an important ingredient which, along with moisture offers a great possibility for the leprosy bacilla to survive. Soils of the district vary with the nature of the underlying rock, relief and drainage. In the eastern hilly region, the soils are mostly altered residuals of metamorphic and basaltic rocks. The soil derived from the basaltic rocks are black and fertile. The foothill zone also has shallow black soil. The plains of the Mahi-Narmada doab have alluvial soil in the river flood plains and sedimentry on the higher grounds. The river Vishwamitri is a dividing line between red loams in the north and black soils of the south. The red soils are light and sandy loams while the black soils are heavier clayey loams generally exhibiting shrinkage when dry and swelling when wet. Both these soils are quite fertile. The northern part of this sector is more sandy and its appearence is yellowish grey. Consequently greater gully erosion and dissections has taken place in this soil. The soils of the western part of the doab share the properties of both the red sandy loam of north and the black soil of the south. This is a lowland after faced with problem of drainage and the area is less fertile.

But since leprosy is found everywhere the type of soil is less important compared to the availability of water holding capacity and sub-soil permeability. Figure 10.8 and 10.9 shows the avaliability of water-holding capacity (A.W.H.C) of the soil and sub-surface permeabilty (S.S.P.) of the soils of Vadodara district.

(Note : Both the maps, figures 10.8 & 10.9 are taken from the Sardar Sarovar Narmada Nigam Ltd. The eastern area of



GUJARAT
VADODARA DISTRICT
AVAILABLE WATER HOLDING CAPACITY
INDEX
SR. NO. | A. W. H. C. | SYMBOL
1. | 0·0 TO 2·0
2. | 2·0 TO 6·0
3. | 6·0 TO 9·0
4 | 9·0 TO 12·0
5. | > 12·0
N
0 5 10 15 Km.
SAVLI
PADRA
VADODARA
WAGHODIA
KARJAN
DABHOI
SANKHEDA
NASWADI
TILAKWADA
SOURCE SARDAR SAROVAR NARMADA NIGAM LTD.

Fig.10·8

Naswadi, the entire Pavi Jetpur and Chhota Udaipur talukas do not fall under their command area, so the details of these areas are not included. Hence the few leprosy cases emerging from these areas have been ignored in the analysis of A.W.H.C and S.S.P. as they account for only 14% of the total cases.

Figure 10.8 shows the soil grouping based on available water holding capacity (A.W.H.C.) of soil computed from soil texture data at 90 cm depth. From this figure it can be seen that a large area has soil with adequate water holding capacity. When compared with the disease distribution maps (Figure 10.1) the picture that emerges is summarised in table 10.3.

Table 10.3 : Association between number of leprosy cases and soil groups classified by A.W.H.C. at the depth of 90 cm.

Class	A.W.H.C in %	Total No. of cases			Percentage of	
		MB cases	PB cases	Total cases	Cases	Area covered
1.	0.0 to 2.0	-	-	-	-	-
2.	2.0 to 6.0	16	8	24	2	1.8
3.	6.0 to 9.0	52	26	78	6	2.2
4.	9.0 to 12.0	280	211	491	38	11.0
5.	> 12.0	425	284	709	54	85.0
	Total	773	529	1302	100	100.0

Note : Cases from the talukas of Pavi-Jetpur, Chhota Udepur and South-eastern area of Naswadi Taluka are excluded.

The percentage of leprosy cases was highest where the percentage of availability of water holding capacity is the highest. Also, there is a positive relationship between the extent of area covered by the groups of soils with varying water holding capacity and the distribution of leprosy cases (Figure 10.10). It is evident that the largest number of leprosy cases come from areas where the water holding capacity of the soil is high. These soils extend over 85% of the area under study and coincide with the areas that account for more than 50% of the total leprosy cases.

Figure 10.9 shows the classification of soils according to sub-surface permeability (S.S.P) or rate of intake of water in terms of cm/hr. From the figures it can be seen that larger percentage of area falls in very slow (4) and moderate (1) group of S.S.P. when compared with disease distribution map, i.e., figure 39, the number of leprosy cases, after analysis in the various class of S.S.P is shown in table 10.4

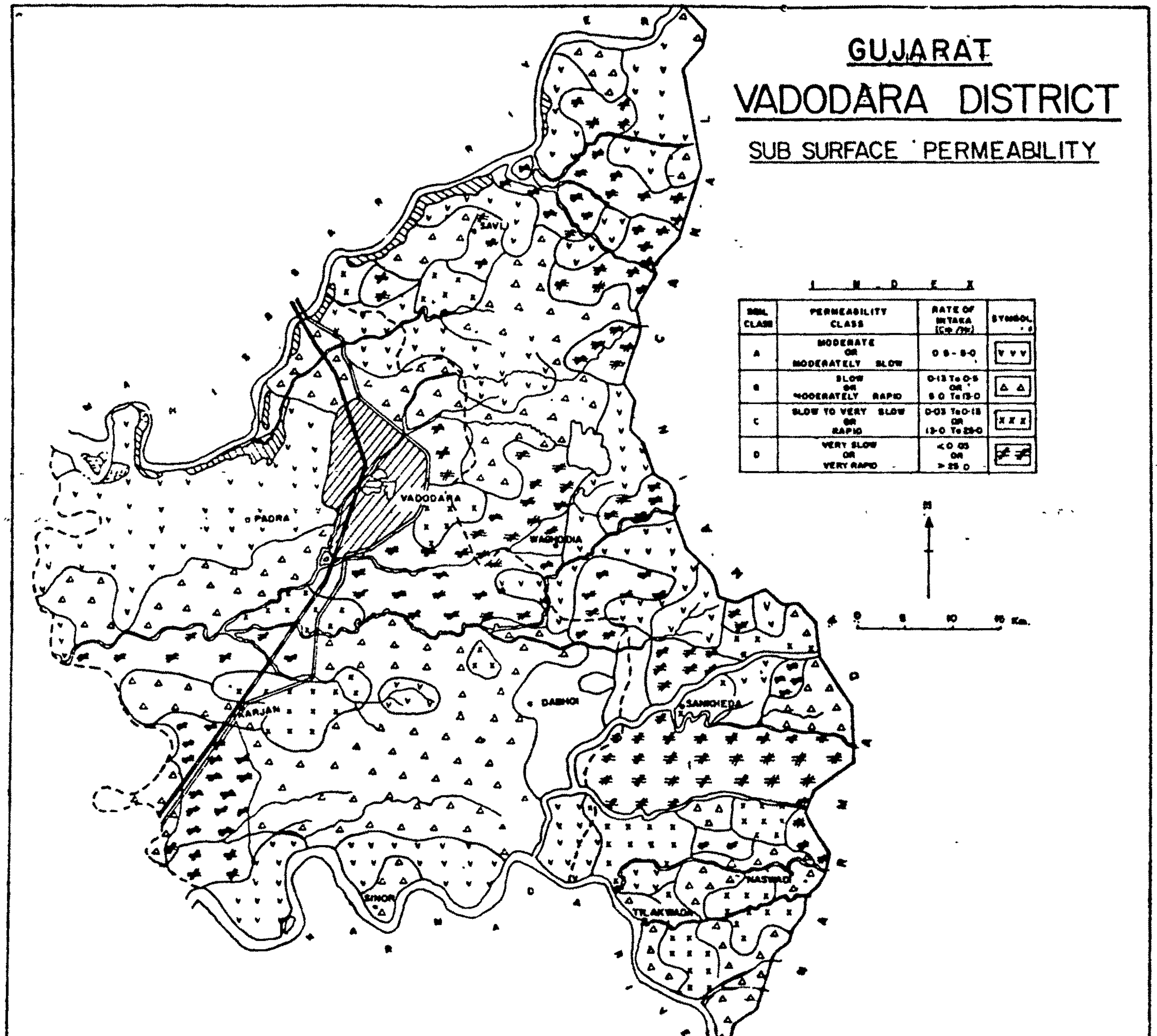


Fig.10.9

SOURCE SARDAR SAROVAR NARMADA NIGAM LTD

Table 10.4 : Association oetween number of leprosy cases and soil groups classified by S.S.P at the depth 90 cm/hr.

