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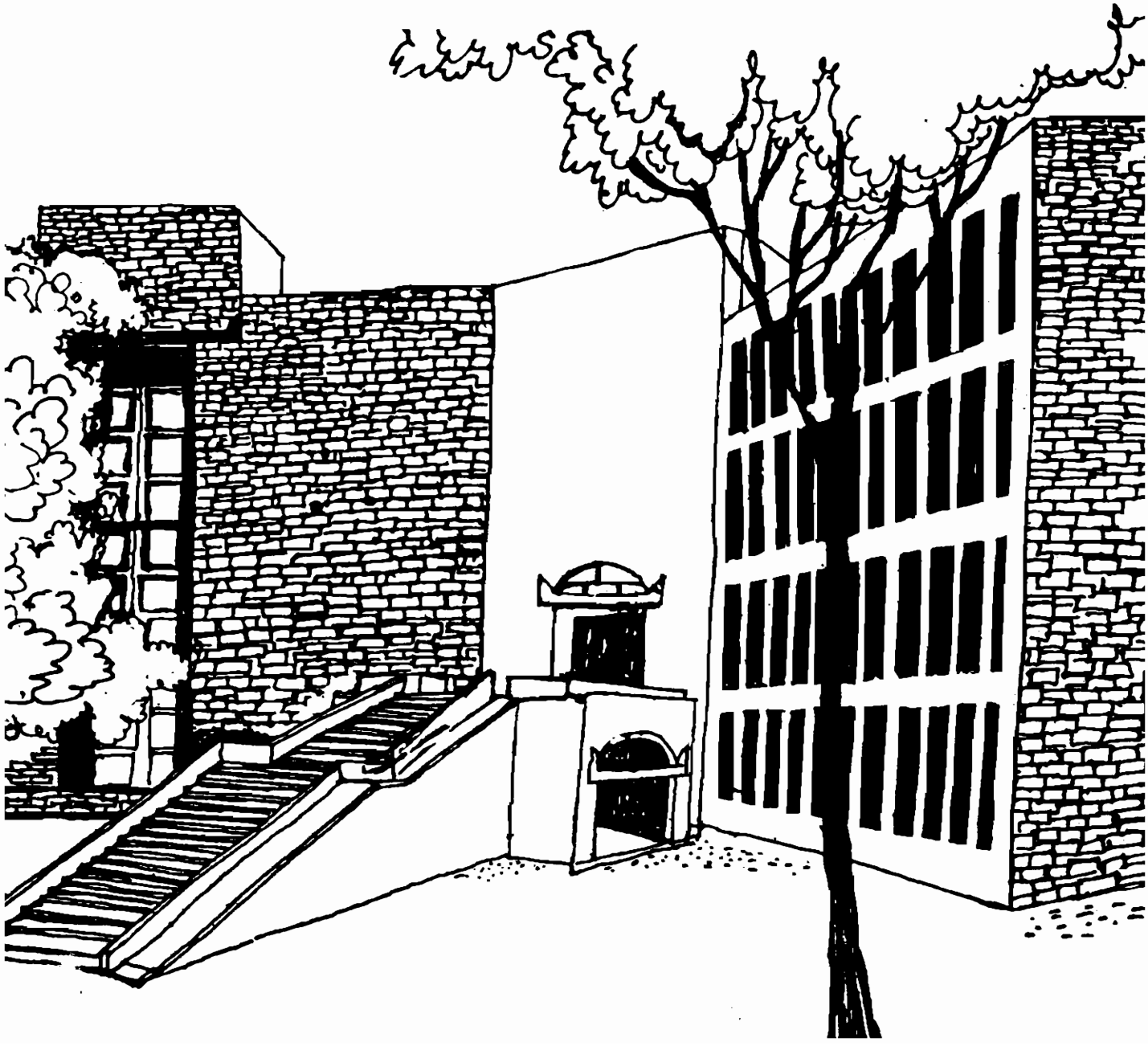

A PRELIMINARY NOTE ON RAIN-SHADOW EFFECT AND STRATEGIC FORESTRY

By
V. R. Gaikwad

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INDIAN INSTITUTE OF MANAGEMENT
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A Preliminary Note on
Rain-shadow Effect and Strategic Forestry

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Abstract

The purpose of this note is to present some tentative ideas on rain-shadow effect which may lead to further exploration of:

a) The relationship between the rain-shadow effect of the Western Ghats (the Syhadri ranges) and the drought-prone regions in the Peninsular India, especially, the Deccan Plateau;

b) Factors associated with the location of and area under the rain-shadow; and

c) Possible effect of manipulation of these factors, (e.g. strategically developed forest cover) on the location of and area under rain-shadow.

Underlying this exploration is a question and a philosophy. Why some regions in the Peninsular India have low rainfall and are drought-prone? If low rainfall is due to rain-shadow, we have two options: One, consider rain-shadow as a given, perpetual, natural topographical/geographical constraint, and concentrate on such activities as exploitation and conservation of available underground and surface water, bringing water to the region by canals, and undertaking relief operations during droughts. Two, scientifically analyse the very - cause, namely, the factors associated with the rain-shadow effect, and explore the possibility of manipulating these factors to minimise the rain-shadow effect.

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on
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1.0 Introduction

Certain regions in the Peninsular India fall under the rain-shadow effect of the Western Ghats. These regions get scanty rainfall and often suffer from drought. Often there is concentration of wastelands in such regions.

The purpose of this note is to present some tentative ideas on rain-shadow effect which may lead to further exploration of:

a) The relationship between the rain-shadow effect of the Western Ghats (the Syhadri ranges) and the drought-prone regions in the Peninsular India, especially, the Deccan Plateau;

b) Factors associated with the location of and area under the rain-shadow; and

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[1] Prepared by Professor V. R. Gaikwad, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad, October 1992.

Author is grateful to Professor Girja Sharan for providing references to various theories on aero-dynamics. Help of Mr. D. S. Parmar, Mr. M. S. Patel and Mr. Ajay K. Shah in preparation of maps is acknowledged.

options: One, consider rain-shadow as a given, perpetual, natural topographical/geographical constraint, and concentrate on such activities as exploitation and conservation of available underground and surface water, bringing water to the region by canals, and undertaking relief operations during droughts. Two, scientifically analyses the very cause, namely, the factors associated with the rain-shadow effect, and explore the possibility of manipulating these factors to minimise the rain-shadow effect.

Climate and rainfall are influenced by many known, and still unknown, factors operating at global level, far away from a locality, and hence at the present state of science and technology, cannot be controlled. However, phenomenon like rain-shadow is also affected by local topographical and other factors. Hence, it is possible to explore for a restricted geographical location the possibility of manipulating, to the extent viable, these local factors to control " micro-climate " for solution of localised problem.

Nature is often harsh, and forces her children to adopt, adjust and invent solutions for survival in harsh environment. None of its children - billions of species of plant and animal - extinct and current - has ever accepted Nature as given, and always invented ways and means for survival using what Nature has given as well as constantly tinkering with the Nature. And in Homo Sapiens this spirit and ingenuity is of the highest order. Using science and technology he has pushed back oceans and deserts, dammed and diverted rivers, tunnelled through mountains and beneath the seas, dug deep shafts in the Earth, carved passages through mountains, levelled hills and created new hills and lakes. The same spirit and ingenuity and use of science and technology should help to minimise the harsh rain-shadow effect. After all what is a mountain or a hill, but a big solidified pile of rocks, stones, sand and soil weathered and eroded for millions of years by Nature itself to its present profile, size and shape which Nature-- the perfectionist, never satisfied with its creation-- continues to change.

2.0 The Western Ghats and Rain-shadow Effect

Rain-shadow effect of the Western Ghats is often referred to by geographers and meteorologists while discussing the physical features and rainfall in Peninsular India. Some of the commonly known features of the Western Ghats and the Deccan plateau are given below.

2.1 Physical Features

The Gazetteer of India describes the physical feathers of the Peninsular plateaus as follows:

> The Peninsular plateaus consist of five distinctive physiographic subdivisions: Western hills, North Deccan plateau, South Deccan plateau, Eastern plateaus, and Eastern hills.
>
> The Western hills cover all the three sections of the Sahyadri-- northern, central and southern. The Sahyadri is composed of at least two different types of rocks of varying hardness on the basis of which the range can be divided into two sections. The northern 640 km. of the Sahyadri is built of horizontal sheets of lava. These have given rise to the typical Deccan Trap landscape. Viewed from the east, the range seems cut up into terraces, but from the west coastal plain it looks like a sheer wall. The crest line runs in broad curves, forming two re-entrants at Trimback and Tamhini, carved by the headwaters of the Godavari and Bhima rivers respectively, and two easterly bulges marked by Harishchandragarh (1,424 m.) and Mahabaleshwar peaks (1,438 m). Two other peaks rise higher, Kalsubai (1,646 m.) near Igatpuri and Salher (1,567 m.) 90 km. to the north of Nasik. Thalghat and Bhorghat are the important passes through which roads & railways run between the Deccan plateau and the Kokan plains.
>
> For the next 640 km, from 16 ^{0} parallel of latitude N. to the Nilgiri mountain, the granitoid gneiss takes the place of basalt and the countryside has a different aspect. The Sahyadri in this section runs very close to the coast and at several places comes down to the seashore, finally joining the Nilgiri mountain near

Gudalur. Vavul Mala (2,339 m.) is the highest peak.[2]

> The Palghat Gap, trending east-west, marks a prominent break in the continuity of the range along the western border of the Deccan plateau. It is about 24 km. wide at its narrowest point and lies at an elevation of 144 m., whereas the broadening ranges rise from 1,500 to 2000 m.... It is mainly due to this gap that the densely populated coastal plains of Kerala can be linked with the rest of the Deccan by roads and railways, and moisture-bearing clouds of the south-west monsoon can penetrate to some distance inland, bringing rain to the parched plains of Mysore. [3]

> Beyond the Palghat Gap the Sahyadri again continues southwards. It has different names in different parts, but is collectively known as the Southern Ghats. Anai Mudi, the highest peak (2,695 m.) is a nodal point from which three ranges radiate in three different directions. The Anaimalai in the north; the Palani in the north-east; and the Cardamom hills or the Elamalai in the south. The Anaimalai descends into a series of terraces to about 1,000 m. and the lower terraces are clothed with magnificent teak forests. [4]

> The orographical features of India have a pronounced effect on the flow of monsoon winds over the country and the distribution of rainfall. [5]

The Social and Economic Atlas of India provides further information on the elevation of the plateaus of the Peninsular India.

> The average elevation of the plateau that dominates most of Peninsular India ranges between 300 and 1800 m. It is possible to distinguish between elevation-based subdivisions of 300-600 m, 600-900 m, and 900-1800 m. A low elevation plateau (300-600 m) occupies the greater

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[2] *The Gazetteer of India: Indian Union, Vol.I, Country and People,* Publication Division, Ministry of Information & Broadcasting, Delhi 1965, p. 45.

[3] *ibid.*, p. 46. Emphasis added.

[4] *ibid.*, p. 46.

