CHAPTER 2

SPATIAL PATTERNS OF CARDIOVASCULAR MORTALITY IN RURAL BIST DOAB

Introduction

The incidence of cardiovascular mortality varies greatly from one area to another, depending upon the variations in physical, socio-economic and behavioural factors. Geography can make extremely useful contributions to the study of cardiovascular diseases through spatial identification of high risk population groups. The disease ecology tradition in the geography of health focuses on the patterns of similarities and differences in the occurrence of a disease between areas and the regional structure of places affected by that disease. Akhtar (1992) has underlined that in geographical analysis of a disease, the focus of research is ‘who suffers what, where and how.’ The stress on ‘where’ highlights the geographer’s preoccupation with spatial inequalities and hence the study of spatial patterns is the most fundamental and essential part in studying the geography of a disease. In fact, the spatial analysis in geography mostly begins with the description of patterns in space. The geographical etiology of cardiovascular diseases can be investigated by discovering where these diseases predominate and subsequently relating their spatial characteristics to the relevant features of physical and human environment.

The present chapter is therefore devoted to address the question of how cardiovascular deaths are distributed in the rural Bist Doab region of Punjab. Initially, an exploratory study of age and gender differentials and spatial patterns of cardiovascular mortality has been conducted at village level. The observed patterns are quantified through a spatial clustering technique to identify the areas of high occurrence of cardiovascular deaths. The mortality rates are then aggregated at block-level for further analysis. Secondly, a composite cardiovascular risk index has been computed at block level by normalizing and aggregating five variables, namely alcohol vends,
milch animals, health services, terrain slope and industrial density. Thirdly, an attempt has been made to construct a regression model of cardiovascular mortality using cardiovascular risk index as an explanatory variable. Finally, the overall burden of cardiovascular diseases in the region has been estimated by calculating the years of life lost due to the resultant premature mortality. The economic loss incurred by these deaths has also been assessed by considering the economically productive age group of 15 to 59 years.

**Data and Methods**

The village-wise Death Registers maintained under Civil Registration System have been chosen as a source of data for the present research work. These unpublished records are available in the Office of Registrar (Births and Deaths) of each district and are an extensive repository of village-wise cause of death statistics. They provide geographically continuous data at the most disaggregated spatial scale, which makes micro-level spatial analysis possible. However, this data set does not permit a temporal analysis, since the cause of death component was added only after 2005 to the format of death registers. Nevertheless this source of data has high utility for the present research work because it enables the generation of detailed village-level pattern of cardiovascular mortality in the study region. The data was collected for all the 3,403 villages of Bist Doab region for the years 2007, 2008 and 2009. However, the data for years 2007 and 2008 was later abandoned at the processing stage, because there were huge gaps in the information on cause of death owing to the absence of ‘cause of death’ column in most of the death registers. The following information was noted down for all 24,573 deaths recorded in the death registers:

- Cause of death
- Month of death
- Age at the time of death
- Gender of the deceased

The individual-level data was aggregated village-wise. The causes of death stated as ‘Heart Attack’, ‘High Blood Pressure’, ‘Stroke’, ‘Brain Haemorrhage’
and ‘Sudden Death’ qualified to be included in the category of cardiovascular deaths. For each village the data was sorted out disease-wise, month-wise, gender-wise and age group-wise. The processed information was entered into the computer system and tables were generated using Microsoft Excel files.

The block-level data on various indicators has been compiled from the ‘Block at a Glance’ publication of Economic and Statistical Organization (Punjab) for all the 30 blocks of the region. The district-wise age structure data was obtained from Census of India website for the year 2001. The topographic map of study region (scale 1:250,000) was downloaded from online library of University of Texas, U.S.A. This toposheet (series 1501 AIR, sheet NH43-3, edition 2) was prepared and published in 1992 by the Defense Mapping Agency Topographic Center, Washington, D.C. (U.S.A.). The data on number and location of licensed alcohol vends was obtained from the website of Excise and Taxation Department (Punjab).

The following methods and techniques were applied for analysis and presentation of data:

1. **Proportional Mortality Rate**

   To begin with, the distribution of cardiovascular mortality was calculated gender-wise, across ten-year age groups for the entire Bist Doab region and the results were displayed through pie-charts and bar diagrams. In order to obtain a comparable spatial picture of the intensity of cardiovascular diseases, Proportional Mortality Rate (PMR) was calculated village-wise using the following formula:

   \[
   \text{PMR} = \frac{\text{Number of deaths from Cardiovascular Diseases}}{\text{Number of deaths from All Causes}} \times 100
   \]

   These values were plotted on map using ArcGIS 9.3 software. Choropleth method was used to visualize variations in the spatial patterns of cardiovascular mortality. Using the average value of cardiovascular mortality in Bist Doab as a reference point, the whole region was divided into very high, high, moderate, low and very low disease-specific mortality categories. The
mortality rates were also aggregated at block level for conducting further analysis.

2. Hot Spot Analysis

The statistical significance of the observed spatial pattern at village level was tested using the Hot Spot Analysis tool of ArcGIS based on Getis-Ord Gi* (G-i-star) statistic. This analysis was used to identify the statistically significant spatial clusters of high values (‘Hot Spots’) and statistically significant spatial clusters of low values (‘Cold Spots’). The output from the Hot Spot Analysis tool was a Z score and p-value (probability) for each feature. A high positive Z score and small p-value for a feature indicated a spatial clustering of high values. A low negative Z score and small p-value indicated a spatial clustering of low values. The higher (or lower) the Z score, the more intense the clustering and if the p-value was below 0.01 it meant that there was less than 1% chance that the hot/cold spot occurred randomly.

3. Cardiovascular Risk Index

The cardiovascular risk index was developed to study the extent of risk to cardiovascular health in different parts of the study region by exploring the composite spatial distribution of various risk factors. The main advantage of using this composite index was that it summarized the geographical antecedents of some of the important risk factors proven to influence cardiovascular health of people. Additionally, it was easier to interpret one number than finding patterns across multiple indicators. However, in order to determine why the composite index was rising or falling and what to do in response, there was a need to go back to the factors upon which the index was based. For addressing this issue, the individual determinants of cardiovascular diseases have been dealt with separately in the subsequent three chapters. In the present chapter this composite index was computed essentially to facilitate the regression analysis of cardiovascular mortality pattern. Cardiovascular diseases are extremely multi-causal in nature. Therefore, the construction of a reasonably good regression model using individual independent variables was not an easy task. Hence the composite index was calculated to overcome this problem. The five variables used in the
index were chosen after a thorough review of literature and keeping in view the availability of block-level data. Unfortunately, spatial data was not available on key risk factors like physical inactivity, smoking, alcohol consumption, intake of fats, psychosocial stress etc. Therefore, indirect measures and surrogate indicators were used to determine the extent of risk to cardiovascular health in various parts of the region. The cardiovascular risk index (CRI) consisted of the following five components:

(i.) Alcohol Vends Index (AVI): It has been observed that the mere presence or absence of an alcohol vend in a village directly affects the availability and level of alcohol consumption in the surrounding area (The Tribune, 19th January 2011 and 10th February 2012). Thus the Alcohol Vends Index was used to portray the availability of alcohol in the region. The indicator used for its calculation was ‘number of males per alcohol vend’ in each block. Lower the number of males served per alcohol vend in an area, higher will be the risk to cardiovascular health owing to higher per capita availability of alcohol. Alcohol Vends Index (AVI) was arrived at using the following formula:

$$AVI = \frac{\max(x) - x}{\max(x) - \min(x)}$$

where \(x\) is number of males per alcohol vend

(ii.) Milch Cattle Index (MCI): This index reflected the availability of milk and milk products in the study area. Since block-wise data on availability or consumption of milk and milk products was not available, so the ‘number of milch cattle per person’ was used as a surrogate indicator such that higher the number of milch cattle per person, higher will be the risk of developing cardiovascular ailment due to great fat consumption. Milch Cattle Index (MCI) was calculated as follows:

$$MCI = \frac{x - \min(x)}{\max(x) - \min(x)}$$

where \(x\) is number of milch cattle per person

(iii.) Health Services Index (HSI): Health Services Index was calculated from the indicator named ‘population served per health institution’. Lower the population served per health institution in an area, lower is the risk to cardiovascular health. Since the data on the number of private health institutions was not available at block-level, so only
government ones were considered. The formula used for computing Health Services Index (HSI) was:

\[ \text{HSI} = \frac{x - \min (x)}{\max (x) - \min (x)} \]

where \( x \) is population served per health institution

(iv.) Average Slope Index (ASI): The role of living on moderate altitudes with uneven terrain in promoting physical activity has been well accepted in existing literature. The eastern parts of Bist Doab region are hilly while the central and western parts are flat plains. Thus physiography of the region has significant influence on the spatial distribution of cardiovascular mortality. Robinson’s method of slope analysis was applied on contour map of the region for calculating the block-wise average slope in degrees. Higher the average slope of an area, lower will be the risk of acquiring cardiovascular diseases, owing to the greater level of physical activity involved. The Average Slope Index (ASI) was calculated as given below:

\[ \text{ASI} = \frac{\max (x) - x}{\max (x) - \min (x)} \]

where \( x \) is average slope in degrees

(v.) Industrial Units Index (IUI): The industries present in an area are a marker of physically inactive workforce and in some cases, high levels of air pollution as well. Therefore, higher the number of industrial units per sq.km, higher is the risk to cardiovascular health. The Industrial Units Index was calculated from this indicator using the following formula:

\[ \text{IUI} = \frac{x - \min (x)}{\max (x) - \min (x)} \]

where \( x \) is density of industrial units

Thus, the Cardiovascular Risk Index (CRI) was calculated as follows:

\[ \text{CRI} = \frac{1}{5} (\text{AVI} + \text{MCI} + \text{HSI} + \text{ASI} + \text{IUI}) \]

A choropleth map was prepared to depict the block-wise distribution of CRI and this score was eventually used in the regression analysis of cardiovascular mortality.
4. Regression Analysis

The regression analysis was done at block level using Ordinary Least Squares (OLS) method in ArcGIS 9.3 software. The OLS tool created a single regression equation as follows:

\[ Y = a + bX + E \]

where,

\( Y \) = Proportional Mortality Rate (Cardiovascular deaths as % of Total deaths)
\( X \) = Cardiovascular Risk Index
\( a \) = Intercept
\( b \) = Regression coefficient
\( E \) = Random error / residual

The intercept represents the expected value for the Proportional Mortality Rate (dependent variable) if the value of the Cardiovascular Risk Index (explanatory variable) is zero. The residuals denote the difference between observed and predicted values of cardiovascular deaths and are shown in the OLS output map as under predictions (where the actual proportion of cardiovascular mortality is lower than predicted) and over predictions (where the actual proportion of cardiovascular deaths is higher than predicted). In a properly specified regression model, the over and under predictions display a random spatial distribution. Moran’s-I spatial autocorrelation test was used to ensure that the over/under predictions do not portray spatial clustering. The value of Moran’s-I index varies between -1 and 1, where -1 denotes perfectly dispersed pattern and 1 signifies perfectly clustered pattern. A value close to 0 represents a randomly arranged pattern. If the over/under predictions tend to cluster, it implies that some key explanatory variable is missing. The results of regression analysis were interpreted from the numeric output of OLS method.