Group	Permeability class	Rate of intake cm/hr	Leprosy MB	PB	cases Tot	Percentage of Cases	Area
1.	Moderate/Moderate slow	0.5 - 0.5	284	191	475	36	33
2.	Slow/ Moderately Rapid	0.13 - 0.5 or 5.0 - 13.0	140	88	228	18	20
3.	Slow to very slow/ Rapid	0.03 - 0.13 or 13.0 - 25.0	38	42	80	6	7
4.	Very slow/Very Rapid	< 0.03 or > 25.0	311	208	519	40	40
	Total		773	529	1302	100	100

Note : Cases from talukas of Pavi-Jetpur, Chhota Udepur and South eastern part of Naswadi taluka had been excluded.

It shows that percentage of leprosy cases is highest where the sub-surface permeability is very slow. Since moisture holding capacity and sub-surface permeability of soils are inversely porportionate, the coincedence of these two parameters of the soil and the porportion of leprosy cases emerging from such areas are clearly evident. A comparision of the two maps (Figure 10.8 & 10.9) shows that the areas having soil with maximum water-holding capacity are those where the sub-surface permeability mostly ranges between very slow to slow.

The overall conclusion that may be drawn is that the moisture of the soil of an area will be more where the premeability of the soil is less and water holding capacity is more. Such a situation helps the leprosy bacilla to survive and thus the number of leprosy cases emerging from these area will be more.

10.7 Quarterly Variation :

As already discussed Vadodara has semi-humid tropical monsoonal type of climate. From figure 10.11a it is quite evident that the number of cases from June-Sept 1992 shows an increasing pattern from all aspects viz. total active cases, New active cases, MB cases and new MB cases but later decrease at the end of the year till March 1993, i.e. with the begining of monsoon when temperature starts falling and humidity goes on increasing (Refer figure 10.5 & 10.6) there is a sharp increase of number of leprosy cases. A very similar type of pattern is also observed in the leprosy cases of the villages found beside rivers as

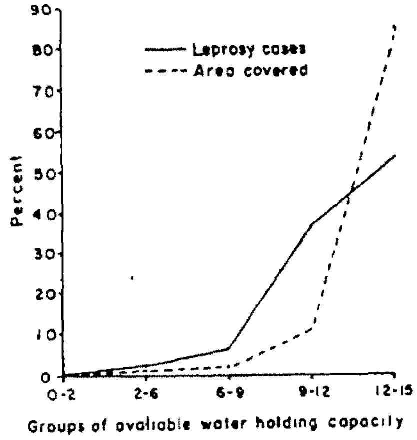


Fig 10 10

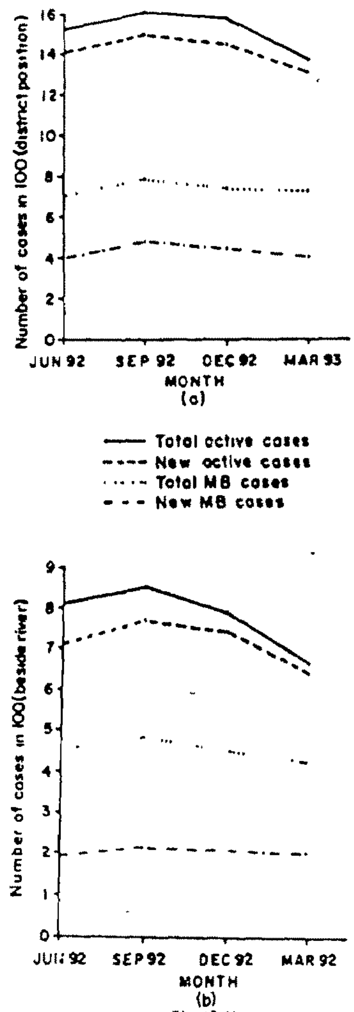


Fig 10 11

shown in Figure 10.11b. Thus there is a possibility that baccilla of leprosy can survive in semi-humid tropical monsoonal type of climate.

Although there is no apparent significant difference in the number of cases occuring at different times in a year, if the percentage variation between the expected and observed cases is taken, it is observed that the total number of new cases and the number of new MB cases are much more than expected during the period June to December, i.e., the time coinciding with the monsoon and immediate post-monsoon period when the humidity is high and the water content in the soil is also high. These variation from the expected values (Table 10.5) are less in the areas along the rivers. This is probably because the moist conditions are available throughout the year near these water bodies as a result of which a large number of new cases emerging throughout the year in such areas as shown in Figure 10.12. Besides, during the rainy seasons, villages near rivers become inaccessible due to floods. Hence there is likely to be under-reporting.

Further it may be noted here, that the expected values have been obtained by computing the average of the number

Table 10.5 : Number of leprosy cases reported at the end of Quarter of the year & their variation (%) from the expected cases

Quater Ending	Totel No. of cases (1)	New cases From col.(1) (2)	New cases expected (3)	% of deviation of col. (4)	Total No. of of MB cases from (1) (5)	New MB cases fro col. (2) (6)	Diff. bet. New MB cases obs. & expe. (7)	% of Deviation of col. (8)
District position								
30th June 1992	1515	1410	-9	-0.6 %	911	403	-35	-7.9 %
30th Sept 1992	1624	1498	+79	+5.6 %	986	482	+44	+10.0 %
31st Dec. 1992	1594	1456	+37	+2.6 %	946	455	+17	+3.8 %
31st March 1993	1375	1312	-107	-7.5 %	839	411	-27	-6.2 %
Total		5676				1751		
Average		1419				438		
Beside River								
30th June 1992	812	709	-9	-1.2 %	454	199	-9	-4.3 %
30th Sept 1992	855	772	+54	+7.5 %	481	216	+8	+3.8 %
31st Dec. 1992	797	749	+31	+4.3 %	452	211	+3	+1.4 %
31st March 1993	665	642	-76	-10.6 %	428	206	-2	-1.0 %
Total		2872				832		
Average		718				208		