[5] *ibid.*, p. 73. Emphasis added.

part of the Deccan, Central India and the Chota Nagpur Plateau, and extends into Tamil Nadu, Karnataka and Andhra. A plateau zone between 600 and 900 m (the Nilgiris) lies in the southern part of the Deccan, where the Eastern Ghats approach and meet the Western Ghats. There are hill ranges in the Nilgiris going up to 1800 m with a peak of 2637 m at Doda Betta, near Udagamandalam. The residual blocks of the Aravalli and the Satpura also belongs to this subdivision. A zone ranging in height from 900 to 1800 m comprises hills and plateaux and is to be found in the Sahyadri range (near Ajanta) and in Orissa. A similar elevation is found in the north-eastern hills. [6]

The physical relief of the Peninsular India is presented in Figure 1. Generalised profiles from the Arabian Sea to Western Ghats crests are presented in Figure 2.

2.2 Annual Rainfall

The spatial variations shown by the isolyets, the line joining places with equal rainfalls, indicate the differences in annual receipts of rainfall in different parts of the country...[7]

The areas east of the 400 cm line along the west coast show rapidly decreasing rainfall averages over the narrow width of the Western Ghat, while the great land mass east of the ghats is a rain-shadow area (40-80 cms).[8]

The variation in rainfall are due to two important factors: The distance from the sea and the rain-shadow effect. The variations at different times shown by the histograms for selected stations emphasize the role, these factors play in the rainfall India gets....[9]
The rainfall distribution in the interior of India is mostly controlled by the rain-shadow effect; note the

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[6] *A Social and Economic Atlas of India,* Oxford University Press, New Delhi, p. 2.

[7] *ibid.*, p. 60.

[8] *ibid.*, p. 60. Emphasis added.

[9] *ibid.*, p. 60. Emphasis added.

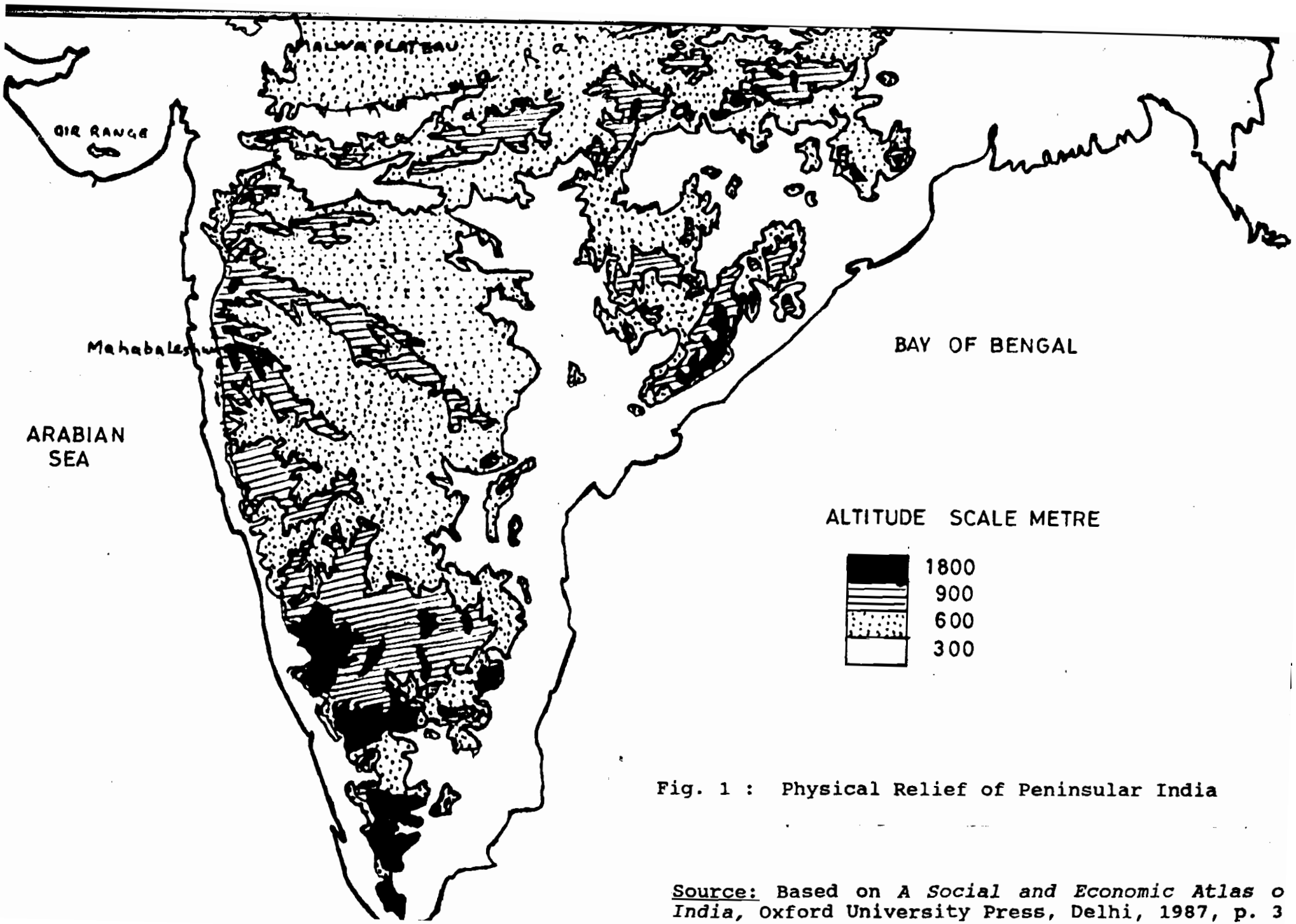
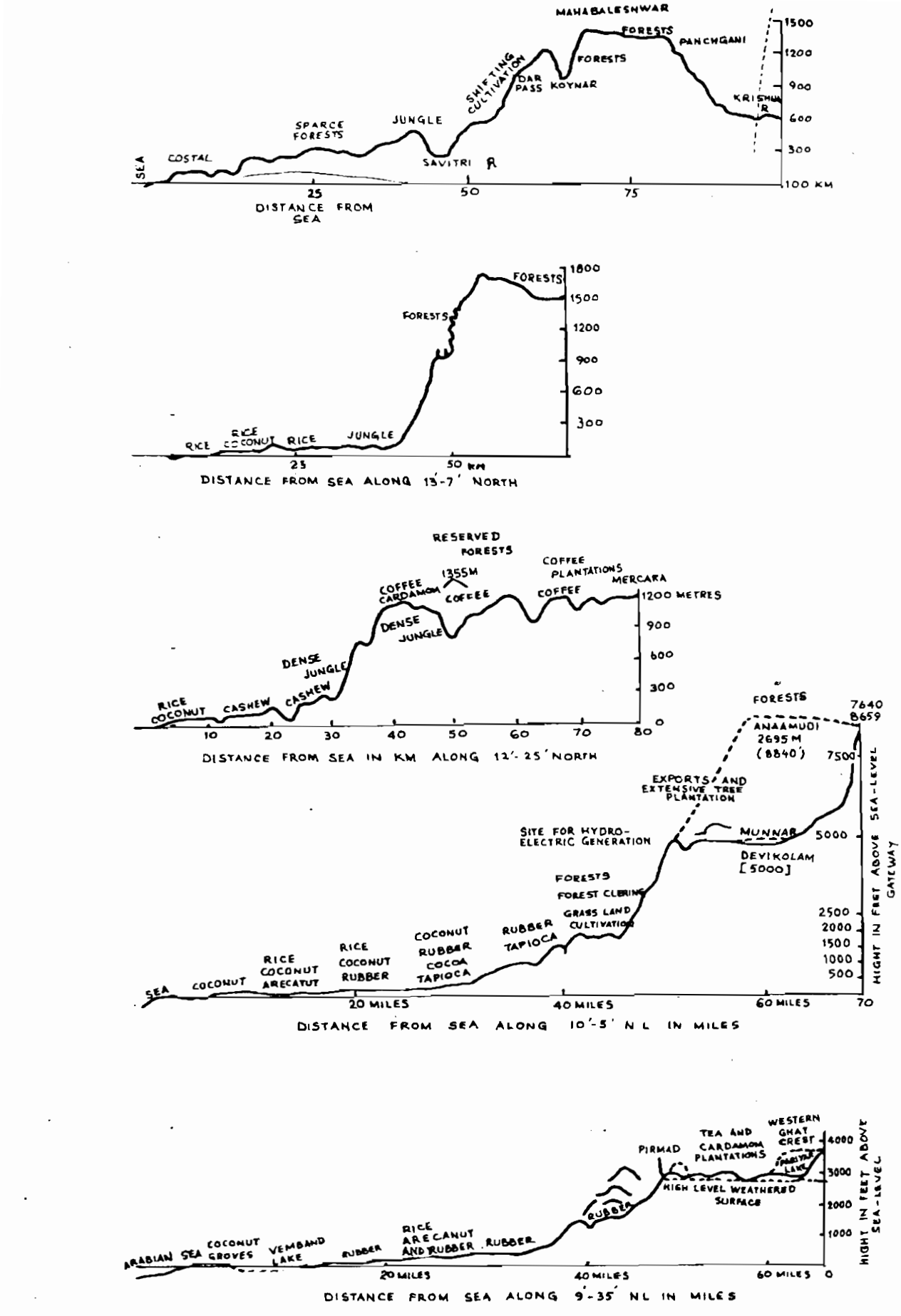


Fig. 1 : Physical Relief of Peninsular India

Source: Based on *A Social and Economic Atlas o India*, Oxford University Press, Delhi, 1987, p. 3



Source: K. R. Dikshit, *Environment, Forest Ecology and Man in the Western Ghats*, Rawat Publications, Jaipur, 1991, p. 195.

differences in rainfall receipts between the western slopes of the Western Ghats and the areas lying to the east - the rainfall decreases with distance from the sea. A reverse of this occurs in the north where the rainfall declines westwards with distance from West Bengal. The orographic, or relief, effect on rainfall is also seen in the distribution of rainfall, for the windward sides of the hills and mountains (Western Ghats, north-eastern hills and the Himalayan foothills) receive more rain than other parts of the country.[10]

2.3 Summer Rainfall

The rains of summer, however, are such that there are discernible variations in the areas covered. This is linked to two factors: humidity and relief. To a great extent, the pattern of rainfall and the pattern of humidity are the same. A low summer humidity of less than 70 per cent, affecting rainfall adversely, is found in two pockets, one along the east coast, taking in parts of Tamil Nadu and Andhra Pradesh (this stretch receives most of its rain from the north-east monsoon) and the other in the north-west, including parts of Rajasthan (the Thar Desert), Punjab and Haryana. On the other hand, wherever there are relief features in the path of the monsoon winds, the cloud-bearing slopes of the Western Ghats and the foothills of the Himalayas, most importantly in north-east India, where the Himalayan-Arakan Yoma ranges make a *funnel* of mountains (Cherapunji is at the mouth of the funnel), receive plenty of rain in summer. These areas also coincides with the areas of high humidity (more than 90 per cent). In the rest of the country the humidity is between 65 and 90 per cent and, correspondingly, rainfall is variable. Where the rain-shadow affects rainfall - in the land that stretches immediately east of the Western Ghats, taking in Tamil Nadu, interior Karnataka, Maharashtra and Andhra Pradesh - the rainfall decreases, the further east the monsoon moves from the high ranges.[11]

Along the west coast, the rainfall is high mainly due to the orographic, or relief, effect. But the rainfall decreases very sharply towards the east. The whole of the Deccan Plateau, accounting for a major part of Maharashtra, Andhra Pradesh, almost the whole of

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[10] *ibid.*, p. 60. Emphasis added.