5. Years of Life Lost due to Premature Mortality (YLL)

This measure has been devised by World Health Organization (WHO) to estimate disease burden of a region in units of time and forms a component of the summary measure of population health called ‘Disability-Adjusted Life Years’ (DALY). The DALY quantifies the burden of premature mortality and
disability for major disease groups by combining estimates of the Years of Life Lost (YLL) due to premature mortality and Years Lived with Disability (YLD). So it measures the difference between a current situation and an ideal situation where everyone lives in perfect health up to the age of the standard life expectancy (Pruss-Ustun et al., 2003). The YLL metric essentially is a function of the death rate and the duration of life lost due to a death at each age. It corresponds to the number of deaths multiplied by the standard life expectancy at the age at which death occurs. Thus the basic formula for calculating the YLL for a given cause, age or gender is:

$$YLL = N \times L$$

where $N$ = number of deaths

$L$ = standard life expectancy at age of death (in years)

The YLL measure can also be rated according to social preferences under which the value of each year of life depends on age. Discounting health with time reflects the social preference of a healthy year now, rather than in the future. To calculate YLL in this case, the value of a year of life is generally decreased annually by a fixed percentage. Thus the formula becomes:

$$YLL = \frac{N}{r} (1 - e^{-rL})$$

where $N$ = number of deaths

$L$ = standard life expectancy at age of death (in years)

$r$ = discount rate (e.g. 3% corresponds to a discount rate of 0.03)

Age-weights can also be used in YLL calculation in order to give higher weight to a year of life in young and mid-adult years and lower weight to a year of life at older years. If both age-weighting and discounting are applied, the formula for YLL is modified as follows:

$$YLL = \frac{KCe^{a\beta}}{(r + \beta)^a} \left[ e^{-(r + \beta)L+a} \right] - \frac{1}{r} - \frac{K}{(1 - e^{-rL})}$$

where $a$ = age of death (in years)

$r$ = discount rate (usually 3%)

$\beta$ = age-weighting constant (here, $\beta = 0.04$)
This formula for YLL has been programmed into Microsoft Excel spreadsheet template as part of DALY measure, which is available at the website of WHO (http://www.who.int/entity/healthinfo/bodreferencedaly.calculationtemplate.xls). In the present chapter, this template has been used to calculate YLL at block level to make comparative assessment of burden of cardiovascular diseases in various parts of Bist Doab region. The number of cardiovascular deaths was summed up for each block in five-year age groups. The district level census data on population age structures was used to proportionately calculate population in various age groups of the respective blocks. The average age at death ($a$) in each age group was also computed for all blocks. The model life table ‘West Level 26’ developed by Coale and Demeny (1966) was used to calculate standard life expectancy at average age of death ($L$) in each age group. This model life table has been derived from the largest number and broadest variety of cases and it portrays the most general mortality pattern in developing nations (Murray et al., 2001). Based on it, the standard life expectancy at birth was set at 80 years for males and 82.5 for females. YLL was calculated with discount rate ($r$) = 3%, age-weighting constant ($\beta$) = 0.04, age-weighting modulation constant ($K$) = 1 and adjustment constant for age-weights ($C$) = 0.1658. These are the usual standard values used by WHO to compute YLL. The calculations were done for males and females separately in five-year age groups and then added up to obtain a complete picture. The YLL measure by age groups and gender was represented through a multiple bar diagram for the whole region. The values of block level YLL were plotted on map using choropleth method in ArcGIS 9.3 software.

6. Potentially Productive Years of Life Lost (PPYLL)

The measure of Potentially Productive Years of Life Lost (PPYLL) was used to assess the economic loss caused by premature cardiovascular mortality. The concept of potentially productive life years lost is based on the
productive value of individuals. While the YLL measure of WHO was used to assess the burden of cardiovascular diseases in terms of healthy years lost across all age-groups, PPYLL quantified the effect of cardiovascular mortality on economy of the study region. The PPYLL measure presumes that the potentiality to work and earn is generally governed by the age of the person (Zhou et al., 2003). Thus, the economically productive age group lies between 15 to 59 years (Chandna, 2002). The future years lost from death are calculated by subtracting the mid-point of each age group from the standard eldest productive age (60 years). For deaths before the age of 15, it is assumed that if the children had survived, they would have worked the full 45 years of their economically productive life span up to the age of 60. The results are multiplied by number of cardiovascular deaths in respective age groups and tabulated as shown in Table 2.2. The economic loss incurred by premature cardiovascular deaths has been estimated by multiplying the total PPYLL by average per capita income of Punjab. According to Economic Survey of Punjab (2011-12), the state per capita income in 2009-10 was Rs. 42,752 at constant prices of 2004-05 base year.

**Gender and Age Differentials in Cardiovascular Mortality**

The total number of deaths from all causes occurring in rural areas of Bist Doab region in 2009 was 24,573. Out of these, 6,796 deaths (nearly 28%) were caused due to cardiovascular disorders. Approximately 65% of the persons who died from cardiovascular diseases were males, while the rest 35% were females (Fig 2.1). As far as the mortality from other causes is concerned, the proportionate share of males and females is quite equitable, with males constituting 58% and females comprising 42% of the deaths occurring due to non-cardiovascular reasons. This indicates that the incidence of cardiovascular diseases is highly skewed towards the male population of the region.

The gender-specific share of cardiovascular deaths out of the respective total deaths reveals a clearer picture. Cardiovascular diseases are responsible for as many as 30% deaths among males. On the contrary, this figure is 24% in case of females. This comparison reinforces the fact that
male population in the study area is much more prone to cardiovascular diseases. The reasons for this bias can be traced in the inherent cultural characteristics of the population under focus. Under the traditional dietary norms the males, unlike females, are nurtured on fat-laden diets rich in milk and milk products, right from their childhood. This discrimination eventually results in the early development of cardiovascular disorders, leading to a higher mortality rate among the males.

Fig 2.1 - Rural Bist Doab: Proportionate Share of Males and Females in (a.) Deaths from Cardiovascular Diseases, and (b.) Deaths from Causes Other Than Cardiovascular Diseases

Another reason for this skewness can be attributed to the consumption patterns of alcohol and tobacco in the region. It has been observed that in the rural areas, it is largely the male population that consumes alcohol and tobacco products, while abstinence from alcohol is still a cherished value among the females (Lal and Singh, 1978; Mohan et al., 2001). The primary data collected through fieldwork (Chapter 5) also showed that only the male persons in sample smoked tobacco in the form of bidis and cigarettes, whereas the females did not consume tobacco at all. Thus male population of the study region has a massive exposure to the leading risk factors of cardiovascular diseases, resulting in higher rate of mortality.
The age structure of deaths caused due to cardiovascular diseases (Fig 2.2) reveals that the proportionate share of mortality below the age of 10 is around 1% which gradually rises to 2% for the age group of 10 to 20 years. This percentage doubles to 5% for persons dying between 20 to 30 years of age, and becomes 7% for the next age group. The share of deaths occurring in the age category of 40 to 50 years gets almost doubled to more than 12% which further rises to 14% in the successive age group. The age group of 60 to 70 years records the highest proportion of cardiovascular deaths (19%), with the next age group registering a slight decline in the proportionate share (18%). All the subsequent age categories mark a rapid decline in the share of cardiovascular deaths in the region, recording 14% and 6% for the age groups of 80-90 and 90-100 years respectively. Less than 2% of the cardiovascular deaths occur at the age of 100 or above.

Fig 2.2 - Rural Bist Doab: Age group-wise Cardiovascular Mortality

<table>
<thead>
<tr>
<th>Age Groups (Years)</th>
<th>Percentage of Cardiovascular Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>0</td>
</tr>
<tr>
<td>10-20</td>
<td>2</td>
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<tr>
<td>20-30</td>
<td>3</td>
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<td>30-40</td>
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<td>70-80</td>
<td>8</td>
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<tr>
<td>80-90</td>
<td>9</td>
</tr>
<tr>
<td>90-100</td>
<td>10</td>
</tr>
<tr>
<td>100 &amp; Above</td>
<td>1</td>
</tr>
<tr>
<td>Age not stated</td>
<td>1</td>
</tr>
</tbody>
</table>

Source of Data: Village-wise Death Registers, 2009
The above results show that 3% of all cardiovascular deaths occur below the age of 20 years. It is a small but crucial figure because it reflects that even the youngest age group is not free from the burden of cardiovascular diseases. However, the conventional risk factors of these diseases (tobacco and alcohol consumption, physical inactivity etc.) have a little role to play in such deaths. The sudden cardiac deaths in young population can be attributed mostly to inborn structural abnormalities of the cardiovascular system and inflammation of the heart muscle. Exposure to passive smoking is also an important culprit. Children who are continuously exposed to second-hand smoke in their daily lives demonstrate high risk of developing atherosclerosis (hardening of arteries) in early adulthood, which is a major cause of death (Koromos, 2009).

About 60% of the deaths related to cardiovascular diseases in the study region occur below the age of 70. This figure is quite high when compared to that for India (50%) and the western countries (22%). Goenka et al. (2009) has also noted that Indians are succumbing to cardiovascular diseases 5 to 10 years earlier than their western counterparts. The most critical point is that as many as 38% of cardiovascular deaths in the study region occur in the age bracket of 20 to 60 years, which is the most productive time span of human life. The consumption of traditional high fat diet, heavy intake of alcohol and tobacco, coupled with sedentary lifestyle results in an early onset of these diseases. According to the data of 2008-09, the per capita availability of milk in Punjab is 955 ml/day, which is highest in India. Although the primary data collected through fieldwork (Chapter 5) shows that the per capita consumption of milk in the sampled persons of Bist Doab is only 224.29 ml/day (mainly because most of them belonged to lower socio-economic strata of society), yet the region on a whole has traditionally high per capita production of milk than the rest of the state (Rani, 1992). Further, the total fat consumed by sampled population from major food items, i.e. butter, desi ghee, milk and mustard oil amounted to 44.31 gm/day, which was way too greater than that recommended by WHO (29 gm/day). Cooking oil and butter are the largest source of fat consumed by the sampled persons (18.59 gm/day and 15.52 gm/day respectively). In all, the Punjabi diet is very
rich as compared to other parts of the country (The Times of India, 4th August 2008). The intake of alcohol is also very high. The state is at second slot in India, just behind Kerala in liquor consumption. In 2009-10, as many as 29 crore bottles of Indian-made foreign liquor and country-made liquor were sold in the state (The Times of India, 13th February 2011). Apart from this huge supply of liquor from government approved liquor vends, illicit brewing and distillation is a common practice in rural areas. In addition to it, liquor is sold in military canteens and also smuggled from neighbouring states at low rates. The per capita consumption of liquor in Punjab has increased by a whopping 59.2% in just six years, from 2.5 proof litres in 2005 to 4.09 proof litres in 2011 (The Times of India, 30th March 2012). In fact, the per capita availability of alcohol is very high in rural Bist Doab, with as many as 23 out of the total 30 community developments blocks of the region having availability of more than 4.0 proof litres per male in 2006-07. This provides enough evidence to support the view that population of the study region has a very high prevalence of major risk factors, resulting in high rate of cardiovascular deaths in the most productive years.