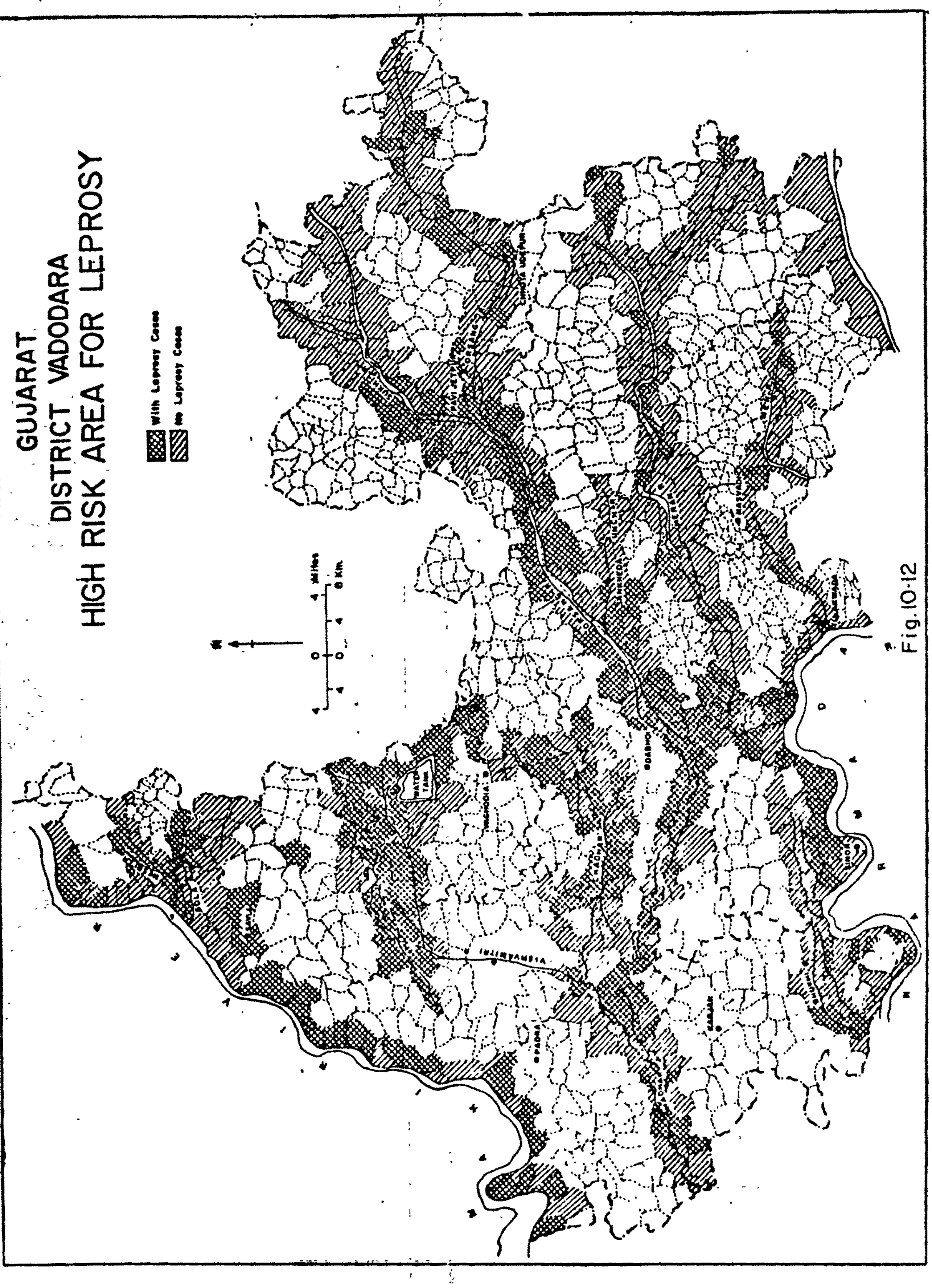

GUJARAT
DISTRICT VADODARA
HIGH RISK AREA FOR LEPROSY
With Leprosy Cases
No Leprosy Cases
WATER TANK

Fig.10.12

of cases noted in each of the four time periods.

10.7.1 Limitation :

Although positive conclusions cannot be drawn by the results of only one year's data, it indicates a possible link that needs to be investegated over a longer period of time of atleast a decade. Besides, atmospheric humidity data was not available at the micro level as a result of which indirect inference had to be made. However, if the association noted here are accepted, it would clearly be possible to forecast the areas and the seasons when leprosy is likely to occur, and adequate preventive steps can therefore be taken (as will be discussed in chapter-15).

10.8 Hypothesis 5 :

Humidity is not the major climatic element related to the prevalence rate of leprosy.

Step 1 : In order to find relationship of climatic element (Viz., Rainfall Temperature and Relative Humidity, partial correlation coeffiecient method is used.

a) In order to find relation between prevalence rate and rainfall keeping temperature and Relative humidity constant, the following formula are used :-

$$r_{12.34} = \frac{r_{12.3} - r_{13.4} \times r_{23.4}}{\sqrt{(1 - r^2_{13.4})(1 - r^2_{23.4})}} \quad \ldots. \text{(A)}$$

Now in order to find $r_{12.3}$, $r_{13.4}$ and $r_{23.4}$, the following formula is used :-

$$r_{12.3} = \frac{r_{12} - r_{13} \times r_{23}}{\sqrt{(1 - r^2_{13})(1 - r^2_{23})}} \quad \ldots. \text{(a1)}$$

$$r_{13.4} = \frac{r_{13} - r_{14} \times r_{34}}{\sqrt{(1 - r^2_{14})(1 - r^2_{34})}} \quad \ldots. \text{(a2)}$$

$$r_{23.4} = \frac{r_{23} - r_{24} \times r_{34}}{\sqrt{(1 - r^2_{24})(1 - r^2_{34})}} \quad \ldots. \text{(a3)}$$

Now in order to find r_{12} the following formula is used :-

$$r_{12} = \frac{\Sigma X_1X_2 - \frac{\Sigma X_1 \Sigma X_2}{n}}{\sqrt{\left((\Sigma X^2_1) - \frac{(\Sigma X_1)^2}{n}\right)\left((\Sigma X^2_2) - \frac{(\Sigma X_2)^2}{n}\right)}} \quad \ldots. \text{(1)}$$

As r_{12} is calculated, simillarly, r_{13}, r_{23}, r_{14}, r_{34} and r_{24} can be calculated by the same formula used for r_{12}.

(Note : r_{12} is same as r_{21} and similar is same for r_{13}, r_{23} ... etc.)

b) In order to find relation in between prevalence rate and temperature, keeping rainfall and humidity (Relative) constant, the following formula is used :-

$$r_{13.24} = \frac{r_{13.2} - r_{12.4} \times r_{23.4}}{\sqrt{(1 - r^2_{12.4})(1 - r^2_{23.4})}} \quad .... \text{(B)}$$

Now in order to find $r_{13.2}$, $r_{12.4}$ and $r_{23.4}$, the following formula is used :

$$r_{13.2} = \frac{r_{13} - r_{12} \times r_{32}}{\sqrt{(1 - r^2_{12})(1 - r^2_{32})}} \quad .... \text{(b1)}$$

$$r_{12.4} = \frac{r_{12} - r_{24} \times r_{14}}{\sqrt{(1 - r^2_{14})(1 - r^2_{24})}} \quad .... \text{(b2)}$$

$$r_{23.4} = \frac{r_{23} - r_{24} \times r_{34}}{\sqrt{(1 - r^2_{24})(1 - r^2_{34})}} \quad .... \text{(b3)}$$

c) In order to find relation in between prevalence rate and Relative humidity keeping Rainfall and Temeprature constant, the following formula is used :-

$$r_{14.23} = \frac{r_{14.3} - r_{12.3} \times r_{42.3}}{\sqrt{(1 - r^2_{12.3})(1 - r^2_{42.3})}} \quad .... \text{(C)}$$

Now in order to find $r_{14.3}$, $r_{12.3}$ and $r_{42.3}$, the following formula is used :

$$r_{14.3} = \frac{r_{14} - r_{13} \times r_{43}}{\sqrt{(1 - r^2_{13})(1 - r^2_{34})}} \quad .... \text{(c1)}$$

$$r_{12.3} = \frac{r_{12} - r_{13} \times r_{23}}{\sqrt{(1 - r^2_{13})(1 - r^2_{23})}} \quad .... \text{(c2)}$$

$$r_{42.3} = \frac{r_{42} - r_{43} \times r_{23}}{\sqrt{(1 - r^2_{23})(1 - r^2_{43})}} \quad .... \text{(c3)}$$

Step 2 : Using the folowing sample table :

Year	Prevalence rate/10,000 X_1	Total Rainfall X_2	Max-Temperature in C X_3	Relative Humidity in %
1985	45.2	788.3	38.9	58
1986	38.3	570.8	38.9	50
1987	17.7	756.8	40.4	49
1988	10.0	1292.4	38.3	57
1989	7.9	1125.9	34.1	55
1990	6.4	1595.0	33.9	60
1991	5.8	990.0	34.5	56
1992	4.7	961.6	33.8	58
Total	136.0	8080.8	292.8	443

Let Prevalence rate $= X_1$, Rainfall $= X_2$, Max-Temperature $= X_3$

Relative Humidity $= X_4$ and $n = 8$.

Let $\Sigma X_1 = 136$, $\Sigma X_2 = 8080.8$, $\Sigma X_3 = 292.8$ and $\Sigma X_4 = 443$.

