"AGRO-CLIMATIC AND AGRO-ECOLOGICAL CHARACTERIZATION OF CHHATTISGARH"

M.Sc. (Ag.) THESIS

by

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DEPARTMENT OF AGROMETEOROLOGY
COLLEGE Of AGRICULTURE
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CERTIFICATE - I

This is to certify that the thesis entitled **"AGRO-CLIMATIC AND AGRO-ECOLOGICAL CHARACTERIZATION OF CHHATTISGARH"** submitted in partial fulfilment of the requirements for the degree of **"MASTER OF SCIENCE IN AGRICULTURE"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Shri SANJAY BHELAWE** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate, awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: 23/9/07

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CERTIFICATE - II

This is to certify that the thesis entitled **"AGRO-CLIMATIC AND AGRO-ECOLOGICAL CHARACTERIZATION OF CHHATTISGARH"** submitted by Shri **SANJAY BHELAWE** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) in partial fulfilment of the requirements for the degree of **M.Sc. (Ag)** in the **Department of Agrometeorology** has been approved by the external examiner and Student's Advisory Committee after oral examination.

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"Education plays fundamental role in personal and social development and teacher plays a fundamental role in imparting education. Teachers have crucial role in preparing young people not only to face the future with confidence but also to build up it with purpose and responsibility. There is no substitute for teacher pupil relationship". I start in the name of God who has bestowed upon me all the physical and mental attributes that I possess and skills to cut through and heal a fellow human.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
ACRI	Agroclimatic Resource Index
AEC	Agro-ecological cells
AER	Agro-eco Regions
AESR	Agro-eco Sub regions
AEZ	Agro-ecological zoning
ASTER	Advanced Spaceborn Thermal Emission and Reflection Radiometer
ATM	Airborne topographic mapper
DEM	Digital elevation modal
FAO	Food and agriculture organization of united nation
GIS	Geographical information system
IBSRAM	International Board for Soil Research and Management
IDW	Inverse Distance Weighting
IFSAR	Intermap Interferometric Synthetic Aperture Radar
IIASA	International institute of applied system analysis
LADA	land degradation assessment in dry lands
LGP	Length of growing period
LIS	Land information system
LUT	Land utilization type
MACRES	Malaysian Centre for Remote Sensing
MOMS-2P	Modular optoelectronic multispecteral
TERRA	Thermal Emission and Reflection Radiometer

Introduction

CHAPTER- I

INTRODUCTION

Agro-ecological Zone (AEZ) is a land resource mapping unit, having a unique combination of land form, soil and climatic characteristics and/or land cover having a specific range of potentials and constraints for land use.

The AEZ concept involves the representation of land in layers of spatial information and combination of the layers of spatial information using a Geographic Information System (GIS). The combination/overlay of layers produces agro-ecological cells. In this way a land resources database is created which contains information on the AEZ cells. AEZ integrates in the database of various kinds of geo-referenced data sets which can include topography, administrative boundaries, road/communications, towns and settlements, rivers/water bodies, geology, soil, physiography, landform, erosion, rainfall, temperature, moisture regime, watersheds, irrigable areas, land use/land cover and forest reserves.

AEZ models are applied on the database to analyse potentials of land for various kinds of uses. The AEZ models include models for the calculation of length of growing period, irrigation requirements, crop biomass, land suitability, and land productivity.

The purpose of zoning, as carried out for rural land-use planning, is to separate areas with similar sets of potentials and constraints for development.

Specific programme plannings can then be formulated to provide the most effective support to each zone.

Agro-ecological zone (AEZ), as applied in FAO studies, defines zones on the basis of combinations of soil, landform and climatic characteristics. The particular parameters used in the definition focus attention on the climatic and edaphic requirements of crops and on the management systems under which the crops are grown. Each zone has a similar combination of constraints and potentials for land use, and serves as a focus for the targeting the recommendations designed to improve the existing land-use situation, either through increasing production or by limiting land degradation. When combined with an inventory of land use, expressed as land utilization types and their specific ecological requirements, zoning can then be used as the basis of a methodology for land resource appraisal. AEZ can be regarded as a set of core applications, leading to an assessment of land suitability and potential productivity, and a further set of advanced or peripheral applications, which can be built on the inventories and results of the core AEZ studies. Outputs of core applications include maps showing agro-ecological zones and land suitability, and quantitative estimates on potential crop areas, yields and production. Such information provides the basis for advanced applications such as land degradation assessment, livestock productivity modelling, population support capacity assessment and land-use optimization modelling. Before applying the procedures of AEZ, the potential user should have a good appreciation of the underlying concepts, so that the potential uses and limitations of the methodology are understood. The essential elements of the core application of AEZ comprises of: land resource inventory, inventory of land utilization types, crop requirements and land suitability evaluation. Land suitability evaluation includes potential maximum yield calculation and matching of constraints and requirements.