The senior age bracket of above 80 years accounts for only 22% of total cardiovascular mortality in rural Bist Doab. This proportion is low because most of the deaths occur in younger age groups due to high prevalence of important risk factors in the study region. The well-known Framingham Heart Study has evaluated cardiac impact of six major risk factors – high total cholesterol, low HDL (“good”) cholesterol, high blood pressure, diabetes, obesity and smoking. The results reveal that a person who is free of all the six risk factors has a remarkably low 5% risk of developing cardiovascular disease by 95 years of age. On the other hand, the risk for a person with two or more risk factors is 69%. In addition, a risk free person can expect to enjoy 11 more years of life than a person with two or more risk factors (Koromos, 2009).

In absolute terms, the number of male cardiovascular deaths in all age groups is consistently higher than that of the females, with males recording a total of 4396 deaths from cardiovascular diseases and females registering 2400 deaths in the region. However, a comparative study of the proportionate
distribution of cardiovascular deaths occurring among males and females in various age groups presents a different picture (Fig 2.3). The data reveals that below 10 years of age, the share of females (1%) dying from cardiovascular disorders is slightly higher than that of the males (0.9%). This trend is continued in the age group next in order, with females having higher proportion (2.4%) of deaths than the males (2%). However, from the age group of 20 to 30 years, the relative share of cardiovascular deaths among females starts decreasing. The gap widens in the succeeding age category of 30 to 40 years with females recording 5% of their total cardiovascular deaths and males registering 8% of this disease specific mortality.

![Rural Bist Doab: Age group-wise Male and Female Cardiovascular Mortality](image)

**Fig 2.3** - Rural Bist Doab: Age group-wise Male and Female Cardiovascular Mortality

The next age group of 40 to 50 years sees a sharp increase in cardiovascular mortality with males recording 14% of their total cardiovascular...
deaths and females having 9% share of their total figure. Thus the gap
between the respective percent share of males and females is accentuated
further with males recording a much higher mortality from cardiovascular
diseases than the females. This male-female differential is maintained
between the age of 50 to 60 years as males register 16% of their respective
cardiovascular deaths against 11% of female deaths. The successive age
group of 60 to 70 years records maximum share of male cardiovascular
deaths (19%). On the other side, the percent of female cardiovascular deaths
in this age group increases stupendously to 19%, which further rises to 20%
in the next age group. However, the male deaths from cardiovascular
disorders decline to 17% between the age of 70 to 80 years. The subsequent
age categories of 80 to 90 years and 90 to 100 years further demonstrate a
steep decline by recording 12% and 5% of male cardiovascular deaths
respectively. The share of female deaths from cardiovascular diseases, which
is highest in the age group of 70 to 80 years, also decrease to 17% and
further low to 8% in the successive two age groups of 80 to 90 and 90 to 100
years respectively. But the decline in share of cardiovascular deaths recorded
among females is not as sharp as that of males.

It is pertinent to note that among the male population, more than 46%
of the cardiovascular deaths occur below the age of 60 years. However, as far
as the female deaths from cardiovascular disorders are concerned this share
is only 33%. The number of males dying from cardiovascular ailments
increases stupendously upto the age of 60 years and then it shows a decline.
The case for females is entirely different. The deaths recorded from
cardiovascular diseases among the females show a very gradual increase
upto the age of 70 years and then decline slowly in the subsequent years.
This shows that a major chunk of male deaths are recorded in younger age
groups, while a large share of female cardiovascular deaths occur in
comparatively older age groups. The maximum proportion of cardiovascular
deaths among males is recorded in the age group of 60 to 70 years, whereby
in case of females the figure is highest in the interval of 70 to 80 years of age.
Moreover, after the age of 70 years, the age group-wise percent share of
female cardiovascular mortality is consistently higher than that of the males,
and this trend is continued even for the deaths recorded in the last age group of 100 years and above. This clearly shows that there is more likelihood for males to die from these diseases in younger age categories than their female counterparts. On one side, this imbalance can be justified by the fact that females are biologically healthier and sturdier than men so that they normally outlive the males on an average by five years. But on a precise note, this age differential in gender-specific cardiovascular mortality can be attributed to the general abstention of alcohol drinking and smoking among the females of the study area, which definitely delays the onset of cardiovascular disorders, enabling them to live longer than the male population.

**Spatial Patterns and Clusters of Cardiovascular Mortality**

On the basis of village-wise proportional mortality rate of cardiovascular diseases, the entire rural Bist Doab region can be divided into following five categories of areas (Fig 2.4):

1. Areas with very high cardiovascular mortality (more than 40% of total mortality)
2. Areas with high cardiovascular mortality (30 to 40% of total mortality)
3. Areas with moderate cardiovascular mortality (20 to 30% of total mortality)
4. Areas with low cardiovascular mortality (10 to 20% of total mortality)
5. Areas with very low cardiovascular mortality (less than 10% of total mortality)

1. **Areas with very high cardiovascular mortality (more than 40% of total mortality)**

The areas recording very high proportion of mortality caused by cardiovascular diseases (more than 40% of total deaths) comprise of 827 villages, which account for nearly 30% of all villages of the study region. These villages are mostly situated in close proximity to the urban areas. The largest group of such villages exists in the form of a continuous belt surrounding the urban centres of Jalandhar and Nakodar. In fact, the rural areas with very high rate of cardiovascular mortality are present in the shape of uninterrupted rings around these two cities. Both these rings of villages are
so large in their expanse that they totally coalesce with each other to form a broad belt running from north-east to south-west direction. This belt widens towards the south of Nakodar along the river Satluj and fades away near Shahkot in the west and Nurmahal in the east. The factors that account for high cardiovascular mortality rate vary spatially over this belt.

There are as many as 67 villages around the city of Jalandhar which have registered more than 40% deaths from cardiovascular diseases. The consumption of alcohol is very high in this area. According to the data of 2007, the average population served per alcohol vend for entire rural Bist Doab is 4398 persons per vend, whereas this figure is just 2330 persons per vend in case of Jalandhar-I tehsil, which encompasses most of the villages of this cluster. Considering the fact that alcohol is consumed only by male population of the study region, the gender-specific ratio of males per alcohol vend has been calculated to represent a more precise picture of the existing scenario. There is one alcohol vend for every 1220 males in rural areas of
Jalandhar-I tehsil, whereas this figure is 2286 males per alcohol vend for the rural Bist Doab. It clearly indicates that liquor is more easily and readily available to the rural males living around the city of Jalandhar. Fieldwork also reveals that the intake of alcohol is highest in this area of the study region. Additionally, this area also leads the region in consumption of milk and milk products. Cigarette smoking is also quite prevalent here, though the smoking of bidis (hand rolled cigarettes) is comparatively less popular than rest of the region.

Moreover, 60% of the total workers of this area are engaged in non-agricultural activities, which exceed the average for all villages of Bist Doab (55%). This shows that most of the people are employed in secondary and tertiary sector occupations either in villages or in the urban centre of Jalandhar, which is the chief industrial and commercial hub of the study region. Jalandhar is the third largest city of Punjab and has a substantial range of industries which manufacture products like leather goods, bus and truck body structures, rubber and plastic goods, electrical equipments etc. It is world famous for sports goods industry. Therefore, this huge industrial cluster provides ample job opportunities not only to the local city dwellers, but also to the skilled and semi-skilled rural folks from the surrounding areas. These non-farm sector occupations are essentially sedentary in nature, since they do not require much strenuous labour. Such conditions create physically inactive work environment, which predisposes the workers to a higher risk of developing cardiovascular diseases (Gregory, 2007; Ding et al., 2011). Moreover, the city of Jalandhar as well as the surrounding areas have high levels of air pollution caused by industries and motor vehicles (The Tribune, 12th November 2010, 16th November 2011). Such high levels of air pollution are again associated with greater incidence of cardiovascular diseases (Nautiyal et al., 2007).

The level of urbanization is also very high in Jalandhar-I tehsil (80.93%) as compared to the entire study region (33.92%). The degree of urbanization in an area is a fair index of the level of its socio-economic progress, because the urban centres once established tend to influence the whole socio-economic milieu of the region (Chandna, 2002). This implies that
higher the degree of urbanization in an area, greater is the prevalence of urbanism even in the rural areas. The adoption of an urban way of life by rural population brings about a change in the social setup and attitude of the village folks (Davis, 1967). Therefore, people of this area enjoy relatively higher standards of living than rest of the region. In developing societies, a strong positive association has been found between socio-economic status and obesity (Park and Clifford, 1989; Singh et al., 1998; Poston II and Foreyt, 1999). The presence of a large population base engaged in non-agricultural activities also indicates a higher magnitude of rural-urban commuting, facilitated through well-developed network of roads, resulting in strong rural-urban relations (Kaur, 1994). Therefore, the level of urbanism and affluence is high in the villages situated close to the city of Jalandhar which encourages sedentary lifestyle owing to the heavy dependence on electrical and mechanical equipments. The people with low socio-economic status are more likely to engage in physically demanding work while persons with more resources are likely to have access to better nutrition, non-traditional foods and labour-saving devices (Poston II and Foreyt, 1999). The ownership of household electrical and mechanical appliances and two-wheelers is known to be associated with reduced physical activity and heightened risk of cardiovascular diseases (Gupta et al., 2006). The peripheral location of these villages also increases the distance between residence and workplace, which in turn promotes the reliance on automobiles and minimizes walking, leading to obesity (Zhao and Kaestner, 2010). All these factors explain a higher incidence of cardiovascular mortality in this area.

As far as the area around Nakodar is concerned, there is a set of 68 villages which have registered very high cardiovascular mortality. The population of this area is mostly engaged in agricultural activities. However, the main reason for primacy of cardiovascular diseases in this area is again the high level of alcohol consumption. There exists one alcohol vend for every 1866 male individuals in rural areas of Nakodar tehsil. This problematic situation is aggravated by the free flow of illicit liquor manufactured by a huge number of small production units operating clandestinely in this area. Although there is no systematic research work done on the trade of illicit liquor
in Punjab, yet various newspaper reports published from time to time provide a fair picture of the patterns of this covert market. The entire flood plain (‘bet’) belt along the Satluj river from Nawanshahr to Mehatpur is known for its illicit liquor distilleries, which is a flourishing cottage industry (The Times of India, 2nd April 2004). The practice of illegal liquor brewing is deep-rooted in the flood plain because this area is traditionally known for sugarcane cultivation. The easy availability of raw material and sugarcane fields provide favourable sites for running the business of illicit distillation of alcohol. The town of Mehatpur, situated to the immediate south of Nakodar, is believed to be the largest trading market of illicit liquor in Punjab. Many newspaper reports reveal that huge quantities of this illegal liquor are routinely confiscated through police raids at various places in and around Nakodar (The Tribune, 18th and 25th April, 18th May, 23rd June 2011). Since no government revenues are paid, illicit liquor is considerably less expensive than licensed country liquors and thus finds a ready market among the rural poor (Saxena, 1999). This is the prime reason why these villages experience very high rate of cardiovascular mortality.