Testing Hypothesis (H_0) : Humidity is not the major climatic element related to prevalence rate of leprosy.

Alternative Hypothesis (H_1) : Humidity is not the major climatic element related to prevalence rate of leprosy.

Step 3 : Critical

If $r_{14.23} > r_{13.24}$ and $r_{14.23} > r_{12.34}$

Accept the alternative Hypothesis (H_1) OR

If $r_{14.23} > r_{13.24}$ and $r_{14.23} < r_{12.34}$

OR

If $r_{14.23} < r_{13.24}$ and $r_{14.23} > r_{12.34}$

OR

If $r_{14.23} < r_{13.24}$ and $r_{14.23} < r_{12.34}$

Accept the Hypothesis (H_0)

Step 4: Calculation

Year	x^2_1	x^2_2	x^2_3	x^2_4
1985	2043.04	621416.89	1513.21	3364
1986	1466.89	325812.64	1513.21	2500
1987	313.29	572746.24	1632.16	2401
1988	100.00	1670297.76	1466.89	3249
1989	62.41	1267650.81	1162.81	3025
1990	40.96	2544025.00	1149.21	3600
1991	33.64	980100.00	1190.25	3136
1992	22.09	924674.56	1142.44	3364
Total	4082.32	8906723.90	10770.18	24639

Here ΣX^2_1 = 4082.32, ΣX^2_2 = 8906723.90, ΣX^2_3 = 10770.18 and ΣX^2_4 = 24639

Year	X_1X_2	X_1X_3	X_1X_4	X_2X_3	X_2X_4	X_3X_4
1985	35631.16	1758.28	2621.6	30664.87	45721.4	2256.2
1986	21861.64	1489.87	1915.0	22204.12	28540.0	1945.0
1987	13395.36	715.08	867.3	30574.72	37083.2	1979.6
1988	12924.00	383.0	570.0	49498.92	73666.8	2183.1
1989	8894.61	269.31	434.5	38362.50	61924.5	1875.5
1990	10208.0	216.96	384.0	54070.5	95700.0	2034.0
1991	5742.0	200.1	324.8	34155.0	55440.0	1932.0
1992	4519.52	158.86	272.6	32213.6	55772.8	1960.4
Total	113176 29	5191.54	7389.8	291734.23	453848.7	16165.8

ΣX_1X_2 = 113176.29, ΣX_1X_3 = 5191.54,

ΣX_1X_4 = 7389.8, ΣX_2X_3 = 291734.23,

ΣX_2X_4 = 453848.7 & ΣX_3X_4 = 16165.8

Now in order to find r_{12}, value from sample table and calculation table are substitute in formula (1) which is as follow :

$$r_{12} = \frac{\Sigma X_1 X_2 - \frac{\Sigma X_1 \Sigma X_2}{n}}{\sqrt{\left((\Sigma X_1^2)^2 - \frac{(\Sigma X_1)^2}{n}\right)\left((\Sigma X_2^2) - \frac{(\Sigma X_2)^2}{n}\right)}}$$

$$= \frac{113176.29 - \frac{136 \times 8080.8}{8}}{\sqrt{\left(4082.32 - \frac{(136)^2}{8}\right)\left(8906723.9 - \frac{(8080.8)^2}{8}\right)}}$$

$= -0.666599386 \quad = -0.67$

Using the similar type of formula for r_{13}, r_{23}, r_{14}, r_{34}, and r_{24}, the following values are found for each of the following : $r_{13} = 0.70$, $r_{23} = -0.64$, $r_{14} = -0.33$, $r_{34} = -0.63$ and $r_{24} = 0.72$.

Now substituting these values in formula a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2 and c_3, the following values are found for each of the following :-

$$r_{12.3} = \frac{r_{12} - r_{13} \times r_{23}}{\sqrt{(1 - r^2_{13})(1 - r^2_{23})}}$$

$$= \frac{-0.67 - (-.70 \times -0.64)}{\sqrt{(1 - (0.70)^2)(1 - (-0.64)^2)}}$$

$= \; - \; 0.404570965$

$= \; - \; 0.41$

Similarly the other values are calculated which are as follow: $r_{13.4} = 0.68$, $r_{23.4} = -0.35$, $r_{13.2} = 0.48$, $r_{12.4} = -0.66$, $r_{23.4} = -0.35$, $r_{14.3} = 0.20$, $r_{12.3} = -0.40$ and $r_{42.3} = 0.53$.

Now putting these values in formula $r_{12.34}$, $r_{13.24}$ and $r_{14.23}$, we get the following results :-

$$r_{12.34} = \frac{r_{12.3} - r_{13.4} \times r_{23.4}}{\sqrt{(1 - r^2_{13.4})(1 - r^2_{23.4})}}$$

$$= \frac{-0.41 - (0.68 \times -0.35)}{\sqrt{(1 - (0.68)^2)(1 - (-0.35)^2)}}$$

$$= -0.250423599$$

$$r_{12.34} = -0.25$$

Similarly,

$$r_{13.24} = \frac{r_{13.2} - r_{12.4} \times r_{23.4}}{\sqrt{(1 - r^2_{13.4})(1 - r^2_{23.4})}}$$

$$= \frac{-0.48 - (0.66 \times -0.35)}{\sqrt{(1 - (0.66)^2)(1 - (-0.35)^2)}}$$

$$= 0.353819921$$

$$r_{13.24} = 0.36$$

$$r_{14.23} = \frac{r_{14.3} - r_{12.3} \times r_{42.3}}{\sqrt{(1 - r^2_{12.3})(1 - r^2_{42.3})}}$$

$$= \frac{-0.20 - (0.40 \times -0.53)}{\sqrt{(1 - (0.40)^2)(1 - (-0.53)^2)}}$$

$$= 0.530106254$$

$$r_{14.23} = 0.53$$

Step 5 : Conclusion

Since $0.53 > 0.36$ and $0.53 > -0.25$

i.e. $r_{14.23} > r_{13.24}$ and $r_{14.23} > r_{12.34}$

Accept the alternative Hypothesis (H_1).

i.e., Humidity is the major climatic element related to the prevalence rate of leprosy.

Humidity helps the bacilla to survive in the soil at room temperature for 46 days. Thus the humid zones, particularly near rivers, are more prone to the occurence of the disease.

10.9 Talukawise Classification :

In order to study the situation in individual talukas a similar excercise was done to enable comparision between the leprosy cases found in the total leprosy affected villages of the talukas and leprosy cases found in leprosy affected villages besides river stream or water bodies.

Figure 10.13 and 10.14 show that both the prevalence rate (P.R.) and incidence rate (I.R.) beside river in all talukas is more than the total PR and IR of each taluka. This situation is the same as that for the district as a whole as already noted.

In case of MB case rate as shown in Figure 10.15 the situation, however, is quite different. Only in three talukas, viz., Vadodara, Padra and Naswadi talukas, MB case rate of the villages beside rivers is more than the overall MB case rate of talukas but when one looks in the new MB case detection rate as shown in figure 10.16 in almost half of the talukas, viz., Vadodara, Padra, Savli, Vaghodia, Sankheda and Tilakwada, villages beside rivers