Chhattisgarh can be divided in to three distinct Agro-climatic zones; *viz:* Chhattisgarh Plains, Bastar Plateau and Northern Hills and it covers 50.52, 28.62 and 20.86 % area respectively. Similarly topographically also the state varies a lot from high elevated areas to the low lying areas. This vast elevation difference between various areas of the state makes it to differ in their climatic element also. There is a wide variability in climatic factors also. On an average a total of 1200-1600 mm annual rainfall is recorded in different parts of Chhattisgarh in about 64-91 rainy days. (About 90% of rainfall in Chhattisgarh concentrated to four monsoon months i. e; June to September.) It has been recorded that 1200-1400 mm, 1400-1600 mm and 1400-1600 mm annual rainfall is received in Chhattisgarh Plains, Bastar Plateau, and Northern Hills respectively. Similarly variations can be seen in temperature and humidity. Basically four types of soil are found in the state which are Entisols (Bhata), Inceptisols (Matasi), Alfisols (Dorsa) Vertisols (Kanhar). In Chhattisgarh plains these soil are found 20, 45, 10, and 25 %, respectively. Different types of soil are locally known as Tikra, Merhan, Mal and Gbhar are found in Bastar Plateau and Goda, Chawar, Gadar and Bahra are found in Northern hills.

Agro-ecological zoning (AEZ) through remote sensing is an alternative to delineate areas having similar agro-climatic and agro-edaphic conditions for better assign crop yield potentialities. A GIS based model for agro-ecological zoning was developed and optimal land use is suggested for a watershed in Uttar Pradesh (Patel *et al.,* 2000) India measuring 50 thousand hectares area. Satellites database on physiographic, soil land use/ land cover and digital elevation model (DEM), derived slope along with agro-meteorological parameters and ground water table information collected during field survey from basic input. In view of this studies on agro-climatic analysis are carried out mainly to capture the important agriculture feature of the state and to analysis the pattern of different climatic parameters and its spatial variabilities.

Agro-climatic zone can be defined as a land unit having a greater degree of commonality or homogeneity with respect to various conditions and resources such as climatic, parameters important for agriculture and cropping pattern etc.

Food and Agriculture Organization (FAO) of United Nation and International Institute of Applied System Analysis (IIASA) have developed a methodology for characterization of Agro- climatic and Agro-ecological zones. This method provides a wide range of different activities, which are often related yet quite different in scope and objectives like characterization relevant to agricultural production, identifying crop specific limitations, quantification of land productivity, cultivation potentiality and population supporting capacity of the land and multi criteria optimization. Agro-ecological zoning is one of the most important basis for agricultural developmental planning because the survival and failure of particular land use or farming system in a given region heavily realizes on careful assessment of agro-climatic resources. It provides information on several important factors as land tenure, land availability nutritional requirement of human and livestock population, infrastructure and has enabled the development of more advanced application in natural resources analysis and land use planning.

This study was an attempt to capture the benefits of AEZ and Agro-climatic zones characterization in C.G. state. With the above aspect in view, the present investigation was carried out with the following objectives:

1. Screening of different Agro-climatic parameters important for crops.
2. Preparation of Agro-climatic and Agro-ecological database.
3. Agro-climatic characterization of Chhattisgarh.
4. Agro-ecological characterization of Chhattisgarh.