Immediately to the east of this Jalandhar-Nakodar belt lies another group of 47 villages surrounding the city of Phagwara with very high cardiovascular mortality. These villages are split into two sub-groups situated to north-east and south of the urban area of Phagwara. Only 28% people of these villages are engaged in farming, while the remaining 72% are employed in non-agricultural activities. Like Jalandhar, Phagwara is also an important industrial centre of the study region and is situated on the main line of transport of the state. Apart from the famous J.C.T. cotton textile mills, there is a sugar factory and other small industries which manufacture agricultural implements, electrical equipments and mechanical tools. These industrial units provide employment opportunities to the surrounding rural areas, imposing a sedentary lifestyle on the workers. Additionally, Phagwara tehsil has an extensive web of registered alcohol vends in rural areas, with one alcohol vend for every 1062 male persons. This ratio is lowest in the study region indicating the easiest availability of liquor in this part. Thus the prevalence of cardiovascular diseases is very high in this area.
The fourth major stretch of rural areas experiencing very high rate of cardiovascular deaths extends along river Beas from the town of Dasuya in the east to Kapurthala in the west. These villages form an uneven belt consisting of several pockets of high mortality, starting from the areas surrounding Dasuya, running through the rural areas situated to the north-east of Tanda, passing further through the areas lying to the north and south of the town of Begowal, forming a closed ring around the urban area of Bholath, further extending along the eastern and southern margins of Dhilwan and finally ending up to the south-west of Kapurthala. As an offshoot of this irregular belt, a cluster of villages with very high cardiovascular mortality also exists to the west of Sultanpur Lodhi town. In all, this long-stretching belt consists of 227 villages dotting the entire flood plain (‘bet’) of river Beas. Most of the people (56%) in this area have farming as their occupation. However, the ratio of male population per liquor vend is quite low in rural areas of Kapurthala (1630 males per vend), Sultanpur Lodhi (1943 males per vend) and Bholath (2036 males per vend) tehsils, pointing towards the easy accessibility of liquor to the masses. The intake of alcohol is so widespread in this belt that even at a religiously sacred place like ‘Baba Kahan Dass Shrine’ situated at Kala Sanghian village near Kapurthala, only liquor is accepted as an offering. At this place, every evening the various varieties of liquor so collected are mixed in buckets and served to the devotees (Swami, 1999). Besides, illicit liquor is also openly brewed in the flood plain (‘bet’) area of river Beas. The neighbouring area of Gurdaspur district across the Beas river is infamous for this thriving trade. This area consists of more than 24 villages where many families are engaged in this illegal profession from generation to generation for earning their livelihood. For instance, in one of these villages, 60% of the residents are in this trade and they produce approximately 10,000 litres of illicit liquor on a daily basis. The home-distilled liquor is sold not only locally, but it also finds its way into the study region, especially in the area lying along Beas river (Punjab Newsline, 8th August 2012; The Tribune, 10th August 2012). To make the matters worse, illegal liquor is smuggled into this area from the neighbouring state of Himachal Pradesh as well. Several villages of this adjoining state situated along National Highway-1A produce illicit liquor in abundance, which is smuggled into Pathankot (Gurdaspur
and eventually reaches far flung places like Mukerian, Dasuya and Tanda lying in the study region (Punjab Newsl ine, 8th August 2012). Extensive fieldwork in this belt revealed that besides excessive alcohol consumption, smoking of bidis is also very popular, particularly in the villages around Dasuya and Tanda in Hoshiarpur district. Bidis are much cheaper than cigarettes and the rural poor can easily afford them. However, they are far more harmful because they deliver higher amounts of nicotine, carbon monoxide and tar than cigarettes, increasing the risk of cardiovascular diseases manifolds among the users. Similarly, the consumption of red meat is also very high, especially in the areas inhabited by relatively affluent people of Lubana caste, along the river Beas in Kapurthala district. Over the past few decades these people have acquired a lavish lifestyle, thriving on the remittances made by their family members working in foreign countries. Their opulent standard of living can be easily judged from the palatial houses dotting the entire stretch of rural landscape along river Beas. The interplay of all these factors results in very high rate of mortality from cardiovascular diseases in this belt.

Another area of very high incidence of cardiovascular deaths is present in a somewhat curvilinear form starting from the villages situated in the southern parts of block Bhunga, advancing down southwards, passing through the villages located between the urban areas of Shamchaurasi and Hoshiarpur and terminating on the western flank of Adampur. Adampur experiences extremely cold winter temperatures which usually drop to sub-zero level. In 2008, the temperature went down to a freezing low of −5 ºC (The Tribune, 19th January 2011). This area lies in the direct path of the sliding cold and dry winds descending from the Dhauladhars and Shiwalik hills, making it the coldest spot not only of the study region but of the entire state (Manku, 2002). The elevated rate of cardiovascular mortality in this area can be attributed, alongwith other factors, to such low temperature conditions in winter season (Mercer et al., 1999; Cheng, 2005 and 2009; Goncalves et al., 2007).

An auxiliary branch of the above-mentioned belt of very high cardiovascular mortality stretches in the southeastern direction over the
villages lying between the urban centres of Hoshiarpur and Mahilpur. There is an additional almost continuous belt of very high mortality rate existing along the straight-line distance between Mahilpur in the east and Phagwara in the west. The areas lying on both sides of the road connecting Mahilpur to Garhshankar also record very high cardiovascular mortality. Almost all these villages are situated along the prominent highways connecting the urban areas. In the south-eastern parts of Bist Doab region too, villages registering very high mortality caused by cardiovascular disorders appear sporadically along the major highways. Thin linear belts exist along the roads connecting Garhshankar to Nawanshahr, Nawanshahr to Balachaur, Balachaur to Ropar, Garhshankar to Balachaur and Rahon to Garhshankar. The presence of good quality roads encourage the use of vehicles even for short distance travel, which leads to considerable reduction in the level of physical activity of the villagers. Moreover, the residential proximity to major roadways increases the risk of cardiovascular diseases because the level of air pollution is generally high along major road routes (Ward-Caviness et al., 2012). Several industrial units have come up along the above-mentioned highways due to concessions and subsidies provided by the government, which are causing serious problem of air pollution in the nearby rural areas. The residents of many villages have been protesting from time to time for relocation of these industries because high level of pollution in these areas is giving birth to critical health issues (The Tribune, 21st October 2011). In particular, villages around the industrial area of Saila Khurd form a prominent cluster of cardiovascular mortality. The elevated incidence of cardiac deaths recorded in this area can be pertinently attributed to the above-stated reasons.

2. Areas with high cardiovascular mortality (30 to 40% of total mortality)

Areas with high proportion of cardiovascular deaths, ranging between 30 to 40% of total mortality, are situated spatially contiguous to those recording very high rate of cardiovascular mortality. In fact, most of these villages recurrently appear in the clusters and belts of very high cardiovascular mortality. However, there are three distinctly noticeable groups of villages recording high rate of cardiovascular deaths. The first group is located between Jalandhar and Phagwara, extending southwards along the
western flanks of Phagwara upto Goraya. The second set of villages with high cardiovascular mortality is situated on the eastern and western sides of Nakodar, extending upto Nurmahal and Shahkot respectively. The third group lies in the Kandi region and can be sub-divided into three segments. The first segment is situated around Talwara in the extreme north-eastern parts of Bist Doab region; the second part is again located in the north-east around Dholbaha; and the third sub-group is situated to the south-eastern side of the city of Hoshiarpur. Apart from these areas, villages with high cardiovascular mortality are found almost in conjunction with the very high mortality areas in all parts of Bist Doab region. The factors that account for high cardiovascular mortality in these areas are almost same as those for the adjoining very high mortality belts.

3. Areas with moderate cardiovascular mortality (20 to 30% of total mortality)

The areas with moderate cardiovascular mortality are those in which deaths from cardiovascular diseases formed 20 to 30% share of total mortality from all causes. The average figure for the entire rural Bist Doab region (27.7%) lies in this category. Most of the villages falling in this category are again situated in juxtaposition with the areas of high and very high cardiovascular mortality. A large group of such villages is situated on the western and south-western side of Phagwara stretching towards Nurmahal. These villages fall in Rurka Kalan and Phillaur blocks, which have the highest availability of alcohol (9.72 and 9.03 proof litres/male respectively) in Bist Doab region. Another set of villages with moderate cardiovascular mortality rate exists on the eastern flanks of Jalandhar, extending along the southern side of Adampur. A small group of villages falling in this category lies to the east of the road connecting Garhshankar to Balachaur and also along the route connecting Rahon to Nawanshahr. There are also a few such villages situated around Hoshiarpur and on the north-eastern side of Kapurthala. All the areas lying in this category form a sort of transitional zone between the areas recording high and very high cardiovascular mortality and the areas having low and very low mortality rates. These villages are mostly situated in-between the urban centres and thus have moderate effect of urbanism.
4. Areas with low (10 to 20%) and very low cardiovascular mortality (less than 10% of total mortality)

The areas recording cardiovascular mortality rate ranging between 10 to 20% of total mortality are mostly situated to the south of Hoshiarpur and to the far east of Jalandhar. All these villages are situated quite away from the major urban areas of the region and are located close to the areas experiencing very low rate of cardiovascular deaths. The areas recording cardiovascular mortality rate of less than 10% form three clearly discernible belts on the map. The first belt runs from north-eastern to south-western direction, starting from the extreme northern parts of Bist Doab region with its end on the western edge of the region. This belt of very low cardiovascular mortality runs in between the very high mortality areas with Hoshiarpur-Adampur-Jalandhar-Nakodar region lying to its south and Dasuya-Tanda-Begowal-Bholath-Dhilwan-Kapurthala belt on the north. These villages are literally situated far away from the big urban centres of Bist Doab region. The second prominent strip of villages with very low cardiovascular mortality lies in the lower Shiwaliks. This belt runs in the north-western to south-eastern direction along the eastern boundary of Bist Doab region. Most of the villages in this area have a hilly terrain with undulating topography. The adjoining state of Himachal Pradesh, having similar physiography has the lowest cardiovascular mortality rate in India. The main reason of this very low rate in hilly areas is the higher levels of physical activity in these populations (Gupta et al., 2006). The third group of villages registering very low mortality from cardiovascular ailments is located in the south-eastern parts of Bist Doab region. Almost all these areas are situated away from the major road routes of this part of the region and most of them fall in Garhshankar and Balachaur tehsils which have the lowest levels of urbanization in the study region (recorded at 7.97% and 10.20% respectively). The eastern parts of Bist Doab are relatively poor and the size of landholdings is also small.

An analysis of the broad spatial patterns of cardiovascular mortality discussed above has been done to quantify the observed patterns and to find out whether the high or low values tend to group together into statistically significant clusters in the region. In other words, the observed spatial patterns
have been statistically analyzed in order to understand if there are areas with serious problem of cardiovascular diseases in the Bist Doab. The analysis reveals that Z-score of the values is equal to 7.87 standard deviations, which points towards the existence of prominent clusters of high and low values in the dataset. The significance level of this pattern comes out to be 0.01, which means that there is less than 1% likelihood that the clustering of high or low values could be the result of random chance. Therefore, it was found that statistically significant spatial clusters of villages with high and low values of cardiovascular mortality existed in the study area. These clusters were mapped to find out the major **hot spots** and **cold spots** of cardiovascular mortality in Bist Doab region (Fig 2.5).