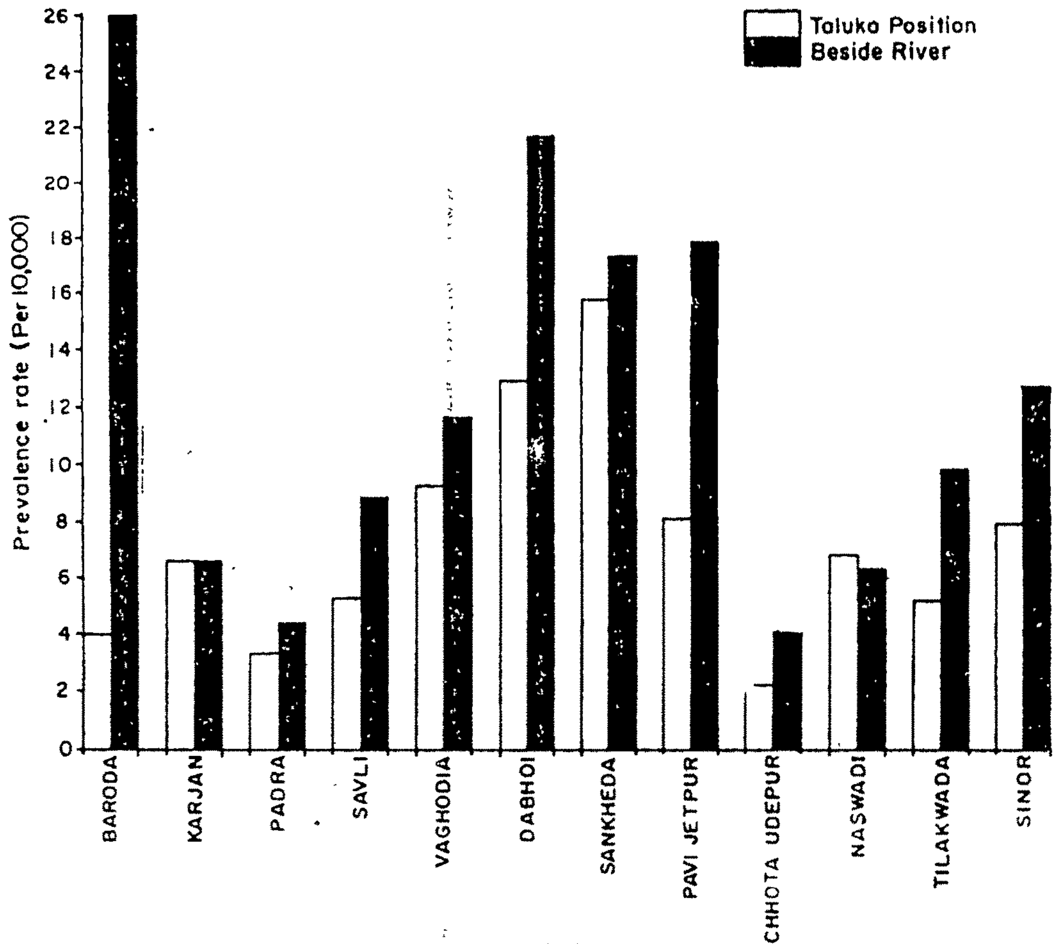


Fig. 10·13

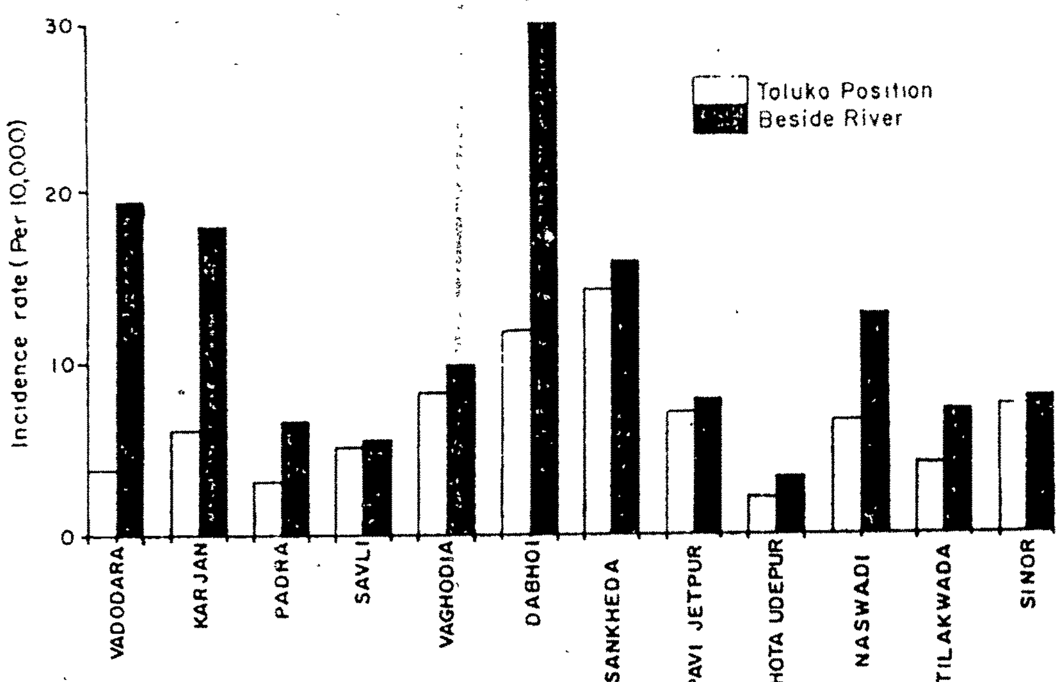


Fig. 10·14

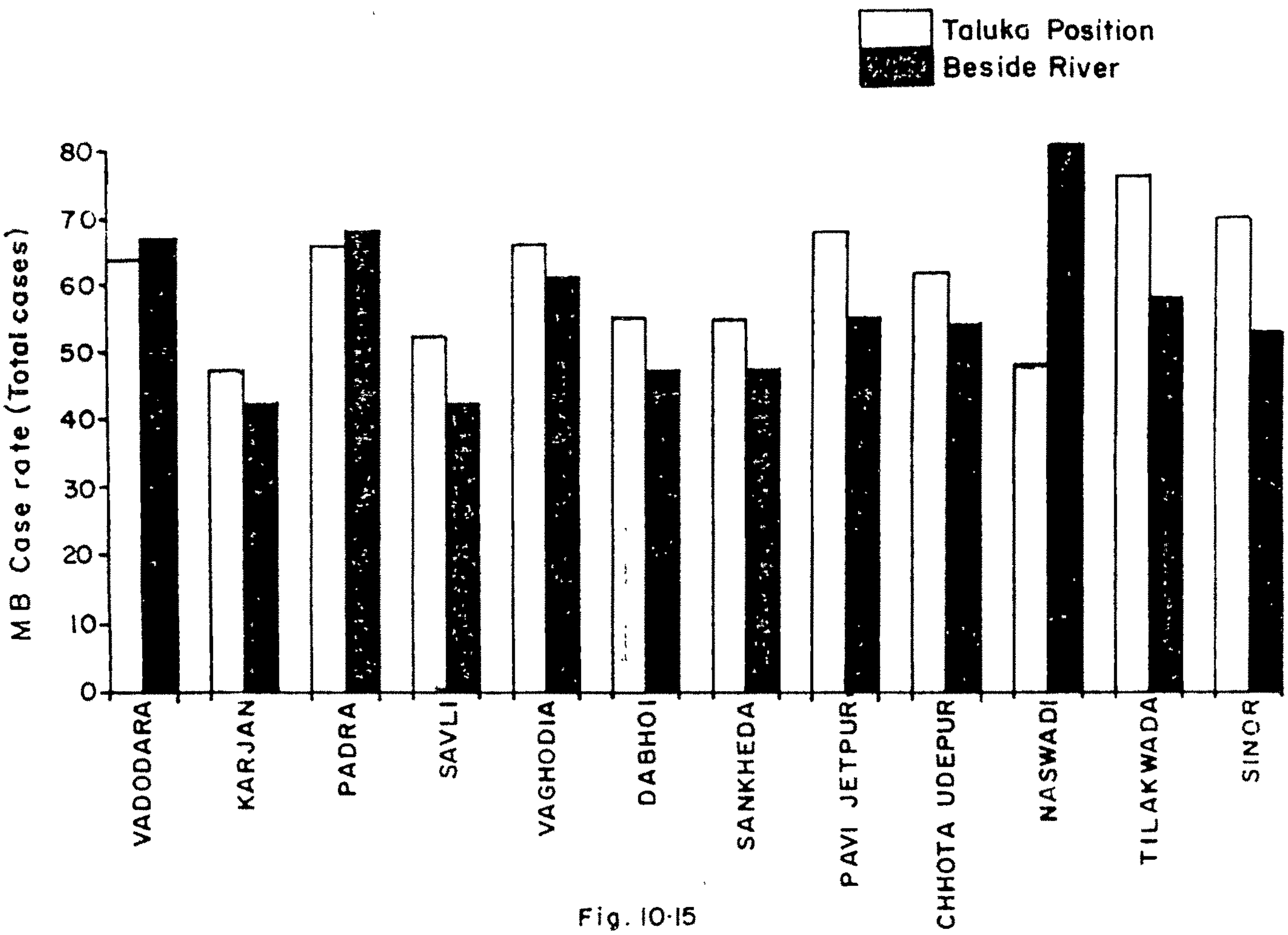


Fig. 10·15

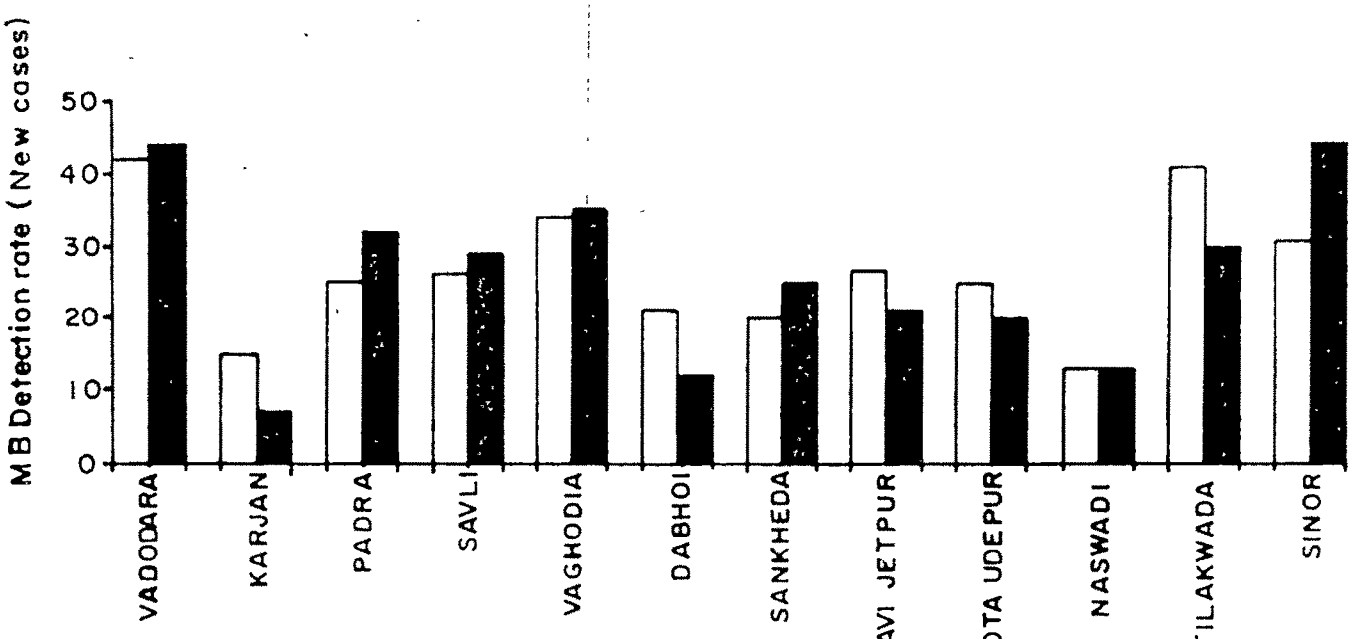


Fig. 10·16

show greater new MB case detection rate. These conflicting findings cannot be easily explained. However, it is possible, that after being detected as MB cases, many patients move out of their villages either for treatment in the hospital located in Vadodara city or in order to escape social ostracism .

10.10 Classification of Prevalence Rate :