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

The study was started with a search in the relevant secondary information like review articles covering a broad range of topics in the larger area under study, some reviews of literature related to the present study are presented under following heads:

1. Digital elevation model and Extraction of spatial features.
2. Spatial interpolation of climatic elements.
3. Land use land cover mapping
4. Agro-climatic characterization
5. Agro-ecological characterization

Digital elevation model and Extraction of spatial features

Qualified digital elevation model has been generated for an area of 10000 km^2 based on a Modular Optoelectronic Multispectral (MOMS-2P) stereo scene by Buyuksalih and Jacobsen (2001). For the scene orientation, control points have been taken from a topographic map 1: 25000. The control point accuracy is the major limitation of the final product because the image matching is possible with sub-pixel accuracy. Even based on MOMS-scenes it is necessary to eliminate the points, not located on the solid ground, but on vegetation and buildings. This has been done automatically with the Hannover programs RASCOR and DTMCOR. Approximately 20% of the points have been removed, resulting in a sufficient contour-plot which does not include the noise of the original matched points

Csatho *et al.*, (2001) revealed that researchers of NASA's Goddard Space Flight Center (GSFC) are currently developing a scanning airborne photon-counting laser altimeter. To study coastal erosion several sections of the Atlantic and Pacific coast have been mapped by NASA's Airborne Topographic Mapper (ATM) conical scanning altimeter. They selected two 5 km long and about 1 km wide stretches of the coast in Maryland to create precise Digital Elevation Models (DEM). One site is urban area (southern Ocean City) and the other was characterized by coastal marshes and beaches (Northern Assateague Island). The main use of this DEM for the microlaser altimeter validation is to assess the accuracy of the surface elevation.

Wang *et al.*, (2002) automatically generated the 'bald-earth' digital elevation models (DEMs) from digital surface models (DSMs) using TAR-3i - the Intermap Interferometric Synthetic Aperture Radar (IFSAR) system. The method uses a hierarchical surface fitting technique to yield bald earth DEMs. This novel method extracts terrain surface points from an image pyramid and interpolates a bald-earth surface hierarchically. Since the derived bald-earth surface at each level is used as a reference for the next level during surface fitting, spurious terrain surface points can be eliminated effectively, and a bald-earth DEM can be generated. As the method works in a hierarchical way, it is suitable for different resolutions of input data and for different scale sizes of above-terrain object.

Indian Remote Sensing Satellites IRS-1C/1D carry on-board push broom Linear CCD PAN camera providing high resolution (5.8 m) stereo imagery of the earth's surface. DEM has been derived from PAN stereo pair of IRS-1C/1D using suitable mathematical models; Jayaprashad *et al.*, (2002). It has been used to generate contours and extract drainage patterns. DEM generated from stereo data has been validated using ground control points (GCPs) and also by the surface to surface comparison method. Evaluation of drainage pattern is carried out by morphometric analysis. It is possible to retrieve useful terrain parameters/features from the satellite-derived DEM. Automatic method used for extraction of drainage pattern can also help in identifying buried channels. Further, validation of DEM needs to be carried out by measuring height values using differential GPS.

Badarinath, Himkund and Thapovan landslides not only disrupt the yatras but also damage property and lives in the region. The changes in local topography are so fast in this region, that SOI maps cannot provide required information. Therefore there is an urgent need to evolve a method to generate DEM frequently reflecting the change in topography. DEM generated from stereo satellite images like IRS-PAN, ASTER, SPOT and IKONOS could be an alternative solution. Jain and Ravi Babu (2002) conducted study by using ASTER data to generate DEM using ENVI 4.1 ASTER DTM. This DEM is used to map landslide area on the basis of probability of slope failure. Using ASTER DEM on the basis of slope calculated, about 7% area was identified as very high landslide zone. ASTER DTM module of ENVI 4.1 proved to be very useful tool for generating DEM's, this DEM may be used where contour data is not available.

Vegetation mapping and slope characteristic in shervaryan hill carried out by Balaguru *et al.,* (2003) reported that the woody species were measured at 30 cm gbh. The analysis showed that the forestland occupied a major part of the hill

(49.50%) followed by villages (38.12%) and forest plantation (12.37%). The slope was directly proportional to the number of individuals, but indirectly proportional to the girth of the woody species. The data provided by the spatial distribution of the vegetation classes in different slope categories could help in the effective management/conservation of vegetation in the Shervarayan hills.