[11] *ibid.*, p.62. Emphasis added.

> Karnataka and Tamil Nadu, experience very low rainfall (less than 40 cms) with only a few hilly areas relieving this arid monotony with a rainfall of 80 cms. Coimbatore and the south-eastern tip of Tamil Nadu, consisting of the coastal areas of the districts of Ramanathapuram and Tirunelveli, share with west Rajasthan, and Jammu & Kashmir the distinction of having the lowest rainfall in the entire country.[12]

Figures 3 and 4 present rainfall during June and December respectively. Figures 5, 6 and 7 present average annual, summer and winter rainfall respectively. Figures 8, 9, and 10 present average annual temperature and seasonal temperature (for July and January) respectively.

As an illustration of rain-shadow effect, data pertaining to topography, rainfall, vegetation cover, temperature and rain-shadow effect for Mahabaleshwar region are provided in Figures 11, 12 and 13. A comparative picture of temperature, humidity and rainfall at Harnai, Mahabaleshwar and Pune is provided in Figure 14, and of elevation, precipitation and evaparation at five locations in the Western Ghats in Figure 15.

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[12] *ibid.*, p. 62.

Fig. 3 : Rainfall during June

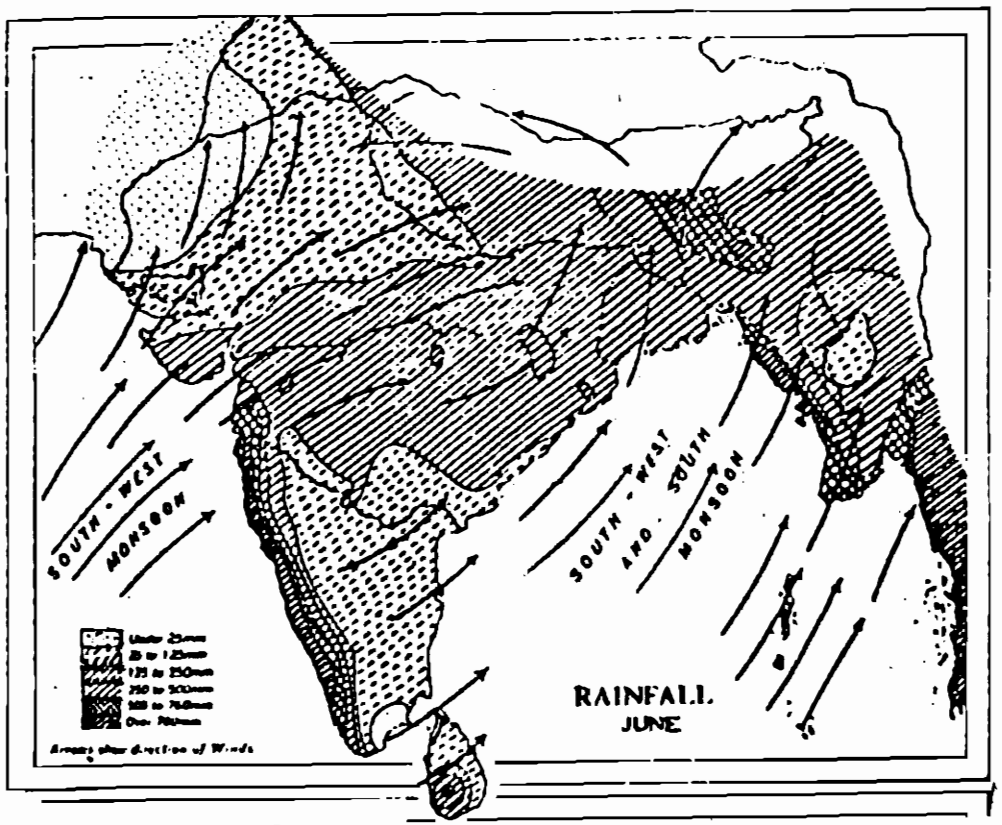
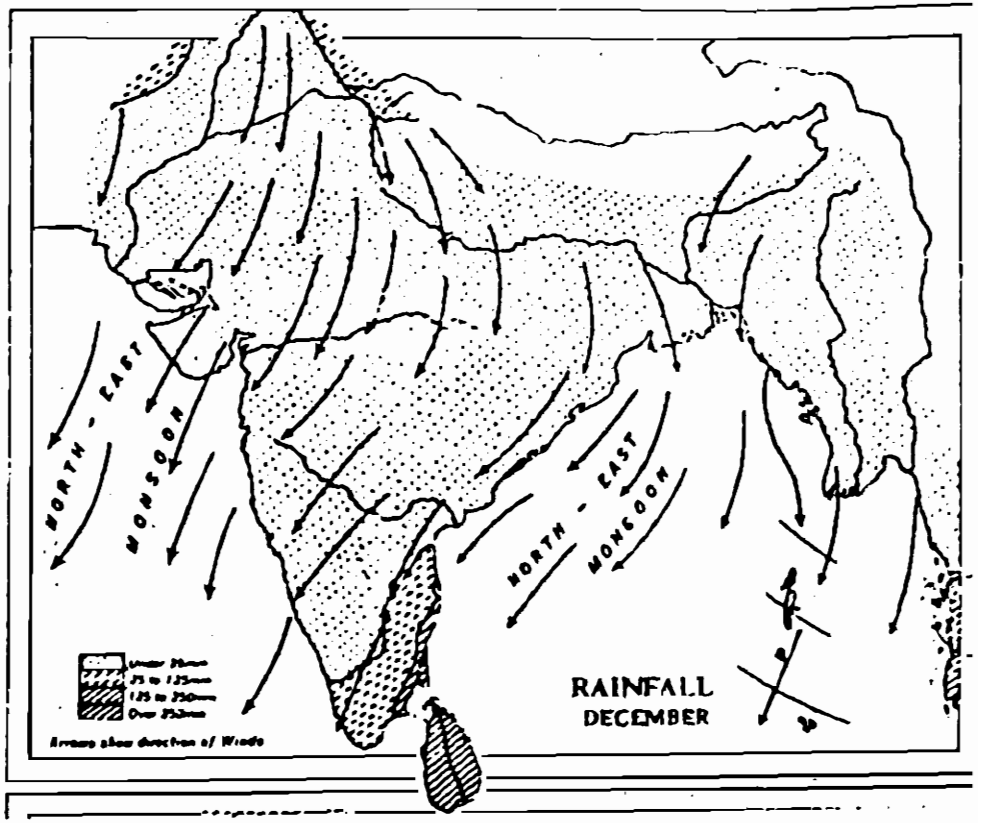
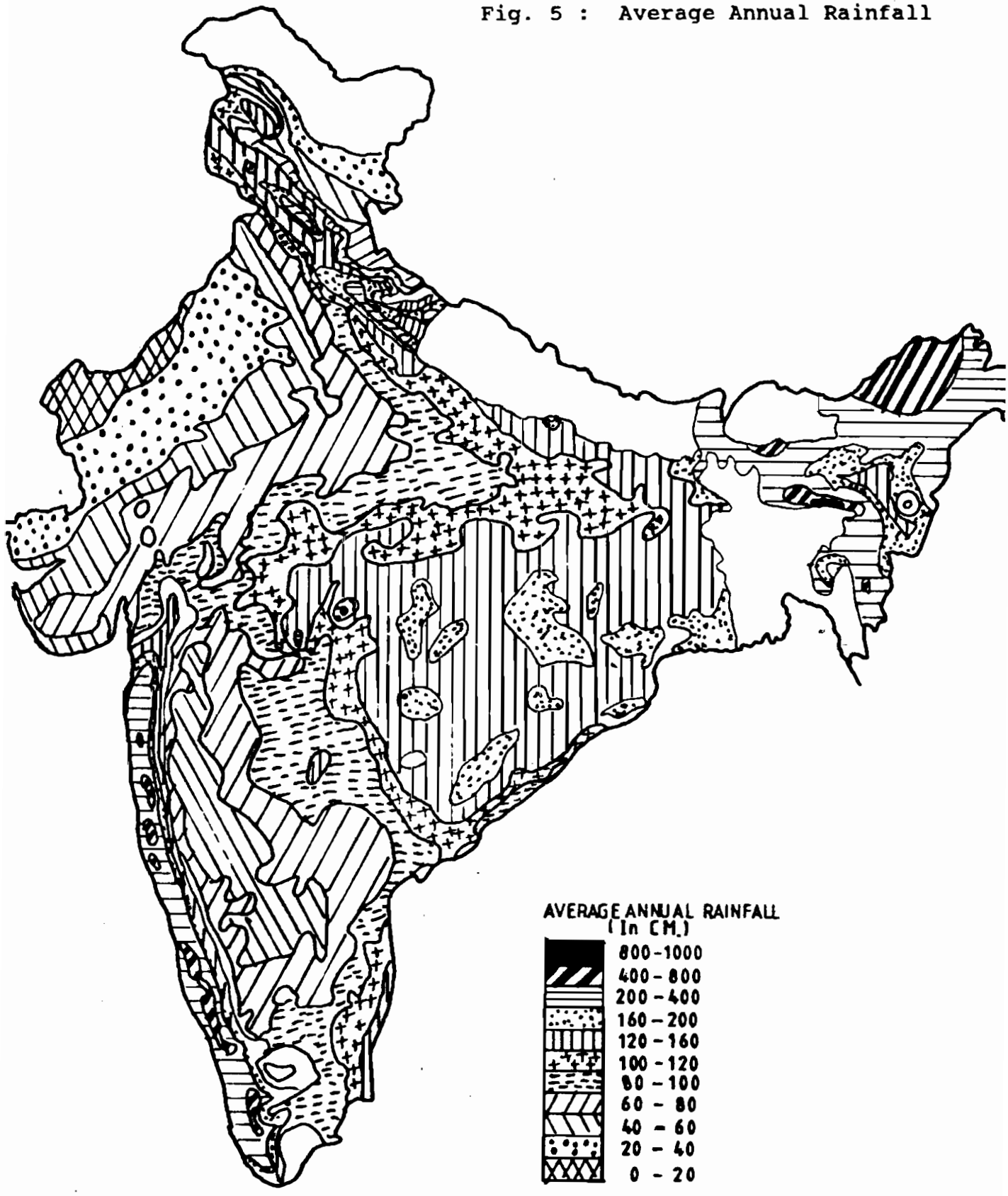