The information on our groups (viz, low, moderate, high and very high) of prevalence rates from appendix 6.1 & 6.2 is summarized in table 10.6 from figure 7.1, 7.2, 7.3 & 7.4 the four class of prevalence rates are highlighted for the entire year at the interval of three months.

Table 10.6 : Classification of village and towns and leprosy cases found in it according to prevalence rates of Vadodara district.

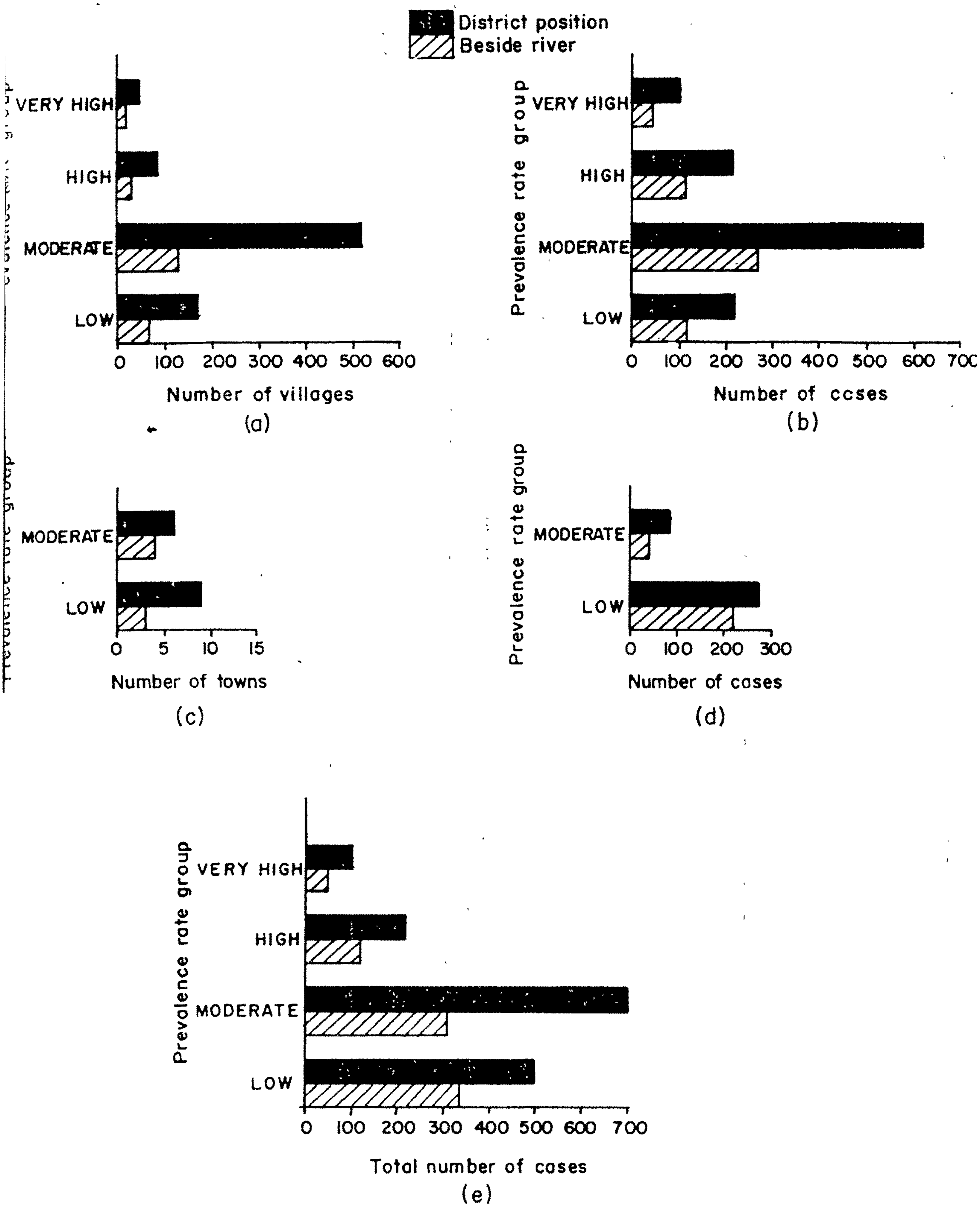
Sr. No.	P.R.Class	Villages		Towns		Village cases		Town cases		Total cases	
		DP	BR	DP	BR	DP	BR	DP	BR	DP	BR
1.	Low (No)	169	64	9	3	219	116	278	222	497	338
	(%)	21	26	60	43	19	21	76	85	33	42
2.	Moderate (No)	514	130	6	4	618	270	86	39	704	309
	(%)	63	53	40	57	54	49	24	15	46	38

Cont..