It is important to consider not only variables like aspect, geology, and land cover for existing landslides, but the distribution of these variables over the entire area of concern is also necessary. Using only data obtained from landslide deposits can lead to a false sense of prediction and conclusions. It is also important to consider the overall area affected by the variables. Therefore, when reporting the results of landslides research, the comparison of the variable frequency against the overall occurrence of the variable in the entire study area must be considered. The relationship, if any, between slope aspect and landslides, is determined partially by normalizing the landslide deposit area to reflect area of landslide per aspect, and dividing the total area available for that aspect. However, circular histograms comparing the aspect of landslides versus overall slope can be used in initial analysis to determine what, in any; additional analysis is necessary Sawyer *et al.*, (2004).

Spatial interpolation of climatic elements

Early reviews of interpolation techniques (Lam 1983; Ripley 1981) often provided little information on their efficacy and did not evaluate them quantitatively. Recent studies, however, have focused on efficacy and quantitative criteria, through comparisons using datasets.

The quality of weather data in agricultural research depends more and more on methods to deal with crop and soil variability like weather generators (computer applications that reduce simulated weather data using climate profiles), and spatial interpolation. The estimation of the value of properties at unsampled sites within an area covered by sampled points, using the data from those points is known as interpolation. Bouman *et al.,* (1996) stated that especially in developing countries, there is a need for accurate and inexpensive quantitative approaches to spatial data acquisition and interpolation (Mallawaarachchi *et al.*, 1996).

Eight spatial interpolators across two regions for two temperature variables (maximum and minimum) at three temporal scales were compared by Collins and Bolstad (1996). They found that several variable characteristics (range, variance, correlation with other variables) can influence the choice of a spatial interpolation technique. Spatial scale and relative spatial density and distribution of sampling stations can also be determinant factors.

Sharolyn (2000) evaluated the spatial interpolation methods on air temperature in Phoenix, Arizona, USA using three methods of interpolation to be used on air temperature data from the Phoenix Metropolitan area. The air temperature measurements were taken at thirty-six discrete locations. Much of the geographical spatial analysis requires a continuous data set and this study was designed to create that surface. This study identified the best spatial interpolation method to use for the creation of continuous data for air temperatures. The reviewed techniques include SPLINE, Inverse Distance Weighting (IDW) and KRIGING. A statistical assessment of the resultant continuous surfaces indicates that there was little difference between the estimating ability of the three interpolation methods with KRIGING performing better overall.

Lanza *et al.,* (2001) studied about the stochastic rainfall interpolation and downscaling and concluded that direct validation of downscaling models is strictly impossible (except for methods focused only on the rainfall process in time) due to the lack of reliable measurements of aerial rainfall and the related patterns in both space and time. Indirect validation is therefore widely resorted and hydrological rainfall-runoff models are sometimes used to transform the variability of rainfall in space and time into simulated flow discharges in river courses

Hong *et al.,* (2005) developed gridded climate database for China at a resolution of 0.01^0 latitude and longitude using spline interpolation technique. A digital elevation model (DEM) was developed at the same resolution to improve the accuracy of interpolation based upon the general spatial dependence of climate on topography. Climate data for the period 1971-2000 from meteorological station in China were used to develop thin-plate smoothing spline surfaces for monthly mean temperature and precipitation. A regularly gridded climate database was produced by coupling the spline surfaces with the underlying DEM. The summary statistics showed interpolation errors for monthly temperatures varying within $0.42\text{-}0.83^0$ C and 8-13% for monthly precipitation. These climates were superior to results produced by methods commonly used in China. The fine-resolution spatial climate database had many potential applications in natural resource management.

For example, it can be used as baseline for climate change studies, in which potential distributions of flora and fauna can be predicted under the impact of climate change and priority areas for biodiversity conservation can be identified.

Renard, *et al.*, (2007) evaluated the rainfall spatial interpolation methods, on different places and times: a small urban area (France), a large rural water catchments (Senegal) and the northern Atlantic region and concluded that Weighting method and the Spline were the less efficient interpolation methods. On the contrary, Ordinary Kriging method allowed sharpest interpolation and is the most representative. However, Global Polynomial Interpolation method supplies very precise interpolation, without needing a lot of decision making and parameter choices, although being less flexible than Kriging. Despite the differences in results, the four interpolation techniques provide relatively sharp estimation, as shown with cross validation. To conclude, Global Polynomial Interpolation method is sharp and can be preferred to the time consuming kriging method which needs a lot of geo-statistical knowledge, parameter decision, and requires more computation.