Fig. 4 : Rainfall during December



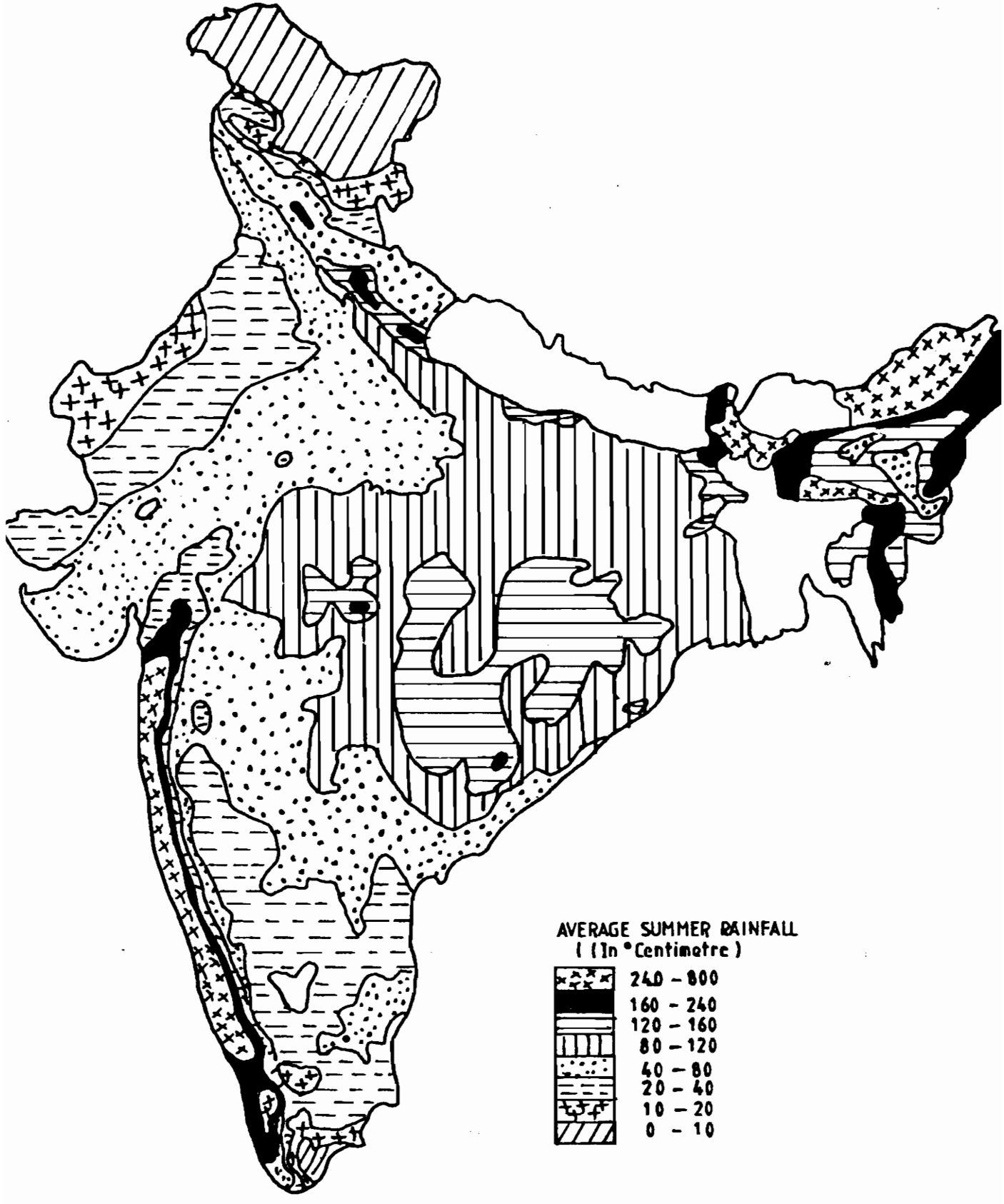
Source: *The Oxford School Atlas*, Twenty-Second Edition, Oxford University Press, London, 1973, p.15

Fig. 5 : Average Annual Rainfall



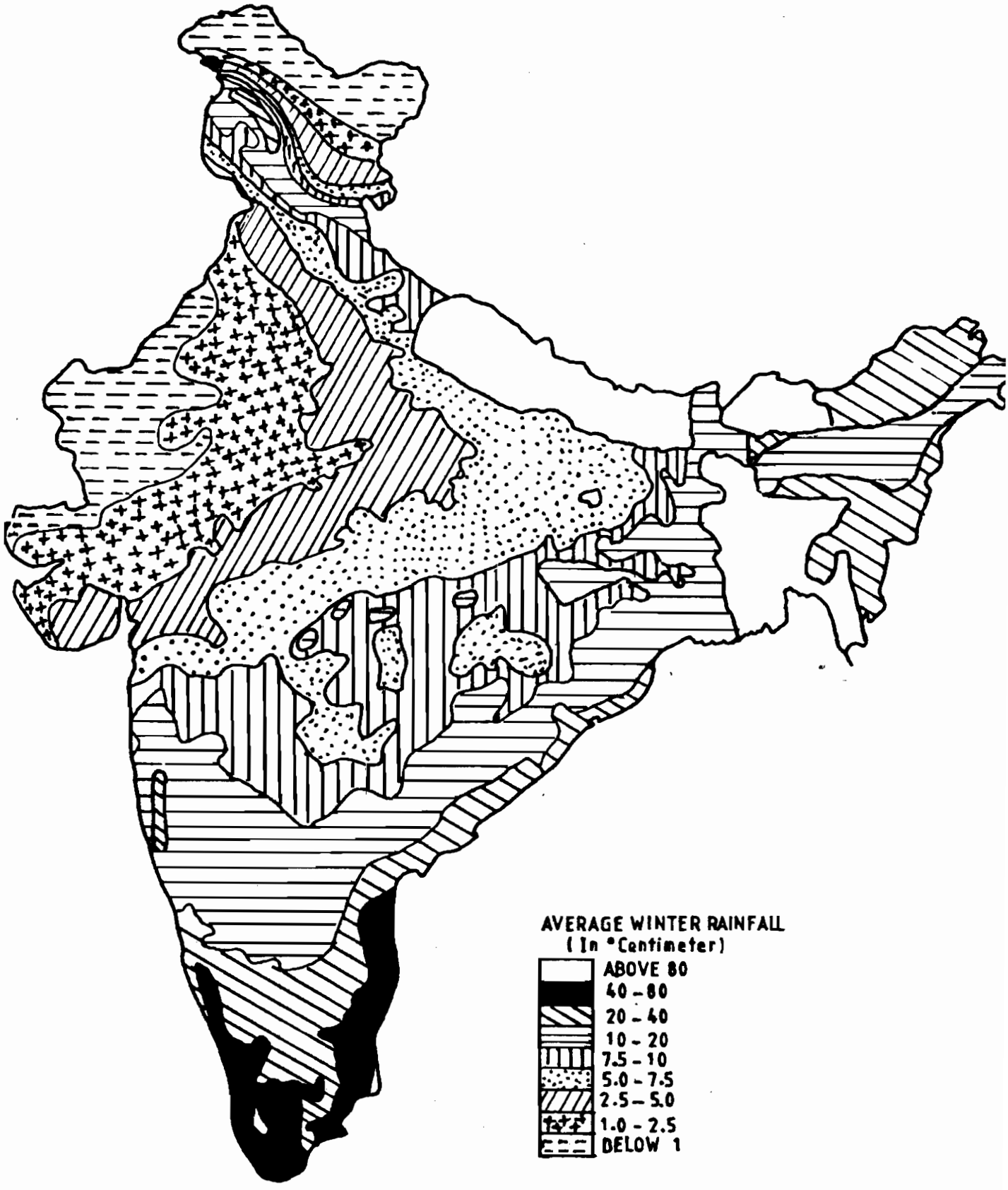
Source: *A Social and Economic Atlas of India, op.cit.*, p.61.

Fig. 6 : Average Summer Rainfall



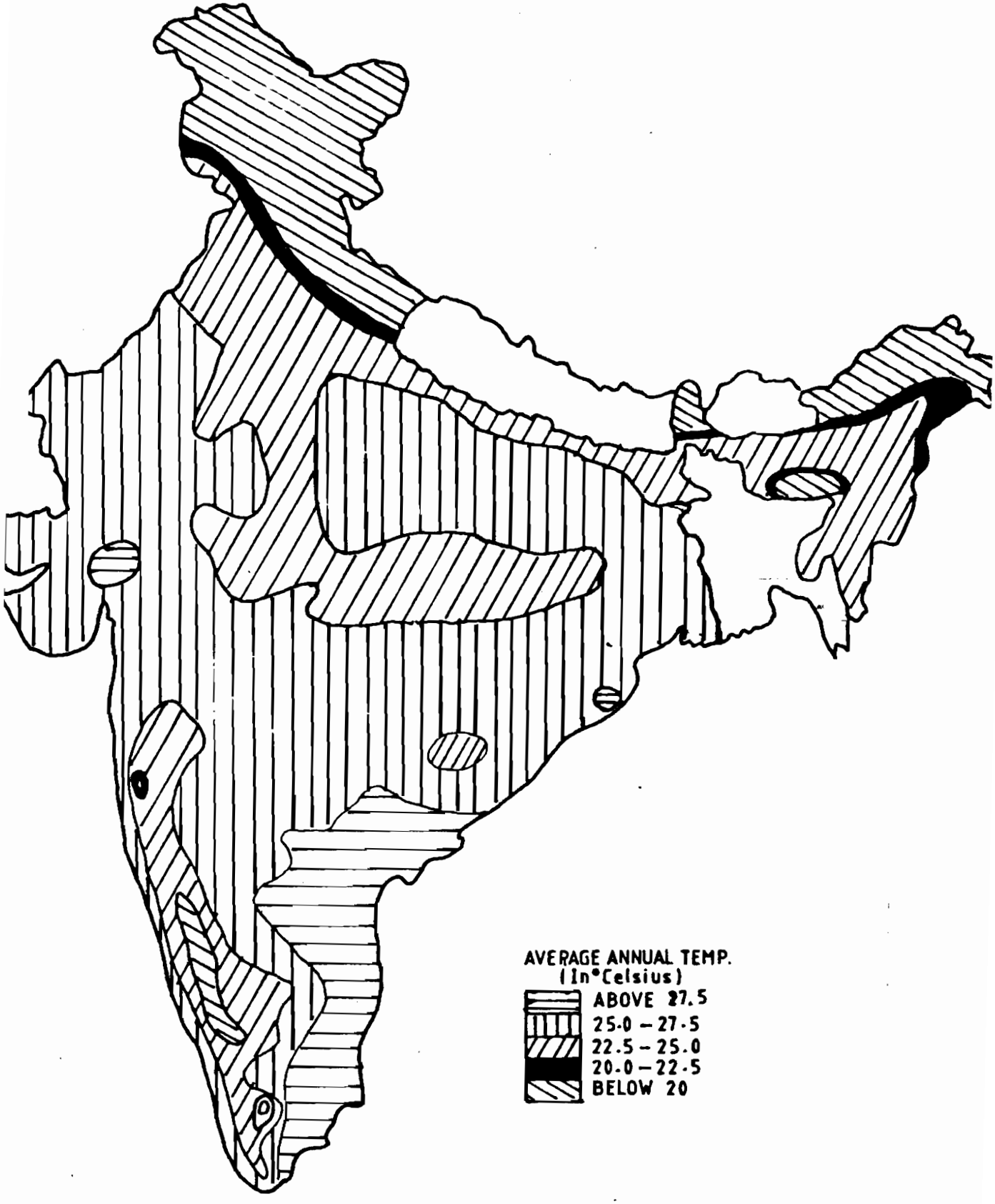
Source: *A Social and Economic Atlas of India, op.cit.*, p. 63.