(a.) Hot Spots

Hot spots represent statistically significant clusters of villages with high values of cardiovascular mortality. In Bist Doab region, the largest hot spot exists in the Jalandhar-Nakodar region, starting from the western flank of the
city of Jalandhar, expanding towards Nakodar and stretching further southwards up to the border of Ludhiana district. Apart from it, a chain of prominent hot spots can be noticed along the entire north-western boundary of the Bist Doab region. These hot spots are positioned around the urban areas of Dasuya, Tanda Urmar, Begowal, Bholath and Kapurthala. Other distinct hot spots are located to the north-east and south-west of Phagwara, to the west and south-east of Hoshiarpur and near Adampur.

(b.) Cold Spots

Cold spots are the statistically significant group of villages with low rates of cardiovascular mortality. Three such important clusters of villages are found in the north-eastern parts of Bist Doab region. One of them is situated to the south of Talwara and the other two are located towards the north and north-east of Mukerian in the extreme north-eastern parts of the study area. Apart from these, a cold spot also exists in the far western end of Bist Doab region to the north of Sultanpur Lodhi. Another significant cluster of villages with low values is present around Bhogpur. In the south-eastern parts of the study area, three large significant clusters are located to the north of Mahilpur, east of Garhshankar and around Rahon. Low values are found to be grouped in villages situated to the east of Nurmahal and north-east of Phillaur. Thus most of the cold spots are found in eastern hilly and foothill parts of the region.

Regression Model of Cardiovascular Mortality

In order to explain the variation in cardiovascular mortality, a regression model has been created at block level by considering Proportional Mortality Rate (PMR) as the dependent variable and Cardiovascular Risk Index (CRI) as the explanatory variable.

(a.) Dependent Variable - Proportional Mortality Rate

A comparison of the patterns of cardiovascular mortality at block level (Fig 2.6) with those at the village level (Fig 2.4) reveals almost similar spatial picture. The distribution of cardiovascular mortality observed at block level shows that the central parts of the region portray a very high rate of mortality
(PMR above 35%). These include the blocks of Nadala (53%), Phagwara (45%), Nakodar (45%), Jalandhar East (43%), Shahkot (41%), Rurka Kalan (37%) and Jalandhar West (36%). The eastern parts and some blocks of the western parts of the region reflect moderately high cardiovascular mortality (PMR from 25 to 35%), which consist of Tanda (32%), Dasuya (31%), Dhillwan (30%), Adampur (29%), Lohian (28%), Hoshiarpur-II (27%), Sultanpur Lodhi (27%) and Kapurthala block (26%).

The blocks falling in the category of moderately low cardiovascular mortality (PMR from 20 to 25%) are largely situated in the south-eastern parts of the region and some of them lie in the east-central parts. These blocks include Saroya (25%), Garhshankar (24%), Nawanshahar (24%), Balachaur (23%), Hoshiarpur-I (22%), Phillaur (22%), Bhogpur (22%), Talwara (21%) and Aur (20%). The category of low cardiovascular mortality (PMR below 20%) encompasses most of the blocks lying in the eastern hilly parts of the study area and one block of the south. These include Nurmahal (19%),
Bhunga (19%), Mahilpur (18%), Mukerian (18%), Hajipur (17%) and Banga block (11%).

(b.) Explanatory Variable - Cardiovascular Risk Index

The patterns of cardiovascular risk index display the distribution of geographically antecedent sources of major risk factors of cardiovascular diseases (Fig 2.7). The index has great variation from one part of study area to the other. The level of risk is high (CRI above 0.6) in central parts of the region and large parts of flood plains of Satluj and Beas rivers, encompassing the blocks of Nadala (0.73), Phagwara (0.70), Phillaur (0.69), Jalandhar East (0.69), Shahkot (0.67), Dhilwan (0.65), Jalandhar West (0.63) and Nurmahal (0.62). The risk score is moderately high (0.5 to 0.6) in the adjoining areas lying both to the east and west of this high risk axis. This group includes the blocks of Rurka Kalan (0.59), Nakodar (0.59), Kapurthala (0.58), Adampur (0.58), Bhogpur (0.57), Lohian (0.57), Sultanpur Lodhi (0.56), Tanda (0.52),
Mukerian (0.52) and Aur (0.51). The third category of moderately low risk score (0.4 to 0.5) is spread over the south-eastern parts and some blocks of the north-eastern parts. The blocks falling in this group include Banga (0.47), Garhshankar (0.47), Mahilpur (0.46), Hajipur (0.45), Dasuya (0.42), Balachaur (0.42), Hoshiarpur-I (0.41) and Saroya (0.41). The spatial expanse of the areas recording low cardiovascular risk score (below 0.4) is spread over the eastern blocks of Nawanshahar (0.38), Hoshiarpur-II (0.37), Talwara (0.23) and Bhunga (0.20).

(c.) Regression Results

The regression analysis was conducted to determine the dependence of cardiovascular mortality on the devised cardiovascular risk score. The value of regression coefficient comes out to be +0.44. The sign of the coefficient reflects positive linear direction of the relationship. This means that as the cardiovascular risk score goes up, the rate of cardiovascular mortality also goes up. The regression coefficient is statistically significant at 0.05 level.
The coefficient of determination (R-squared) is 0.35 which implies that the resultant model explains about 35% of the variation in cardiovascular mortality. The performance of the model could not be enhanced due to serious limitation of data on important behavioural risk factors of cardiovascular diseases like smoking, physical inactivity etc. The spatial autocorrelation of the regression residuals was checked using Moran’s I test. When a regression model is performing well, no structure is displayed by the residuals and they reflect a random spatial distribution. The results of test for spatial autocorrelation reveal that the value of Moran’s I index is 0.16, and the over- and under-predictions of the regression model do not cluster spatially (Fig 2.8).

**Burden of Cardiovascular Mortality**

The concept of disease burden has been developed by the World Health Organization. A disease burden study aims to quantify the burden of premature mortality and disability for major diseases or disease groups, and uses a summary measure of population health called Disability Adjusted Life Years (DALY), which combines estimates of the Years of Life Lost (YLL) and Years Lived with Disabilities (YLD). The first global burden of disease study was published by WHO in 1996 which constituted the most comprehensive and consistent set of estimates of mortality and morbidity yet produced (Murray & Lopez, 1996). WHO regularly develops disease burden estimates at regional and global level for a set of more than 135 causes of disease and injury (Mathers et al., 2002; WHO, 2002).

The initial analysis of the age differentials of cardiovascular mortality in the Bist Doab revealed that a substantial number of deaths occurred in younger age-groups. Therefore it was important to study the dimension of time along with the spatial patterns of cardiovascular mortality. The Years of Life Lost (YLL) component of DALY measure was used to quantify the potential loss from premature cardiovascular deaths in terms of time (years).
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<th>YLL (Females)</th>
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<td>Adampur</td>
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<td>2041</td>
<td>778</td>
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<td>22</td>
<td>Bhogpur</td>
<td>1320</td>
<td>953</td>
<td>367</td>
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<td>26.2</td>
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<tr>
<td>23</td>
<td>Jalandhar East</td>
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<td>1972</td>
<td>1152</td>
<td>24.8</td>
<td>29.9</td>
<td>19.2</td>
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<tr>
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<td>Jalandhar West</td>
<td>4026</td>
<td>3119</td>
<td>907</td>
<td>30.9</td>
<td>45.3</td>
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<td>25</td>
<td>Lohian</td>
<td>1295</td>
<td>960</td>
<td>335</td>
<td>22.0</td>
<td>31.6</td>
<td>11.8</td>
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<tr>
<td>26</td>
<td>Nakodar</td>
<td>6524</td>
<td>4470</td>
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<td>40.9</td>
<td>53.8</td>
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<td>Nurmahal</td>
<td>1882</td>
<td>1134</td>
<td>748</td>
<td>21.2</td>
<td>28.5</td>
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<td>28</td>
<td>Phillaur</td>
<td>3269</td>
<td>2346</td>
<td>923</td>
<td>23.5</td>
<td>32.4</td>
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<tr>
<td>29</td>
<td>Rurka Kalan</td>
<td>3571</td>
<td>2178</td>
<td>1393</td>
<td>40.5</td>
<td>47.3</td>
<td>33.0</td>
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<td>30</td>
<td>Shahkot</td>
<td>2854</td>
<td>2089</td>
<td>765</td>
<td>34.5</td>
<td>48.2</td>
<td>19.5</td>
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<td></td>
<td><strong>Rural Bist Doab</strong></td>
<td><strong>83139</strong></td>
<td><strong>56570</strong></td>
<td><strong>26569</strong></td>
<td><strong>25.7</strong></td>
<td><strong>33.3</strong></td>
<td><strong>17.3</strong></td>
</tr>
</tbody>
</table>

**Source:** Calculated from Village-wise Death Registers, 2009

In 2009, a total of 83,322 years of potential life were lost due to cardiovascular mortality in the Bist Doab. Out of these, 56,752 years belonged to males while the rest (26,570 years) were of females (Table 2.1). On an
average 25.7 years were lost per thousand of population in the region. This figure was 33.3 in case of males and 17.3 in case of females. It clearly shows that the burden of cardiovascular diseases on male population is twice as much as on female population. The study region can be divided into following three broad categories based on the block-wise distribution of YLL per thousand persons and the resultant cardiovascular disease burden (Fig 2.9):

1. Areas of High Disease Burden (more than 30 YLL per thousand persons)
2. Areas of Moderate Disease Burden (24 to 30 YLL per thousand persons)
3. Areas of Low Disease Burden (less than 24 YLL per thousand persons)

1. Areas of High Disease Burden (more than 30 YLL per thousand persons)

The blocks recording more than 30 YLL per thousand of population constitute the spatial category of high cardiovascular disease burden. These blocks include Nakodar (40.8), Rurka Kalan (40.4), Nadala (39.1), Phagwara
(34.7), Tanda (34.7), Shahkot (34.5) and Jalandar West (30.9). All these areas extend in the form of a north-south belt lying in the central parts of the study region. A visual comparison of disease burden map with cardiovascular risk map shows that most of the areas with high cardiovascular risk score have high burden of cardiovascular mortality.

2. Areas of Moderate Disease Burden (24 to 30 YLL per thousand persons)

The areas of moderate burden of cardiovascular diseases recorded 24 to 30 YLL per thousand persons. The blocks falling in this category are Adampur (28.5), Saroya (28.2), Dhillwan (27.2), Hoshiarpur-II (27.5), Dasuya (27.3), Kapurthala (27.2), Jalandhar East (24.8), Talwara (24.7) and Nawanshahar (24.3). Most of these blocks are spatially contiguous to the high burden areas and fall in the moderate cardiovascular risk zone.

3. Areas of Low Disease Burden (less than 24 YLL per thousand persons)

The areas having less than 24 YLL per thousand persons fall in this category of low disease burden. The blocks in this lowest category are Phillaur (23.5), Aur (23.4), Hoshiarpur I (22.1), Lohian (22), Bhunga (21.4), Nurmahal (21.2), Mahilpur (20.4), Sultanpur Lodhi (20.4), Balachaur (20.2), Bhogpur (18.9), Hajipur (18.7), Garhshankar (18.1), Mukerian (15.5) and Banga (10.7). As expected, these blocks mostly have low and moderately low cardiovascular risk score, largely due to better health care facilities and uneven terrain in eastern parts.