Sr. No.	P.R.Class	Villages		Towns		Village cases		Town cases		Total cases	
		DP	BR	DP	BR	DP	BR	DP	BR	DP	BR
3.	High (No)	89	32	-	-	213	119	-	-	213	119
	(%)	11	13	-	-	18	21	-	-	14	15
4.	Very High(No)	46	17	-	-	101	46	-	-	101	46
	(%)	5	8	-	-	9	9	-	-	7	5
	Total	818	243	15	7	1151	551	364	261	1515	812

Note DP - District Position, BR - Beside River.

From table 10.6 it is quite clear that in the entire district majority of villages fall in the moderate group of prevelance rate. A similar type of position is also observed in the villages beside rivers. Thus, number of cases, emerging from villages with moderate prevalence rates in the district as a whole as well as in the villages beside rivers, will be more. This is quite clear in figure 10.17a and 10.17b. From figure 10.17c and 10.17d it is evident that among towns present in the entire district, majority are found in the category of low PR while in case of the towns beside rivers, majority are in the category of moderate P.R. But reverse situation is observed as regards number of cases found in town within



District position
Beside river
VERY HIGH
HIGH
MODERATE
LOW
0 100 200 300 400 500 600
Number of villages
(a)
Prevalence rate group
VERY HIGH
HIGH
MODERATE
LOW
0 100 200 300 400 500 600 700
Number of ccses
(b)
MODERATE
LOW
0 5 10 15
Number of towns
(c)
Prevalence rate group
MODERATE
LOW
0 100 200 300
Number of cases
(d)
Prevalence rate group
VERY HIGH
HIGH
MODERATE
LOW
0 100 200 300 400 500 600 700
Total number of cases
(e)

Fig.10·17

the district as a whole and those beside rivers where majority are coming from low group.

Thus overall position of leprosy cases within the district as whole and that beside rivers shows that the majority of cases are confined between moderate to very high group of P.R. as shown in figure 10.17e.

The difference observed in the prevalence rates in areas near rivers and those in the talukas as a whole, has necessitated the testing or the significance of these differences. This has been done to prove the following hypothesis.

Hypothesis 6 : There is no significant variation in the prevalence rate (P.R.) of leprosy in the talukas as a whole and in the areas beside rivers or water bodies.

Step 1 : In order to test the above hypothesis, paired t-test method is used.

Let x = P.R. of the total village in the taluka.

y = P.R. of the total villages located besides river or water bodies in the taluka.

$d = x - y$ and $d = \bar{d} / n$ (Here n = 12)

$$S_d = \sqrt{d^2/n - (\bar{d})^2} \quad \text{and} \quad t_{cal} = \frac{\bar{d}}{S_d/\sqrt{n-1}}$$

Step 2 : At level of significance $\alpha = 5\%$

Step 3 : Sample Table.

x	y	d = x - y	d^2
3.9	26.5	-22.6	510.76
6.5	6.5	0.0	0.0
3.3	4.4	-1.1	1.21
5.2	8.8	-3.6	12.96
9.2	11.6	-2.4	5.76
12.8	21.6	-8.8	77.44
15.6	17.2	-1.6	2.56
8.1	17.7	-9.6	92.16
2.2	4.1	-1.9	3.61
6.7	6.2	+0.5	0.25
5.1	9.7	-4.6	21.16
7.8	12.5	-4.7	22.09
		Σ -60.4	Σ 749.96

Testing Hypothesis (H_0) = There is no significant variation in the prevalence rate (P.R.) of leprosy in the taluka as whole and in the areas beside rivers or water bodies.

Alternative Hypothesis (H_1) = There is much variation in the prevalence rate (P.R.) of leprosy in the taluka as whole and that beside rivers or water bodies.

Step 4 : Critical

If $t_{cal} > t_{tab}$ Reject the hypothesis (H_0)

Or

If $t_{cal} < t_{tab}$ Accept the hypothesis (H_0)

t_{tab} (12-1) at 11 degree of freedom.

Thus $t_{tab} = 2.201$ at $\alpha = 5\%$

Step 5 : Calculation

$\bar{d} = d / n = -60.4 / 12 = -5.03$

$$S_d = \sqrt{d^2/n - (d)^2} = \sqrt{\frac{749.96}{12} - (-5.03)^2} = 6.096$$

$$t_{cal} = \frac{\bar{d}}{S_d / \sqrt{n-1}} = \frac{(-5.03)\sqrt{11}}{6.096} = -2.7366$$

$|t_{cal}| = |-2.7366| = 2.7366$ ($\because$ it is two tailed test)

Step 6 : Conclusion

At 5% significance level $t_{tab} = 2.201$ and $t_{cal} = 2.7366$

Since 2.7366 $>$ 2.201

i.e. $t_{cal} > t_{tab}$ = Reject the hypothesis (H_0)

This implies that alternative hypothesis (H_1) is true, i.e., there is much variation in the prevalence rate of leprosy in the taluka as a whole and that beside rivers or water bodies.

Thus the higher number of cases found in the villages beside rivers or any water bodies, is a highly significant factor and not merely a chance occurence. The moisture of the soil of such area may be more suitable for the leprosy bacilla to survive. Hence the posibility of the occurence of leprosy cases is more in such type of villages.

Hypothesis 7 : There is no significant variation in the Incidence rate (I.R.) of leprosy in the talukas as a whole and in the areas beside rivers or water bodies.

Step 1 : In order to test the above hypothesis, paired t-test method is used.

Let x = I.R. of the total village in the taluka.

y = I.R. of the total villages located beside river or water bodies in the taluka.

$d = x - y$ and $\bar{d} = d / n$ (Here n = 12)

$$S_d = \sqrt{\frac{d^2/n - (\bar{d})^2}{n}} \text{ and } t_{cal} = \frac{\bar{d}}{S_d / \sqrt{n-1}}$$

Step 2 : At level of significance $\alpha = 5\%$

Step 3 : Sample Table.

x	y	d = x - y	d^2
3.7	19.6	-15.9	252.81
6.0	18.0	-12.0	144.0
3.0	6.5	-3.5	12.25
5.0	5.3	-0.3	0.09
8.3	10.0	-1.7	2.89
12.0	30.0	-18.0	324.0
14.5	16.0	-1.5	2.25
7.2	8.0	-0.8	0.64
2.0	3.3	-1.3	1.69
6.7	13.0	-6.3	39.69
4.5	7.4	-2.9	8.41
7.9	8.0	-0.2	0.04
		-64.4	788.76

Testing Hypothesis (H_0) = There is no significant variation in the incidence rate (I.R.) of leprosy in the taluka as whole and in the areas beside rivers or water bodies.

Alternative Hypothesis (H_1) = There is much variation in the incidence rate (I.R.) of leprosy in the taluka as whole and that beside rivers or water bodies.

Step 4 : Critical

If $t_{cal} > t_{tab}$ Reject the hypothesis (H_0)

Or

If $t_{cal} < t_{tab}$ Accept the hypothesis (H_0)

t_{tab} (12-1) at 11 degree of freedom.