Fig. 7 : Average Winter Rainfall



Source: *A Social and Economic Atlas of India, op.cit.*, p. 65.

Fig. 8 : Average Annual Temperature



Source: *A Social and Economic Atlas of India, op.cit.*, p. 67.

Fig. 9 : July Temperature

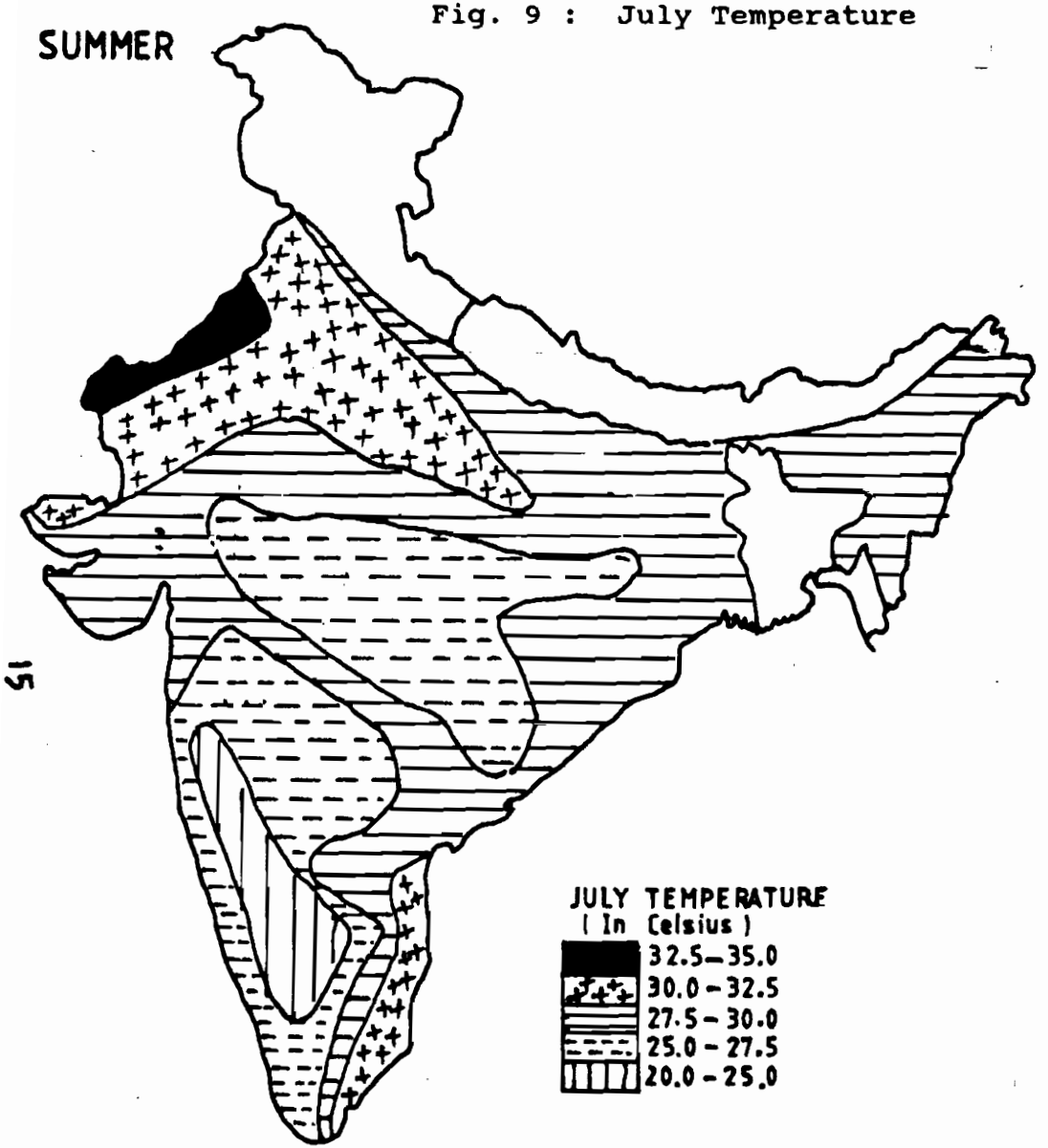
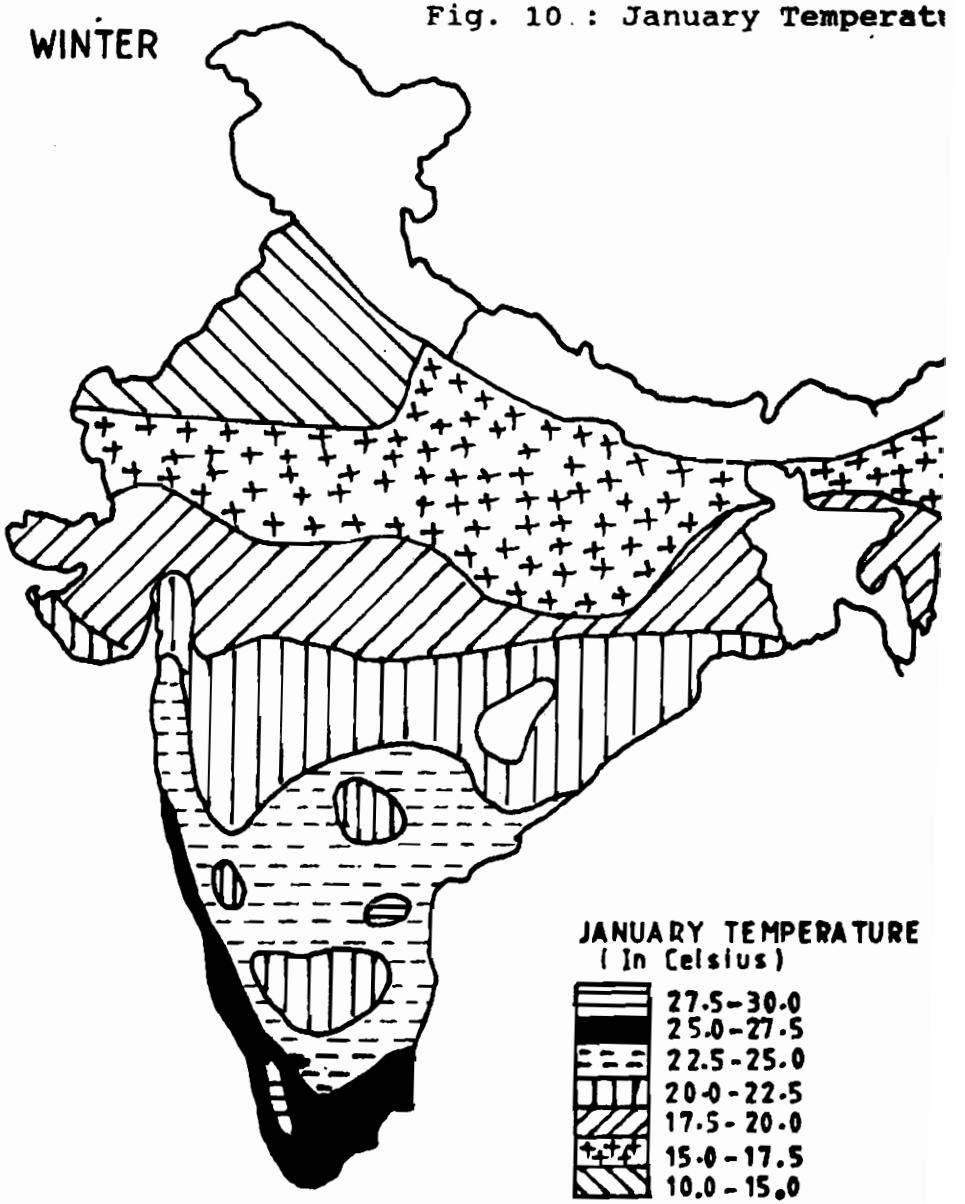
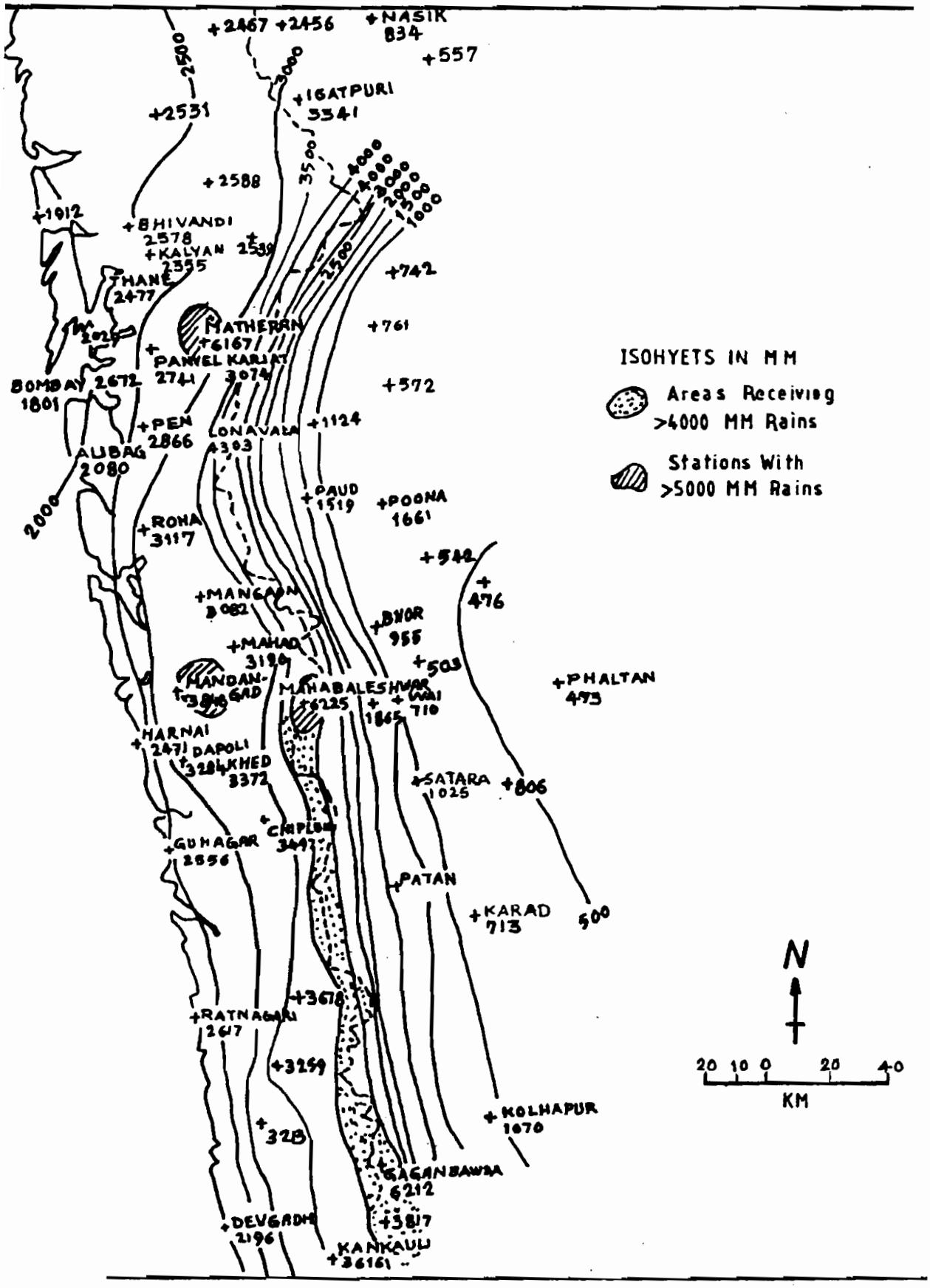