The total economic loss incurred by premature cardiovascular deaths in the region has been given in Table 2.2. The estimates show that in 2009 the economic value of the potentially productive years of life lost due to cardiovascular diseases was more than Rs. 2 billion. The figure reflects the enormous amount of productivity loss caused due to premature cardiovascular deaths. This information is highly useful for the policy and decision makers who strive to improve the productivity of human resources in the concerned region. There is a need to conduct similar research for other leading causes of death to generate a comparative picture.
Table 2.2

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Median age</th>
<th>PPyLL per death (=60- median age)</th>
<th>No. of CVD deaths</th>
<th>Total PPyLL (=PPyLL per death x No. of deaths in each age group)</th>
<th>Economic Loss (Per capita income x PPyLL)</th>
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<tbody>
<tr>
<td>0-4</td>
<td>15*</td>
<td>45</td>
<td>30</td>
<td>1350</td>
<td>Rs. 5,77,15,200</td>
</tr>
<tr>
<td>05-09</td>
<td>15*</td>
<td>45</td>
<td>19</td>
<td>855</td>
<td>Rs. 3,65,52,960</td>
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<tr>
<td>10-14</td>
<td>15*</td>
<td>45</td>
<td>30</td>
<td>1350</td>
<td>Rs. 5,77,15,200</td>
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<tr>
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<td>17</td>
<td>43</td>
<td>101</td>
<td>4343</td>
<td>Rs. 18,56,71,936</td>
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<td>157</td>
<td>5181</td>
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<td>30-34</td>
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<td>185</td>
<td>5180</td>
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<td>23</td>
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<tr>
<td>40-44</td>
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<td>6444</td>
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<td>477</td>
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<td>3704</td>
<td>Rs. 15,83,53,408</td>
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<td>55-59</td>
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<td>1476</td>
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<tr>
<td>60-64</td>
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<tr>
<td>65-69</td>
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<tr>
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<td>0</td>
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<td>60**</td>
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<td>0</td>
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<td>80+</td>
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<td>0</td>
<td>1538</td>
<td>0</td>
<td>Rs. 0</td>
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<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>6796</strong></td>
<td><strong>48382</strong></td>
<td><strong>Rs. 2,06,84,27,264</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: Calculated from Village-wise Death Registers, 2009

*For deaths below the age of 15, it is assumed that if the children had survived, they would have worked for full 45 years of their economically productive life span upto the age of 60.

**Standard eldest productive age.

#Per capita income for Punjab in 2009-10 was Rs. 42,752 at constant prices of 2004-05 base year.

Conclusion

It can be concluded that the male population of the study region has much higher rate of cardiovascular mortality than the females, and most of the male cardiovascular deaths occur below the age of 60 years. In females this peak is noticed in comparatively older age groups. The burden of cardiovascular mortality in males is twice as much as in females. It has also been found that the incidence of cardiovascular mortality portrays clearly discernible micro-level spatial patterns in the study area. These patterns can be effectively attributed to the underlying physical, socio-economic and
cultural peculiarities of the region. The eastern parts of the region with uneven terrain have low rate of cardiovascular mortality, because the people of this area have physically demanding lifestyles and consequent low prevalence of obesity. The central flat plain of the study region has relatively much higher incidence of cardiovascular deaths, particularly close to the urban centres. This high rate is due to the adoption of urban way of life by rural population, sedentary and affluent lifestyle, physically inactive work environment and high levels of air pollution. The rural areas along major highways, especially those situated in close proximity to industrial complexes also have high mortality from cardiovascular diseases. It seems that cardiovascular diseases are radiating out of urban centres, expanding along the main arteries of transportation and trickling down into the rural areas. The flood plain belts of both Beas and Satluj rivers with widespread alcohol consumption also experience very high incidence of cardiovascular deaths. In addition to this, cardiovascular mortality is also high around Adampur, which experiences coldest winter temperatures in the region.

The composite cardiovascular risk index devised in this chapter has been successful in explaining 35% of the variation in cardiovascular mortality observed at block level. In economic terms, the premature cardiovascular mortality is causing huge productivity loss to the economy of the study region. The spatial patterns identified in this research work can serve very useful purpose in formulating rural-targeted health policies to curtail the further ascent of cardiovascular diseases. The rural health plans should concentrate on checking expansion of the modifiable risk factors. The government should take strict measures for controlling illegal liquor trade as well as for scaling down the huge quantities of alcohol sold at approved vends. There is an urgent need to launch mass awareness campaigns to enlighten the rural people about modifiable risk factors of cardiovascular diseases, so that they can learn to make healthy choices for living a risk-free life.
CHAPTER 3
PHYSICAL CORRELATES OF CARDIOVASCULAR DISEASES

Introduction

The physical geography of a region is considered to play a significant role in determining cardiovascular health of the concerned population. The components of physical setup of an area like topography, weather and groundwater hardness are thought to be related to prevalence of cardiovascular diseases through direct and indirect causal pathways. The influence of physical environment on health and well-being of people has been appreciated since ancient times. In 6th century B.C., Hippocrates, the father of Medicine, stated that “Whoever wishes to study medicine properly should proceed thus: In the first place to consider the seasons of the years…. the waters….the ground and the mode in which the inhabitants live and what are their pursuits, whether they are fond of eating and drinking to excess and given to sedentary living or, are fond of exercise and labour” (Adams, 1849). The aim of this chapter is to examine the role of physical factors particularly, relief, seasonal variation in temperature and groundwater hardness in determining the spatial patterns of cardiovascular diseases in rural Bist Doab.

Data and Methods

(a.) Physiography

The study area was divided into four physiographic units based on the variation in altitude (Manku, 2002). The topographical sheet of the region prepared by Defense Mapping Agency Topographic Center, Washington, D.C. (U.S.A.) was used. This toposheet was downloaded from the website of University of Texas, USA. This map was used because it displayed the attributes of whole Bist Doab on one sheet, as opposed to the Survey of India maps which portray the study region in great detail, spread over several sheets. A contour map of Bist Doab was prepared from the downloaded sheet on a contour interval of 50 metres. The data on cardiovascular mortality for
the year 2009 was noted down from the village-wise Death Registers of the study area and the mortality figures were aggregated for each physiographic unit. The method of visual comparison was used to explore the relationship between cardiovascular mortality and underlying physiography of the region. Subsequently, Robinson’s method of slope analysis was applied to calculate average slope in degrees. Karl Pearson’s coefficient of correlation was calculated to estimate the association between average slope and proportional cardiovascular mortality rate at the block level.

(b.) Seasonal variation in temperature

The data and information on temperature conditions of the study area were acquired from the website of India Meteorological Department, the Meteorological Observatory of Air Force Station at Adampur (Jalandhar district) and various newspaper reports. The month-wise deaths caused due to cardiovascular and non-cardiovascular diseases were noted down for the year 2009 from village-wise Death Registers of Bist Doab and were aggregated and plotted month-wise for the entire region using multiple-line graph. The map of climatic zones of the study area was prepared from the corresponding larger map of Punjab state, obtained from the Department of Soil and Water Conservation, Punjab. The method of visual comparison was used to investigate the potential influence of climatic conditions on the spatial patterns of cardiovascular mortality in the study area.

(c.) Groundwater hardness

The groundwater calcium hardness data was obtained from the website of Central Ground Water Board, India for the year 2005. The calcium content (mg/l) was noted down for 27 observation wells in the study area. Based on the variation in calcium content, the groundwater was classified into five categories of varying hardness. The point data of the observation wells was used to generate a continuous surface using Regularized Spline Interpolation technique in ArcGIS 9.3 software. This technique estimates and interpolates values using a mathematical function, by extruding the sample points to the height of their magnitude and bending a sheet of rubber that
passes exactly through the input points, resulting in a smooth surface with minimal overall surface curvature. The method of visual comparison was employed to observe the relationship between groundwater hardness and cardiovascular mortality in different parts of the study area.

**Physical Factors and Cardiovascular Mortality**

**A. Physiography**

The link between physiography and cardiovascular mortality has been thoroughly explored in literature. Living at moderate elevations generally results in protection against death from cardiovascular diseases (Ostadal et al., 2007; Theiss et al., 2008). People who are born at comparatively higher altitudes enjoy better cardiovascular health than their counterparts born at sea level (Faeh et al., 2009). Hill walking has a significant role in curtailing obesity, which is an important risk factor of cardiovascular disorders. It has been established that the people residing in uneven sloping terrain have comparatively higher levels of physical activity than those living in plain areas (Brownson et al., 2001; Sierra-Johnson et al., 2008). Consequently, the prevalence of obesity is low in hilly areas. Walking and living in hilly areas gives sufficient exercise (Bedford Borough Council, 2012). Further, sloping terrain has better quality of green spaces which encourage physical activity (Davies et al, 2008). Hilly areas also correlate with more scenic backgrounds which promote physical activity than the plain areas (Brownson et al., 2001).

In order to explore the role of physiography in determining the spatial patterns of cardiovascular mortality, the study area has been divided into the following four physiographic units based on variation in altitude (Figs 3.1 & 3.2):

(i.) The Shiwalik Hills
(ii.) The Foothill Plain
(iii.) The Upland Plain
(iv.) The Flood Plain
(i.) The Shiwalik Hills

The Shiwalik hills extend along the far eastern parts of Bist Doab region in north-west to south-east direction along the Himachal Pradesh border. The entire stretch of the hilly area has a length of about 130 km and breadth ranging from 5 to 12 km. The height of these hills increases gradually from 400 m to 600 m from west to east. The highest point (741 m) of Bist Doab is located in Mukerian tehsil of Hoshiarpur district. In Garhshankar and Balachaur tehsils, the Shiwalik hills are known as ‘Katar Dhar’. Towards the east of Garhshankar town, they form a rolling and dissected plateau-like upland which is popularly called ‘Beet Manaswal’. The Shiwaliks are mainly composed of sand, gravel, pebble, shale, sandstone and clay. Both the eastern and western slopes of the hills are badly dissected by numerous short ephemeral streams locally known as ‘choes’ and ‘khads’, which are seasonal in nature. The Shiwalik hills impart a pleasant variety to the otherwise
dominantly level topography of Punjab. They look diminutive when backed by the abruptly rising outer Himalayas, but independently they present a look of folded, highly eroded, steeply sloping and patchily forested hills (Hans, 2000).

![Bist Doab Physiographic Units](image.png)

There are 181 villages falling in this physiographic unit and a total of 1458 deaths were registered from all causes in these villages in 2009. Out of this total, 269 deaths (18.45%) occurred due to cardiovascular disorders. The figures given in Table 3.1 clearly show that the proportional cardiovascular mortality recorded in this hilly tract is much lower as compared to other physiographic units. This low incidence can be attributed to the physically demanding lifestyle of the people living in hilly areas. The uneven topography naturally provides opportunities to the inhabitants to develop a physically active lifestyle. In general, the level of physical activity has decreased in modern era as compared to the olden times because there is no need for man to remain physically agile anymore for his survival. Consequently, in recent times the health benefits of being active are derived through voluntary and not
obligatory physical activity (Durnin, 1992). However, people residing in uneven terrain like Shiwalik hills are still obliged to be physically active. Even moderate levels of physical activity are known to impart significant health benefits (Giles-Corti et al., 2002).