Thus t_{tab} = 2.201 at α = 5%

Step 5 : Calculation

$$\bar{d} = d / n = -64.4 / 12 = -5.4$$

$$S_d = \sqrt{\frac{d^2}{n} - (\bar{d})^2} = \sqrt{\frac{788.76}{12} - (-5.4)^2} = 6.048$$

$$t_{cal} = \frac{\bar{d}}{S_d / \sqrt{n-1}} = \frac{(-5.4)\sqrt{11}}{6.048} = -2.962$$

$$\left| t_{cal} \right| = \left| -2.962 \right| = 2.962 \text{ (} \because \text{ it is two tailed test)}$$

Step 6 : Conclusion

At 5% significance level t_{tab} = 2.201 and t_{cal} = 2.962

Since 2.962 > 2.201

i.e. $t_{cal} > t_{tab}$ = Reject the hypothesis (H_0)

This implies that alternative hypothesis (H_1) is true, i.e., there is much variation in the incidence rate of leprosy in the taluka as a whole and that beside rivers or water bodies.

Thus the villages beside rivers or any water bodies will have a larger incidence rate.

10.13 Classification of population Density :

The information on five groups (viz, Very low, low, moderate, high, very high) of population density from appendix 12.1, 12.2 and 12.3 is summarized in table 10.7 from figure 10.18, the five class of population density is highlighted for the entire Vadodara district from 1981 district census handbook.

Table 10.7 : Total number of villages & Towns, number of leprosy affected villages & towns and number of leprosy cases classified according to population density.

Sr. No.	Pop-density Class	Total Position				Leprosy Affected				Total no.of cases			
		Village		Town		Village		Town		Village		Town	
		DP	BR	DP	BR	DP	BR	DP	BR	DP	BR	DP	BR
1.	Very low	225	51	1	1	60	16	1	1	77	39	12	12
	(%)	14	10	5	14	7	6	7	14	7	7	3	5
2.	Low	688	205	4	1	318	95	3	1	396	200	24	11
	(%)	42	42	21	14	39	39	20	14	34	36	6	4

Cont...

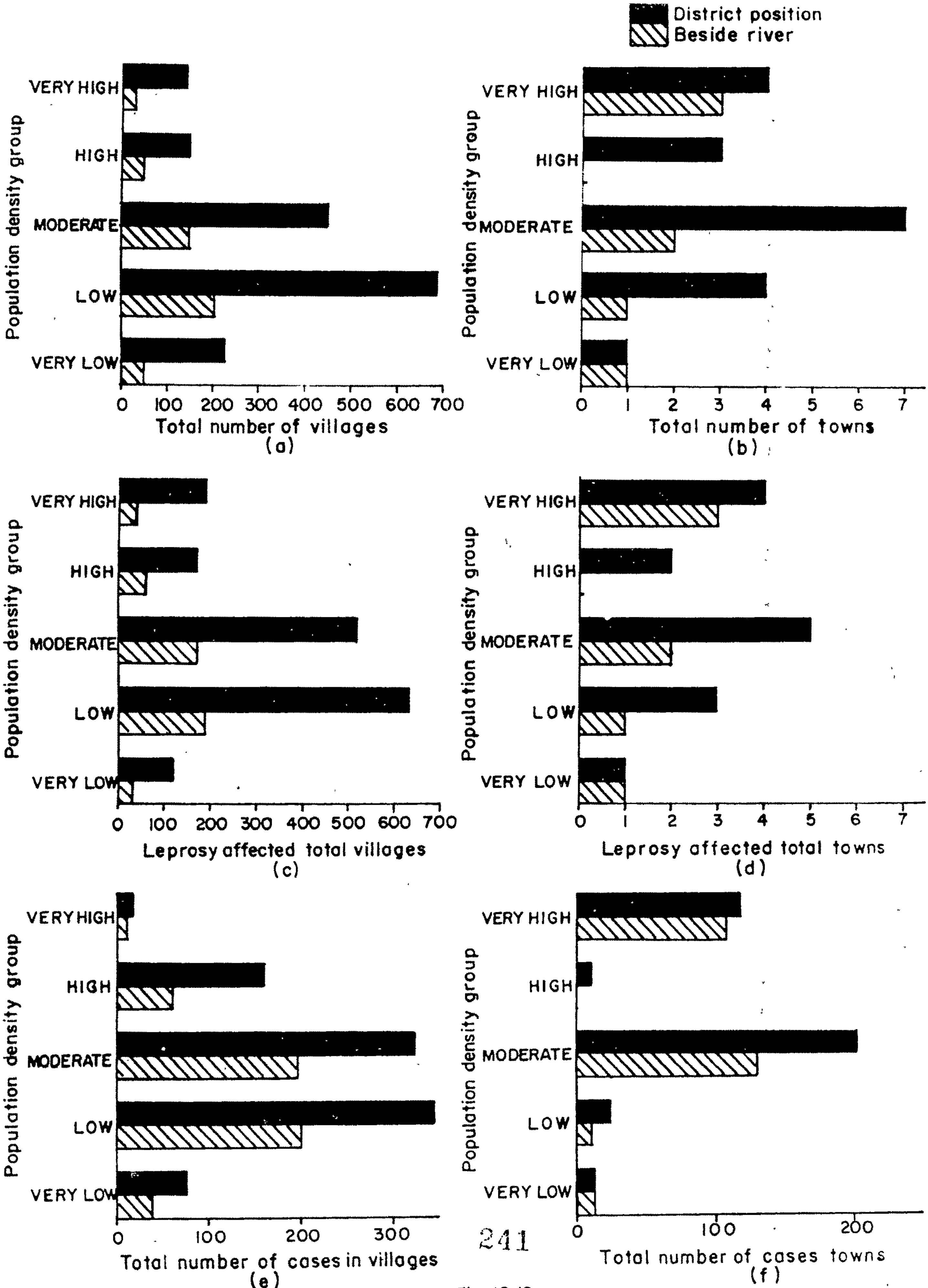
Sr. No.	Pop-density Class	Total Position				Leprosy Affected				Total no.of cases			
		Village		Town		Village		Town		Village		Town	
		DP	BR	DP	BR	DP	BR	DP	BR	DP	BR	DP	BR
3.	Moderate	450	149	7	2	259	84	5	2	325	199	202	131
	(%)	27	31	37	28	32	44	33	28	28	36	55	50
4.	High)	147	46	3	-	86	30	2	-	157	61	10	-
	(%)	9	9	16	-	10	12	13	-	14	11	3	-
5.	Very High	141	31	4	3	95	18	4	3	180	52	116	107
	(%)	8	8	21	44	12	9	27	44	17	10	33	41
Total		1651	482	19	7	818	243	15	7	1151	551	364	261

Note DP - District Position, BR - Beside River.

In case of total number of village for the entire district and for villages beside river majority of village lie in very low to low class of population density. But in case of towns majority of them lie from moderate to very high density classes as shown in figure 10.18a and 10.18b.

In case of total number of leprosy affected villages and towns in the entire district and beside river, majority of villages and towns fall in between very low to moderate groups of population density which is very clear from figure 10.18c and. 10.18d.

A similar type of position is also observed in the total number of affected villages in the district as a whole those and beside rivers, majority of leprosy cases are confined to very low to moderate class of population



District position
Beside river
Population density group
VERY HIGH
HIGH
MODERATE
LOW
VERY LOW
0 100 200 300 400 500 600 700
Total number of villages
(a)
0 1 2 3 4 5 6 7
Total number of towns
(b)
Leprosy affected total villages
(c)
Leprosy affected total towns
(d)
0 100 200 300
Total number of cases in villages
(e)
0 100 200
Total number of cases towns
(f)

Fig.10·18

density in figure 10.18e. But reverse is found in leprosy cases emerging from affected towns. majority of cases are confined to moderate to very high population density classes for both the district as a whole and also for the towns located beside rivers as shown in figure 55f.

It is therefore appears that population density of affetced areas does not play any significant role in the prevalence rate of the disease but possibility of the diffusion of the disease by population dynamics could be major reason in spreading the disease from low to higher population density group.