Fig. 10 : January Temperatu



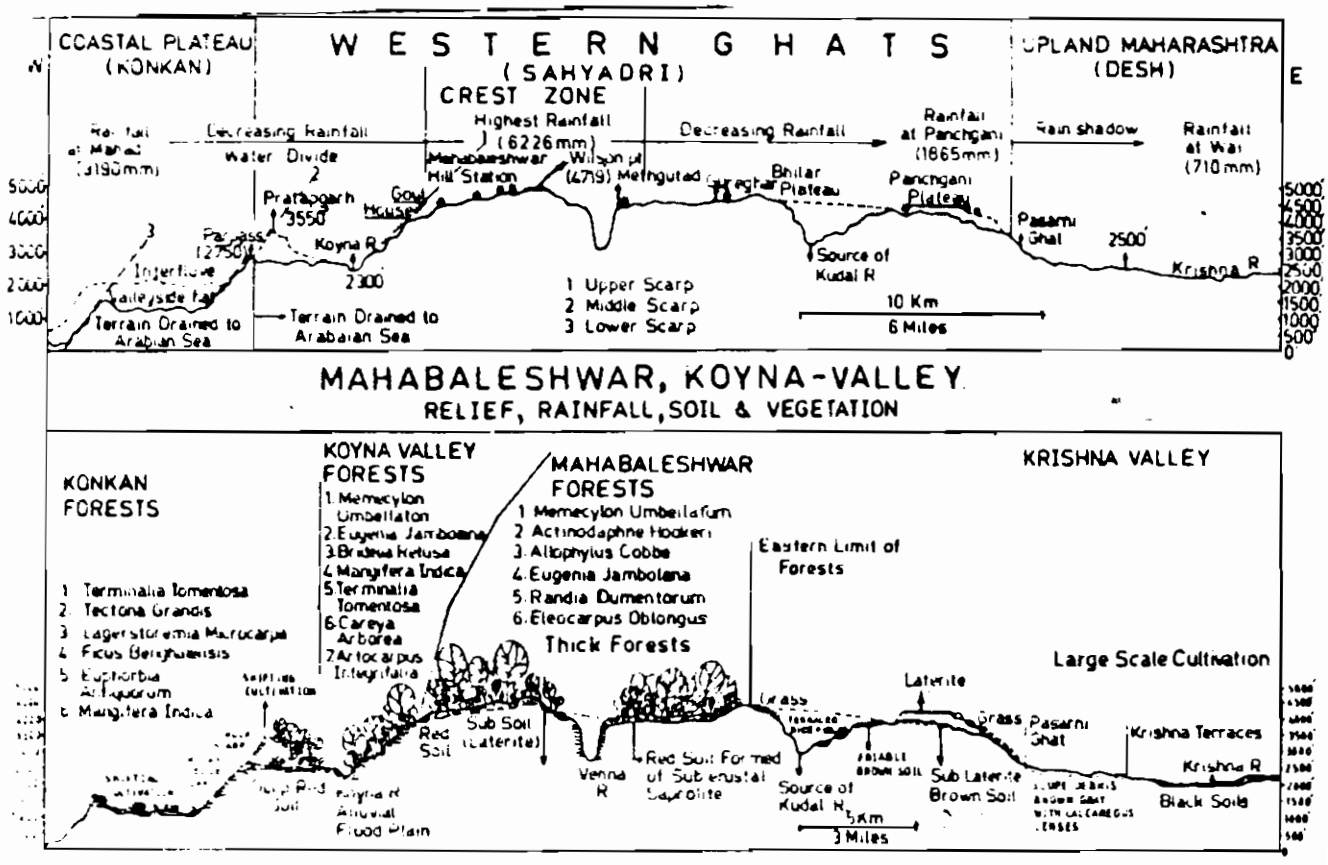
Source: *A Social and Economic Atlas of India*, op.cit., p. 69.

Fig. 11 : Rainfall in Konkan and Sahyadri (with Profile Sections and Rain-shadow Effect)

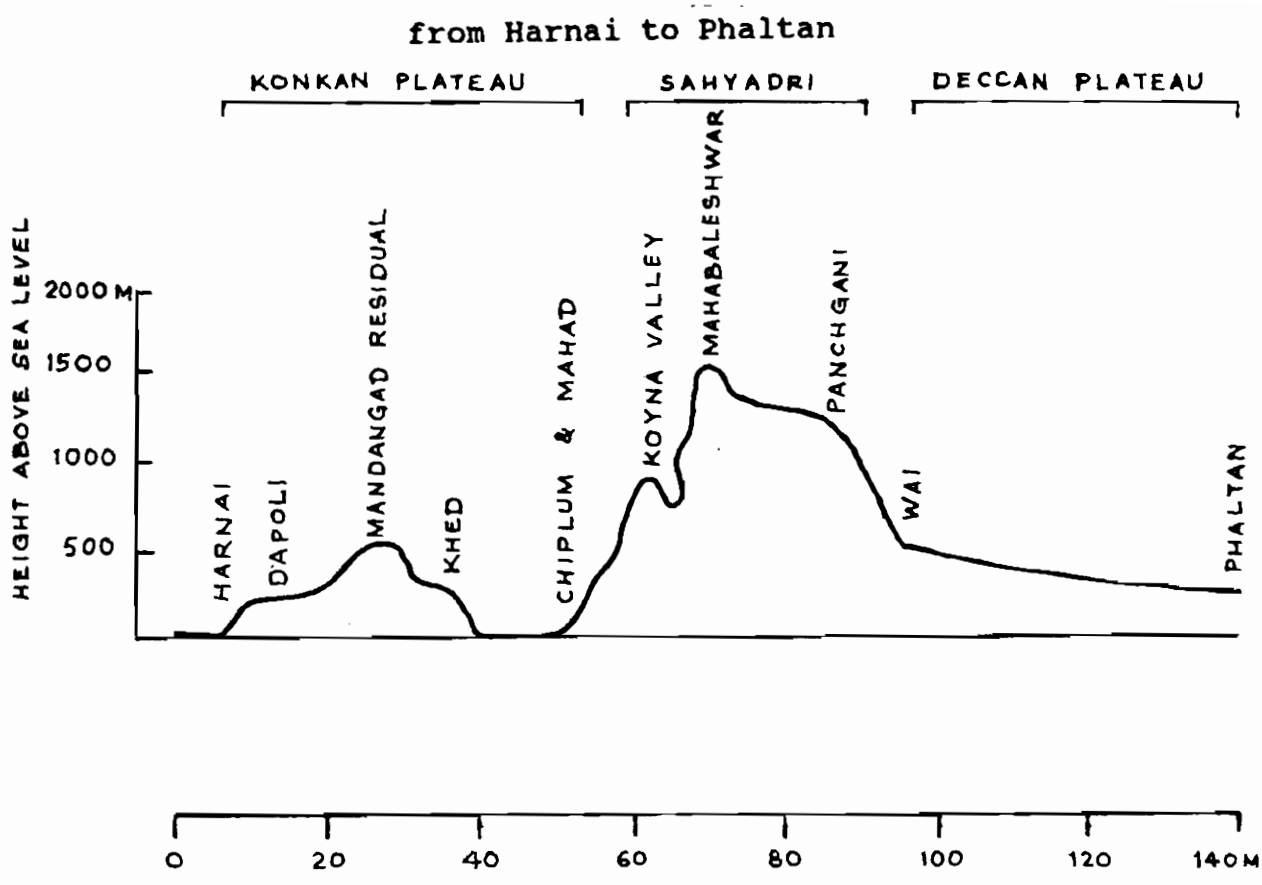


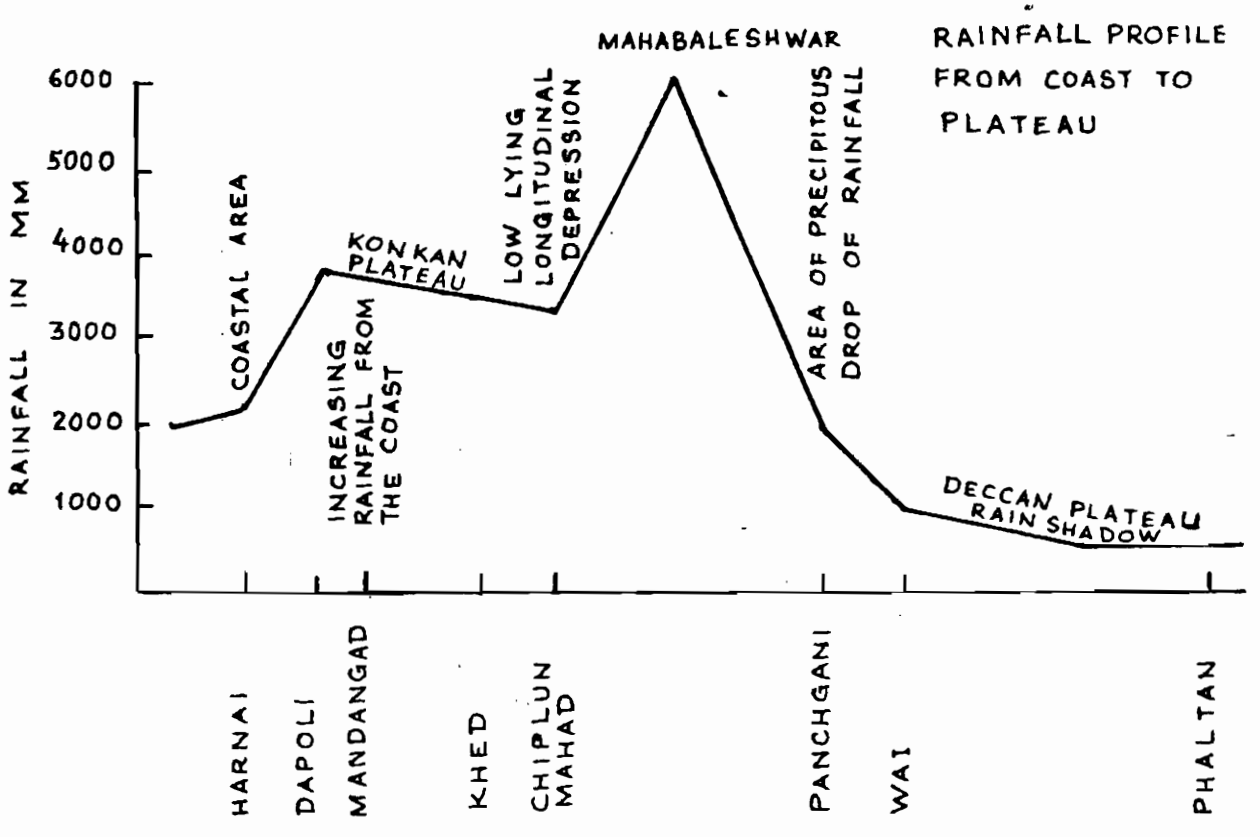
Source: K. R. Dikshit, *op.cit.*, p.25.