Table 3.1
Rural Bist Doab: Physiography and Cardiovascular Mortality (2009)

<table>
<thead>
<tr>
<th>Physiographic Unit</th>
<th>Altitude (in metres)</th>
<th>Total Deaths (from All Causes)</th>
<th>Cardiovascular Deaths</th>
<th>Proportionate Cardiovascular Mortality out of Total Deaths (in percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Shiwalik Hills</td>
<td>400 - 600</td>
<td>1458</td>
<td>269</td>
<td>18.45</td>
</tr>
<tr>
<td>The Foothill Plain</td>
<td>300 - 400</td>
<td>7064</td>
<td>1667</td>
<td>23.60</td>
</tr>
<tr>
<td>The Upland Plain</td>
<td>210 - 300</td>
<td>12910</td>
<td>3782</td>
<td>29.29</td>
</tr>
<tr>
<td>The Flood Plain</td>
<td>200 - 210</td>
<td>4943</td>
<td>1640</td>
<td>33.18</td>
</tr>
</tbody>
</table>

Source: Data aggregated from Village-wise Death Registers, District Offices of Registrar (Births and Deaths), Punjab, 2009

The Shiwalik region is economically less developed as compared to rest of the study area and hence the density of road network is also low. The rural folk generally follow *kutcha* trails on foot for commuting over short distances, which has resulted in the lower prevalence of obesity. In addition to this, the Shiwalik hills have much better tree cover than the rest of Punjab and offer many picturesque locales. The natural environmental conditions are in general less disturbed by human developmental activities. Working in natural environmental settings results in lowering of psychological stress. People who work in natural environment have higher ratings of overall happiness and lower ratings on anger and aggression (Hartig et al., 1991; Maas et al., 2007). Living in such tranquil surroundings promotes cardiovascular health of the concerned population. Moreover, this physiographic unit experiences relatively moderate climatic conditions due to higher altitude and rainfall than the rest of the study area, which reduces the stress related with extreme climatic conditions on the cardiovascular health of the people. The level of air pollution also decreases with increase in elevation, which is again an added
advantage to cardiovascular well-being, since air pollution is also an important risk factor in the development of cardiovascular diseases.

(ii.) The Foothill Plain

The foothill plain is situated on the western side of the Shiwalik range and is locally known as ‘kandi’. It is an uneven and dissected plain, running parallel to the hills between the contour lines of 300 to 400 m. The whole plain is strewn with innumerable choes, which are seasonal water channels. In fact, this piedmont plain has been formed due to the coalescence of alluvial fans formed by the choes flowing down the Shiwaliks. The material deposited in this region primarily consists of sand, with pebbles predominating near the hills. However, as one moves westwards, away from the hills, the deposition of clay becomes abundant.

The foothill plain is spread over 987 villages. In the year 2009, these rural areas registered 7064 deaths from all causes, out of which 1667 deaths (23.60%) occurred due to cardiovascular diseases. A comparison of this proportionate cardiovascular mortality with other physiographic units (Table 3.1) shows that this figure is higher than that for the Shiwalik hills, but lower than the other two physiographic units viz. the upland plain and the flood plain. In other words, this region forms a sort of transition zone between low cardiovascular mortality hilly belt and the high mortality flat plains lying below 300 m altitude. Due to their close proximity, the Shiwaliks exercise a moderation effect on the climate of this foothill zone. This area is also economically less developed and the local population is mostly engaged in primary activities like farming and animal husbandry. The level of affluence among the people is low and thus the mortality from lifestyle diseases like cardiovascular ailments is low.

(iii.) The Upland Plain

It is a flat alluvial plain situated to the west of the foothill plain. This plain has been formed by the depositional work of rivers Beas and Satluj. It is a very fertile plain and is formed of old alluvium (bangar). The slope of this plain is very gentle and varies between 300 m in the east to 210 m in far west
near the confluence of the two rivers. The region is primarily composed of clay and silt, with some mixture of sand and lime. Low sand dunes exist in the south and central parts of Kapurthala district and the south-western parts of Jalandhar district.

There are as many as 1332 villages situated in this physiographic unit, which together recorded 12910 deaths from all causes in the year 2009. Out of this total mortality, 3782 deaths (29.29%) resulted from cardiovascular ailments. This proportionate cardiovascular mortality is quite higher than that recorded for the Shiwalik hills and the foothill plains, but it is lower than the flood plain. The upland plains represent the economically most developed part of the study area. The geographical environment is obesogenic, with people having sedentary lifestyle coupled with rich dietary intake. The extreme summer and winter temperatures are recorded in this zone, both of which are positively associated with cardiovascular mortality.

Owing to the flat surface, the road density is high and hence the level of air pollution from vehicular traffic and industries is high, particularly in and around the big urban centres of Jalandhar and Phagwara (The Tribune, 12th November 2010; 16th November 2011). The rural cardiovascular mortality is high along all the major roads connecting the urban centres of this physiographic unit. Most of the villages lying along highways inter-connecting the urban centres of Jalandhar, Nakodar, Nawanshahr, Rahon, Hoshiarpur, Mahilpur, Garhshankar and Balachaur have recorded proportional cardiovascular mortality rate of more than 40%. This is despite the fact that most of the private cardiovascular specialty hospitals are situated in this area. Residents living in a neighbourhood with high traffic exposure have been found to report high self-rated stress (Yang et al., 2010). Biologically, traffic noise induces the release of stress hormones, which in turn adversely affects the cardiovascular health of the people. Moreover, the high density of motorable roads encourage the use of automobiles, even for short distance travel, which promotes physically inactive lifestyle.
### Table 3.2

Rural Bist Doab: Average Slope and Cardiovascular Mortality (2009)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Block</th>
<th>Average Slope (degrees)</th>
<th>Proportional Cardiovascular Mortality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bhunga</td>
<td>92</td>
<td>19.24</td>
</tr>
<tr>
<td>2</td>
<td>Balachaur</td>
<td>63</td>
<td>23.32</td>
</tr>
<tr>
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<td>Talwara</td>
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<td>20.93</td>
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<tr>
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<td>Mahilpur</td>
<td>52.5</td>
<td>18.44</td>
</tr>
<tr>
<td>5</td>
<td>Garhshankar</td>
<td>43</td>
<td>24.65</td>
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<tr>
<td>6</td>
<td>Hoshiarpur-II</td>
<td>41</td>
<td>27.22</td>
</tr>
<tr>
<td>7</td>
<td>Saroya</td>
<td>37</td>
<td>25.00</td>
</tr>
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<td>Dasuya</td>
<td>27</td>
<td>31.06</td>
</tr>
<tr>
<td>9</td>
<td>Hoshiarpur-I</td>
<td>25</td>
<td>21.93</td>
</tr>
<tr>
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<td>Banga</td>
<td>11.5</td>
<td>11.33</td>
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<td>11</td>
<td>Hajipur</td>
<td>9.5</td>
<td>17.11</td>
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<td>Aur</td>
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**Source:** Data aggregated from Robinson’s Method of Slope Analysis

**(iv.) The Flood Plain**

The flood plain has been formed by rivers Beas and Satluj and exists in the form of elongated belts along the two rivers. These belts are 5 to 7 km wide and are composed of new alluvium (*khadar*) consisting of silt, sand and
clay. The flood plain is locally known as ‘bet’ and is separated from the upland plain by a 3 to 5 m high bluff called ‘dhaya’. The bet area is absolutely flat and is prone to annual floods of the rivers. The whole area is marked by the presence of oxbow lakes, abandoned channels, mud, swamps and sand bars.

This physiographic unit contains 957 villages, in which 4943 deaths were registered from all causes in the year 2009. Out of this total mortality, as many as 1640 deaths (33.18%) occurred due to cardiovascular diseases. This physiographic unit recorded the highest proportion of cardiovascular mortality as compared to the rest of the region. The geographical conditions of this region are quite similar to those of the upland plain. Alcohol consumption is very high in this area. Traditionally, the belt is known for sugarcane cultivation due to availability of suitable soil-water conditions. It has been found through frequent visits to the area that people are using sugarcane (in the form of Jaggery) to produce illicit alcohol. The evidence reveals that this area leads in the production and consumption of illegal liquor, which is a major contributing factor for the recorded high cardiovascular mortality.

The results of Robinson’s method of slope analysis have been shown in Table 3.2 which portrays the distribution of average slope in the study area. The blocks with high degree of average slope are Bhunga (92º), Balachaur (63º), Talwara (56º), Mahilpur (52.5º), Garhshankar (43º) and Hoshiarpur-II (41º), all of which fall in the eastern parts of Bist Doab region (Fig 3.3). The distribution of average slope decreases westwards and almost all blocks falling in the physiographic units of upland plain and flood plain have nil average slope.

In order to analyse the effect of slope and uneven terrain on the incidence of cardiovascular mortality, Karl Pearson’s coefficient of correlation was calculated for the block level data of proportional cardiovascular mortality rate and average slope. The value of correlation coefficient worked out to be -0.4, which clearly proves that there is negative association, though not strong, between the two variables. According to the table of critical values of Pearsonian coefficient of correlation, the value of coefficient is significant (with p<0.05). So the areas with higher degrees of average slope have lower
incidence of cardiovascular mortality and vice versa in the Bist Doab. Thus the hypothesis that ‘the eastern hilly and foothill areas of Bist Doab have lower cardiovascular disease mortality than rest of the region where the relief is plain’ stands validated. It can be inferred from the above results that physiography has an important role to play in determining cardiovascular health of the people in the study region.

B. Seasonal Variation in Temperature

Several studies have highlighted the association of seasonal variation in temperature with cardiovascular mortality. Extremely high temperature can trigger the onset of cardiovascular events in vulnerable population (Koken, 2003; O’Neill et al., 2009; Vidale et al., 2010; Yu et al., 2010). Heat waves negatively affect the proper functioning of the cardiovascular system (Michelozzi et al., 2009). High environmental temperatures put excess stress on the heart. In hot environment, the body attempts to dissipate excess heat (mainly by sweating and by radiating heat from the skin) to maintain a
reasonably normal body temperature. The need to dispel heat places additional stress on the cardiovascular system (Fogoros, 2012). High temperatures also increase platelet and red cell count, blood viscosity and serum cholesterol levels. Moreover, heat-related mortality particularly affects individuals with lower level of socio-economic status because they have no access to indoor air conditioning (O'Neill et al., 2009). All these factors lead to high occurrence of cardiovascular mortality in extreme summer conditions.

On the other hand, cold temperature in winter season can also lead to increase in cardiac workload and higher blood pressure (Manfredini et al., 1999; Cheng, 2009). Cold stress can aggravate hypertension in hypertensive patients (Peng et al., 2002). There are increased chances of the occurrence of heart attack in winter months (Mustad et al., 1996). Many studies conducted in different parts of the world have documented an increase in cardiovascular events during peak winter season (Mercer et al., 1999; Cheng, 2005; Goerre et al., 2007; Widlansky et al., 2007; Vidale, 2010; Diaz et al., 2013). The cold season may also be associated with the flu season and the enhancement in the upper respiratory tract infection can adversely affect the cardiovascular system (Cheng and Su, 2010). The dense foggy conditions experienced during December and January (in northern hemisphere) can also affect the response times to treatment of both the patients and the medical care providers, thereby increasing the overall rates of cardiovascular mortality recorded during the peak winter season (Cheng, 2009).