Fig. 12 : Mahabaleshwar, Koyna-Valley (Relief, Rainfall, Soil and Vegetation)



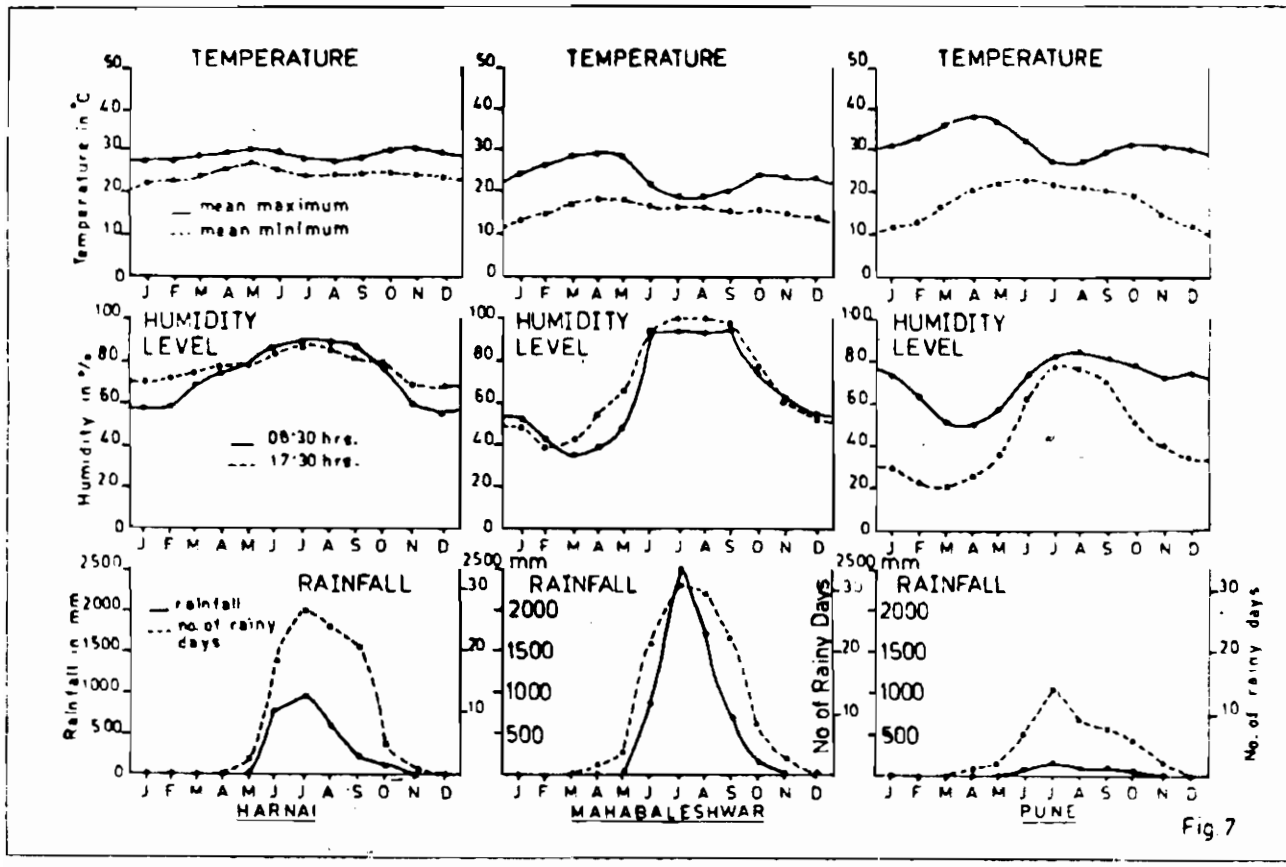
Source: K. R. Dikshit, *op.cit.*, p.82.





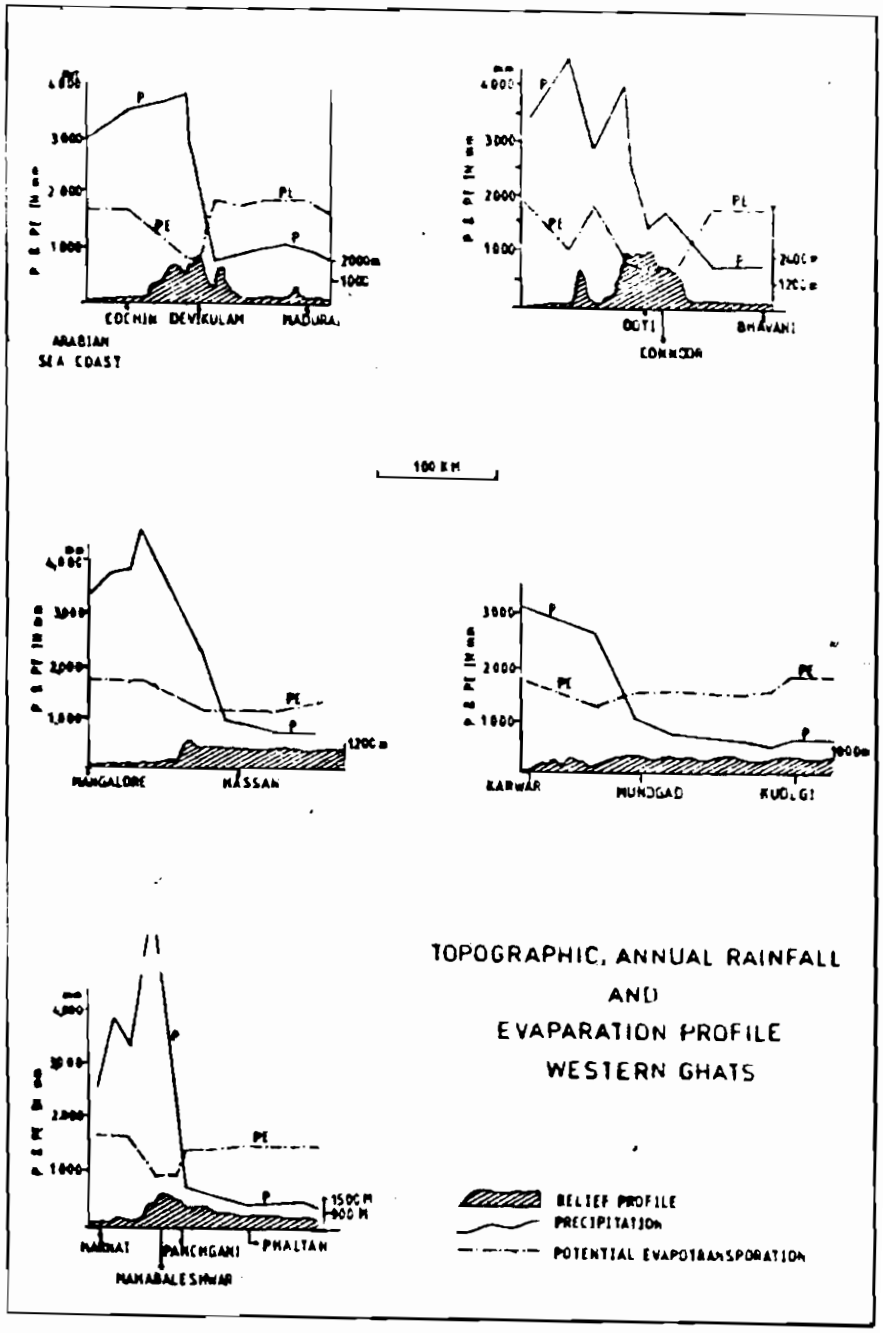
Source: K. R. Dikshit, *op.cit.*, p.25.

Fig. 14 : Temperature. Humidity and Rainfall
at Harnai, Mahabaleshwar and Pune



Source: K. R. Dikshit, *op.cit.*, p.23.

Fig. 15 : Topographic, Annual Rainfall and Evaporation Profile: Western Ghats



Source: K. R. Dikshit, *op.cit.*, p.71.

2.4 Climatic Regions

Three areas constitute the region of sub-humid climate occupying about a third of India, the region immediately east of the Western Ghats but in the northern reaches of the Peninsula receives maximum rainfall in summer, while the region in the south, in the rain-shadow, has a tendency to summer drought.[13]

A *tropical wet* climate is characteristic of the west coast, especially in Kerala, Karnataka and Goa, where both temperature and rainfall are high. A *tropical wet and dry* climate is mainly found along much of the east coast and in the interior of the northern Peninsula, with a tongue of such climate penetrating southwards into Maharashtra and Karnataka. In this region, both temperature and rainfall are important for land related activities, with rainfall perhaps more important, for it does not greatly alter crop rhythms. There are two patches of *semi-arid* areas, one in the south immediately east of the Western Ghats where the rain-shadow has the effect of causing drought, and the other in the north- west circling the desert, *arid* climate type.[14]

Figure 16 presents climatic regions of the Peninsular India.

2.5 Forests and Wastelands

Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu also suffer from lack of forest cover, mainly due to the rain-shadow effect (which makes the Deccan Plateau Semi-arid).[15]

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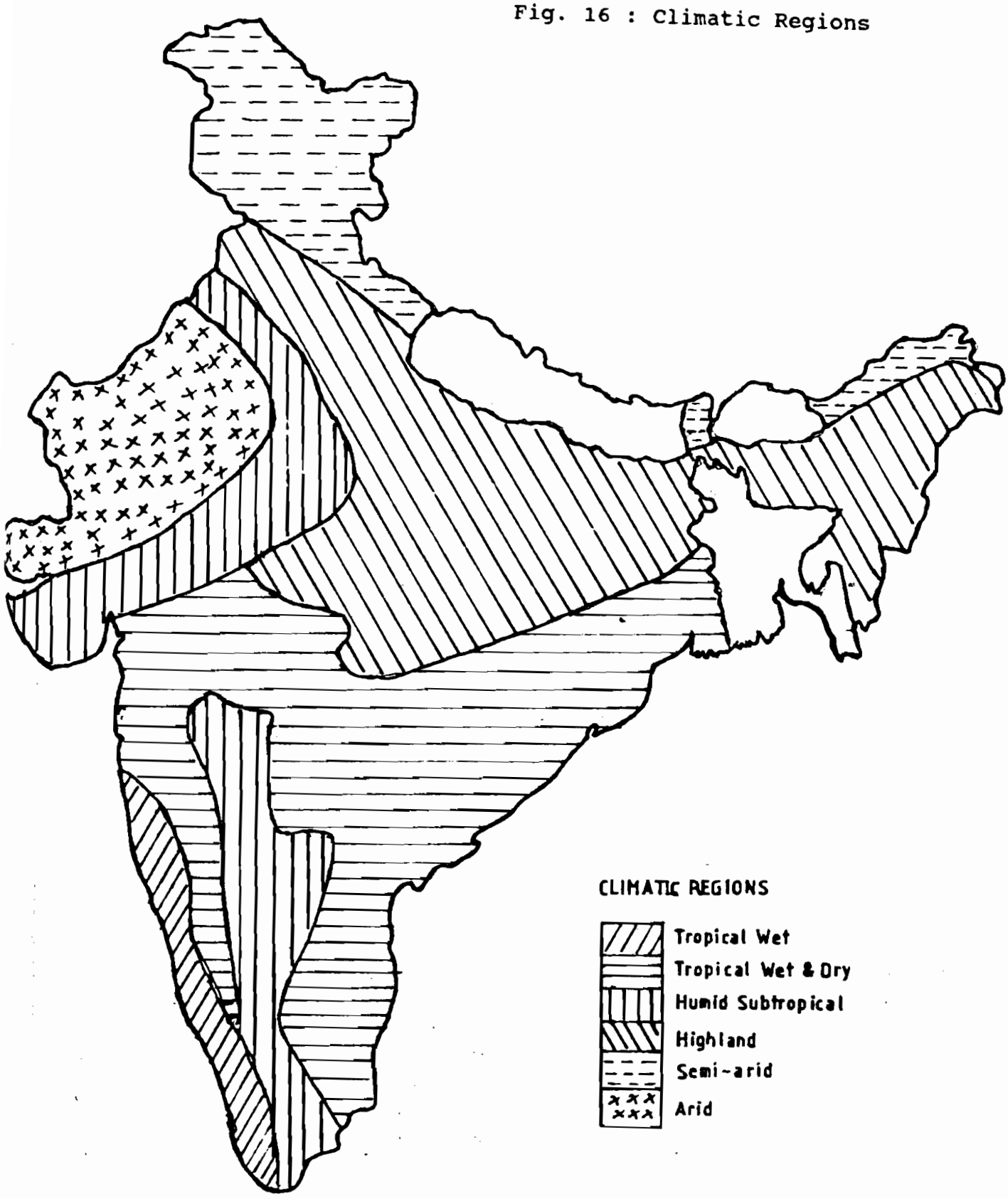
[13] *ibid.*, p. 82. Emphasis added.

[14] *ibid.*, p. 82. Emphasis added.

[15] *ibid.*, p. 84. Emphasis added.

Fig. 16 : Climatic Regions



Source: *A Social and Economic Atlas of India, op.cit.*, p. 83.

3.0 Concepts and Theories

3.1 Rain-shadow Effect

Rain-shadow is generally defined as:

An area of diminished precipitation on the lee side of mountains.... All mountains decrease precipitation on their lee; but rain shadows, as is shown by annual totals are sometimes not marked if moist air comes frequently from different directions, as in Applachin region.

The causes of rain-shadow are (1) precipitation of much of the moisture when air is forced upward on the windward side of mountains, (2) deflection or damming of moist air flow, and (3) downward flow on the lee slopes, which warms the air and lowers it relative humidity.[16]

3.2 Condensation

For condensation in the atmosphere it is necessary that air be cooled to and below its dew point. The only cooling process sufficient to produce appreciable precipitation is adiabatic expansion, which occurs in air rising toward lower pressures.... The rate of condensation in rising saturated air is greater the warmer the air and is directly proportional to the speed of ascent. [17]

3.3 Precipitation

The precipitation patterns can be viewed in terms of the relative frequency with which moist maritime air is present and the frequency with which the air is forced to rise to appreciable heights. The vertical structure and moisture is also important, because the structure may be stable and so resist vertical movement, or it may be conditionally unstable, so that when forced lifting has

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[16] *See,* "Rain shadow", *McGraw-Hill Encyclopedia of Science and Technology,* Vol.11, McGraw-Hill Inc., 1966, p.331.

[17] *ibid,* Vol.10, P.575.

produced condensation, the release of latent heat causes the air to rise to still greater heights.[18]

.... The monsoon areas have their maximum rains during summer, with an influx of very moist, conditionally unstable air. Here, as in the wet equatorial areas, the rainfall mechanisms are convection, orographic lifting, and convergence in minor eddy systems.[19]

The extremely dry areas are characterised by infrequent invasions of moist unstable air and relatively little cyclonic activity. The dry areas are the west east deserts, such as the Sahara; the desert basins that are shielded from fresh maritime air by high mountain, such as the Tarim Bagin; and the polar lands.[20]

3.4 Aerodynamics

There are various theories pertaining to dynamics of air flow around an object or obstacle. These are often evolved following the methods of classical hydrodynamics. Various devices such as airfoil are used to get useful reactions from motion through a fluid. Theories of aerodynamics have been extensively used for streamlining vehicles to reduce drag, and in designing aeroplanes taking into account the lift-drag ratio. To understand rain-shadow effect we will need a good understanding of the aerodynamic force. Such forces are described "in terms of the change in momentum of the air produced by its interaction with the body." [21]

4.0 Factors Associated with Rain-shadow

We, thus, see that the four factors which are interactively associated with rain-shadow effect are:

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[18] *ibid.*, Vol. 3. p. 177. Emphasis added.

[19] *ibid.*, Vol.3. p.177.

[20] *ibid.*, Vol. 3, p. 177.

[21] *ibid.*, Vol. 1. p. 84.

4.1. Wind

a) Wind velocity (speed and direction) at different heights and locations.

b) Effect of slopes (windward and leeward) on wind velocity.

c) Effect of surface resistance to wind velocity.

4.2. Topography

a) Height (elevation) of mountain/hill (obstacle to wind)

b) Direction of mountain/hill in relation to wind direction (parallel or at an angle to wind direction)

c) Length and breadth of mountain/hill

d) Windward and leeward slopes of mountain/hill

e) Elevation of rain-shadow area

f) Valleys and gaps in the mountain ranges and their elevation and width

4.3. Surface of Slopes and Rain-shadow area

a) Surface of windward and leeward slopes (smooth, giving least resistance to wind flow, or rough, obstructing wind flow).

b) Surface of rain-shadow area

c) Vegetation on mountain, slopes and rain-shadow area.

4.4. Temperature and Humidity

a) Moisture content of clouds (saturation level)

b) Temperature and humidity at different points of the

topography.[22]

c) Factors associated with micro-climate--temperature and humidity (such as water bodies, forests, soil structure, large heat generating factories, densely populated urban settlements,etc.), at local levels.

5.0 Rain-shadow Effect and Strategic Forestry

Theoretically speaking, all the factors associated with rain-shadow effect (discussed in Section 4.0) can be manipulated, to a more or less extent, to influence the rain-shadow effect. However, degree of difficulty and costs (both monetary and non-monetary) involved in manipulating different factors and known and unknown side effects will vary from factor to factor. Topography can be changed with levelling hills and/or creating new hills and valleys, and by increasing and/or reducing the angle of slopes by cutting and filling.

Among all the factors, perhaps, the easiest to manipulate, and least controversial, is the vegetation cover. It is expected to affect wind velocity, temperature and humidity factors at a local level and, consequently, the micro-climate of a limited area. If this factor is found to be associated with rain-shadow effect, then vegetation cover can be created at strategic locations, instead of the current practice of growing forests at any available and/or convenient location. Hence, possibility of strategic forestry to control rain-shadow effect and, consequently, the drought and wastelands needs to be explored.

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[22] Experiments have been conducted to encourage precipitation by seeding the rain bearing clouds by silver iodide. In an experiment metal wire nets were erected on the top of a mountain to encourage precipitation by contact cooling which is one of the minor causes of precipitation.

6.0 Need for Further Research

We have presented some information on the physical phenomenon of rain-shadow, and concepts and theories explaining this phenomenon. However, further research is needed to have a closer understanding of the cause-effect relationships between various parameters listed in Section 3.0 above and the rain-shadow effect in the Peninsular India. It is only after deep understanding of these cause-effect relationships one can think of manipulating the factors associated with rain-shadow effect for minimising the harsh conditions created by it.

6.1 Steps for Further Research

1. Review of researches (theoretical and experimental) on:
   a) rain-shadow effect and related factors in India and abroad.
   b) application of various concepts and theories of aerodynamics to rain-shadow and similar phenomena.
   c) concepts and theories on bio-climatology and water balance.
2. A workshop of experts/scholars from various disciplines/fields interested in rain-shadow effect to clarify varies aspects of rain-shadow and work out a research design.
3. Research design, data collection and analysis.

6.2 Approach

Research design and data requirements will very according to approach one follows as discussed below:

A. Macro or Theoretical Approach

Under this approach, we will need data on all the parameters

listed in Section 4.0 above for the entire Western Ghats (all Syhadri ranges) and Deccan Plateau. This will include: a) elevation by contour lines and profile sections at specific points (including in the direction of wind), physical relief (including aerial maps, satellite imageries, and ground data), b) meteorological data (wind velocity, rainfall pattern, temperature and humidity), c) nature of surface of slopes and plateau, and (f) surface cover (forest, grassland, barren land, etc.).

Using various theoretical constants (from theories of aerodynamics and meteorology), possible rain-shadow areas are computer simulated, and areas thus identified are compared with the ground realities --actual meteorological data for the rain-shadow and drought-prone regions --for further simulation and refinement of theoretical models. Based on this exercise, **Rain-shadow Effect (RSE) Tables** are constructed which should help identification of rain-shadow areas from any set of parameters and vice-versa. Possible effects of manipulation of factors associated with rain-shadow on rainfall and other climatic changes at distance places are also theoretically worked out through such exercise.

B. Micro or Applied Approach

Under this approach, each drought-prone region is treated as a clear-cut entity (unit) and is thus demarcated. Assuming that each such regions falls under the rain-shadow of some specific mountain/hill, attempt is made to identify the specific mountain/hill/range, and collect topographical & meteorological data for that specific mountain/hill/range and the associated drought prone region.

Data for each drought-prone unit and associated mountain/hill/range is then analysed following various theories related to rain-shadow effect, and factors associated with rain-shadow effect are identified.

Following this, possible effects of manipulation of various factors are simulated to work out theoretically possible as well as specific practical recommendations for each rain-shadow/ drought-prone unit.

6.3 Composition of Research Team

Such a project by its very nature has to be multi-disciplinary. It will need expertise from various disciplines/fields such as geography, cartography, meteorology, climatology, engineering, statistics, aerodynamics, botany, natural resource, conservation, and economy.

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