The climate of the Bist Doab region is continental monsoon type. Summers are hot and winters are cold. The mean temperature during the summer season varies from 30º to 32º C. A hot wind called ‘loot’ blows around noon during the months of May and June, which increases the temperature considerably. The maximum temperature in the region can go up to 45º C. The winter season is moderately cold. The mean winter temperature ranges between 10º and 15º C. January is the coldest month, with temperature falling below the freezing point on many occasions. Fog and night frost is common during December and January. The lowest temperature of Bist Doab as well as Punjab has often been recorded at Adampur. In 2007, mercury declined to
a low of -3.8°C at Adampur, while in 2008 the temperature went down to a freezing low of -5°C. Till date, it was the year 1972 in which Adampur recorded the lowest ever temperature of -5.2°C which threw the normal life out of gear (The Tribune, 6th January 2011; 11th January 2011).

**Fig 3.4** - Rural Bist Doab: Month-wise Registered Deaths (2009)

The month-wise distribution of deaths caused by cardiovascular diseases (Fig 3.4) reveals that most of the cardiovascular deaths in the study area have occurred either in the intense cold month (January) or the extreme hot month of the year (June). Although the percentage of deaths recorded from cardiovascular diseases and non-cardiovascular diseases is almost the same during most part of the year, however there are two significant departures from this similarity of trends. The first point is that the mortality
from cardiovascular diseases is higher than the mortality from other causes during the hot summer months of May, June and July. The extreme hot months of May and June accounted for around 18% of total cardiovascular mortality in the rural areas of Bist Doab region. The second observation is that after the month of August, the mortality occurring due to non-cardiovascular diseases shows an almost uniform distribution, while the deaths caused by cardiovascular disorders register a considerable decline upto October and then rise drastically during the winter months of December and January. These peak winter months recorded nearly 20% of all cardiovascular deaths. The high rates of cardiovascular mortality recorded in peak summer and peak winter season can be attributed to the role of climatic stress in influencing cardiovascular health of the people (Cheng and Su, 2010).

![Fig 3.5 - Relationship between Temperature and Cardiovascular Mortality](image)

In the study area, the months of July and August have higher relative humidity than the rest of the year. Around 70% of the rainfall is received during the rainy season spanning from July to September. The rainfall in the
months of July and August occurs due to the moisture-laden south-western monsoon winds, while that in September is caused by the retreating monsoons flowing in reverse direction. The entire rainy season experiences heavy showers interspersed with alternate dry spells. The higher level of relative humidity is also associated with higher mortality due to cardiovascular diseases (Cheng and Su, 2010). In short the relationship between temperature and cardiovascular mortality can be visualized as a U-shaped curve (Fig 3.5), with high mortality rate in extreme low and high temperature and lower number of deaths in moderate temperature conditions. Scholars like Pan (1995), Goncalves et al. (2007) and Huang et al. (2012) have also found a similar association between cardiovascular mortality and the atmospheric temperature conditions.

In spatial terms, Bist Doab region can be divided into four climatic zones according to the classification adopted by Department of Soil and Water Conservation, Punjab (Fig 3.6). These four climatic zones are:
(i.) Sub-humid less hot zone (covering the Shiwalik hill areas in the eastern parts of Bist Doab region)

(ii.) Sub-humid dry moist zone (corresponding to the foothill plain adjacent to the Shiwaliks in Hoshiarpur and Nawanshahr districts)

(iii.) Sub-moist semi-arid zone (covering most of the upland plain and flood plain of central parts of the study area in Jalandhar and Kapurthala districts)

(iv.) Dry to sub-moist semi-arid zone (situated in the extreme western parts of the study area).

The spatial arrangement of these climatic regions shows that temperature conditions are comparatively moderate in the eastern parts of the study area, whereas temperature extremes become more prominent as one moves westwards. Visual comparisons show that the areas of Jalandhar and Kapurthala district experiencing severe winter and summer temperature conditions also record higher rates of cardiovascular mortality. In January
2009, the rural areas around Adampur, experiencing lowest winter temperature witnessed very high incidence of cardiovascular deaths (Fig 3.7). There are two clearly noticeable continuous belts of very high proportional cardiovascular mortality (more than 35%) running from southwest to northeast on both sides of Adampur. These belts include the blocks of Dhillwan, Nadala and Tanda, situated to the north of Adampur and blocks Shahkot, Nakodar, Jalandhar East, Rurka Kalan and Phagwara lying south of Adampur. The spatial incidence of winter cardiovascular deaths goes on decreasing towards the eastern margins of the study area. With a few exceptions, almost all the blocks lying in comparatively moderate climatic zones, viz. sub-humid less hot zone and sub-humid dry moist zone have recorded low occurrence of cardiovascular mortality (proportional mortality rate of less than 25%).

The geographical pattern of cardiovascular mortality recorded in June 2009 (Fig 3.8) shows that the blocks falling in sub-moist semi-arid zone and dry to sub-moist semi-arid zone have recorded high proportional mortality rate
(more than 34%). These blocks include Nadala in the north-central parts and Nakodar, Jalandhar East, Phagwara and Rurka Kalan in the south-central parts of the study area. The mortality rates are again low (less than 26%) in the eastern hilly areas and Kandi region, with exceptions of Dasuya and Saroya blocks. The summers are less hot in the eastern parts of the study region due to the moderating effect of the Shiwalik hills.

Thus it has been found that the areas experiencing extreme climatic conditions have recorded high mortality from cardiovascular diseases, whereas the areas with comparatively less extreme temperature conditions have registered lower rates of cardiovascular mortality. Therefore the hypothesis that ‘the areas experiencing lowest winter temperature in the region record higher mortality from cardiovascular diseases’ holds true. The seasonal variation in temperature exerts a strong influence on the spatial distribution of cardiovascular mortality in the Bist Doab.

C. Groundwater Hardness

According to the calcium content, groundwater is generally classified into soft (0 to 20 mg/l), moderately soft (20 to 40 mg/l), slightly hard (40 to 60 mg/l), moderately hard (60 to 80 mg/l) and hard water (above 80 mg/l) (Yorkshire Water, 2014). Groundwater hardness is inversely associated with cardiovascular mortality because of the protective effect of calcium intake from drinking water (Yang et al., 2006). The areas with calcium-enriched environment are acclaimed to have higher longevity. Calcium is known to be one of the most important ionic regulators of the heart, where it has a crucial role to play in maintaining the contractility of the heart muscle. In other words, calcium is necessary to sustain the contraction-relaxation function of the heart (Foster, 1997; Cartwright et al., 2005). The deficiency of calcium may lead to development of cardiovascular diseases. Inadequate levels of calcium intake are also associated with higher blood pressure (McCarran and Reusser, 2001) and hence the low hardness of drinking water contributes to higher occurrence of cardiovascular mortality (Sauvant and Pepin, 2000).
The population of Bist Doab region relies heavily on underground water for drinking and agricultural purposes. In general the water is sweet, however there is a significant variation in the hardness and mineral contents of groundwater (Kumar et al., 2006). The data of Central Ground Water Board for the year 2005 shows that the calcium content of groundwater in rural areas of Bist Doab varies from 87 mg/l at Chohal in Hoshiarpur district to 12 mg/l at Bara Pind in Jalandhar district (Fig 3.9). According to the amount of calcium content, the groundwater hardness of various observation wells of Bist Doab region can be grouped into five categories, as given below:

(i.) **Soft water (calcium content between 0 to 20 mg/l):** The locations having soft underground water include Bara Pind (12 mg/l), Rampur Bilron (16 mg/l) and Shamilpur (19 mg/l). Bara Paind and Shamilpur lie in Jalandhar district. The areas surrounding these two locations have recorded high incidence of cardiovascular mortality.
(ii.) **Moderately soft water (calcium content between 20 to 40 mg/l):** The observation wells recording moderately soft groundwater include Sujjon (21 mg/l), Dalla (21 mg/l), Paddi (25 mg/l), Khurampur (25 mg/l), Hajipur (27 mg/l), Alawalpur (27 mg/l), Udhopur (31 mg/l), Khaira Majha (35 mg/l) and Chak Ladian (39 mg/l). All these point locations are concentrated in the southern and central parts of the study area, except Hajipur and Chak Ladian, which lie in the north-eastern parts of the region. The wells of moderately soft water are situated in close proximity to the locations of soft groundwater and have recorded high rates of cardiovascular mortality.

(iii.) **Slightly hard water (calcium content between 40 to 60 mg/l):** The locations falling under this category are Paddi Jagir (41 mg/l), Jalbhe (41 mg/l), Bahram (43 mg/l), Mawai (45 mg/l), Bahowal (49 mg/l), Rurki (54 mg/l) and Argowal (60 mg/l). Most of these sites fall in juxtaposition to the moderately soft water areas and have also registered high mortality from cardiovascular disorders.

(iv.) **Moderately hard water (calcium content between 60 to 80 mg/l):** This category includes the observation wells at Bassi Mustafa (61 mg/l), Bhavnaur (62 mg/l), Nangal Bihala (62 mg/l), Karimpur Chhawala (62 mg/l), Rahian (68 mg/l) and Durimiwal (78 mg/l). Almost all these locations of moderately hard water fall in the eastern hilly areas of the study region, which corresponds to low cardiovascular mortality rates.

(v.) **Hard water (calcium content of more than 80 mg/l):** This category includes only one location of Chohal (87 mg/l), which falls in Hoshiarpur district. Chohal is again situated in the Shiwalik hills, recording very low mortality from cardiovascular ailments.

In order to generate a continuous raster surface from the point locations discussed above, spline interpolation technique was used. The output surface shows that the eastern parts of Bist Doab region have hard underground water (Fig 3.10). Comparisons with cardiovascular mortality patterns show that these areas are associated with low cardiovascular mortality. Thus the hypothesis that ‘the areas having hard groundwater have
low disease mortality in the region’ is proved. The general trend of hardness goes on decreasing towards the western side of the study area. The areas in central and west-central parts have soft underground water. The rates of mortality from cardiovascular diseases are high in these parts of the region. So it has been found that soft water areas have higher cardiovascular mortality rates, while the areas having hard underground water experience lower cardiovascular mortality.

**Fig 3.10**

**Conclusion**

In the end, it is concluded that physical environment has an important role to play in determining the spatial patterns of cardiovascular mortality in Bist Doab. The eastern hilly areas of the region have low incidence of cardiovascular mortality due to physically active lifestyle of the native population and the consequent low prevalence of obesity. The flat upland plain and the flood plain have high rates of cardiovascular mortality due to
sedentary lifestyle, rich dietary intake and high level of air pollution. The incidence of cardiovascular mortality displays a characteristic rhythm with respect to the seasons. The peak summer and peak winter season experience the highest number of deaths caused due to cardiovascular ailments. The areas in the central parts of the region, recording extreme temperature conditions, have higher rate of cardiovascular mortality. Climatic stress has been found to be an important factor in determining the spatial distribution of cardiovascular mortality. The areas of hard underground water, lying in the eastern parts of the study area have also recorded low occurrence of cardiovascular deaths, whereas the soft water areas towards the west have higher rates of mortality from cardiovascular ailments. Thus, it has been found that the physical factors, especially the physiography, seasonal variation in temperature and groundwater hardness have a crucial role in determining the cardiovascular health of the people. Therefore, it is advocated that the physical environment of an area should be given due consideration while developing preventive measures for this group of diseases.