Land use / land cover mapping

Mendoza *et al.*, (2003) evaluated the land use/land cover mapping in brazilian amazon using neural network with Advanced Spaceborn Thermal Emission and Reflection Radiometer/Thermal Emission and Reflection Radiometer (ASTER/TERRA) data. The area under study located in northern Mato Grosso State, Brazil, and characterized by a strong human occupation process, which caused intensive changes at the landscape, by deforestation, selective logging and agriculture. Field data were acquired in May/June 2003. The use of ASTER data allowed an improvement of the analysis of the occupation process in tropical forest areas. Results of the classification were of satisfactory quality. ASTER bands 2 (630-690 nm), 3 (760-860 nm) and 4 (1600-1700 nm) allowed an increased differentiation of classes, while bands 8 (2295-2365 nm) and 6 (2185-2225 nm) were complementary for the identification of classes. The main land use changes that occurred between 2002 and 2003 were related to deforestation, since many areas of tropical forest were replaced by agriculture and pastures.

Land use and land cover mapping of the Simiyu catchment (Tanzania) using remote sensing techniques carried out by Rwetabula and Florimond (2005) and concluded that remote sensing, Idrisi-32 release 2 image processing software, GIS and extensive and detailed ground information are essential to map land use and land cover of the Simiyu catchment. Land use and land cover is extremely valuable especially for water quantity and water quality predictions, and assessing the hydrological effects of land use changes. Satellite images data acquisition, digital image processing, training sites collection, digital image classification are the processes involved to map the land use of the Simiyu catchment.

Agro-climatic characterization

Williams and Masterton (1980) reported that the choice of an approach to climatic classification is dictated by the ultimate objectives. Provision of the required information to enable the best use to be made of climatic resources for agriculture could be one of the rational objectives.Variations in the responses among different kinds of plants are rarely dealt with in general classification systems.

Three categories of thematic mapping: climatic and Agro-climatic resource mapping were considered. Detailed analysis for specific regions such as the semi-arid tropics may need a different classification system than that required for the world overview. A method of Agro-climatic resource index (ACRI) was proposed and discussed for use in the semi-arid tropics. Computation of the crop climate resource index (CCRI) could facilitate spatial comparison of the availability of moisture, as it affects agricultural production, among different parts of a region. An integration of the Agro-climatic resource analysis with the ecological land classification is proposed.

Yost *et al.,* (1986) demonstrated that how weather data and models driven by weather data are essential in attempts to compare and predict performance of crops and cropping systems in various climates and soils. Suggestions are also presented on how International Board for Soil Research & Management (IBSRAM) could develop a standard set of weather data recording recommendations and support the adoption and development of expert systems to facilitate the transfer of research experience and methodology among collaborating members.

Catalano *et al.,* (1994) carried out a study to identify homogeneous agro-climatic zones of land along the Adriatic Coast in Italy. Definition of land zones was based on potential water deficit (combined with a mean temperature of the coldest month). Fourteen homogeneous agro-climatic zones were identified (each of ~5100 km^2).

Agro-ecological characterization

Gryseels *et al.,* (1992) provided meaningful correspondence with the spatial domains targeted by the International Agricultural Research Centers. TAC could gain much by adopting a more flexible approach to dealing with the agro ecological aspects of agricultural R&D. The same is being followed by other agencies operated at regional, national, or local scales. For most research evaluation purposes there are persuasive reasons why flexible rather than fixed notions of agroecological space are preferred. Indeed there appears little justification for re-aggregating space into fixed agroecologies given the current opportunities

Madan *et al.,* (1994) delineated AEZs and concluded that arable zones with decreasing level of potential for agricultural development, constitutes 85% of the Chitwan district of Nepal. Seven different agro-ecological zones were delineated. Zone I, identified as the most potential zone for crop production with possibility of three crops a year occupies 21% of the arable area; while zone II, identified as the second important zone with potentials for two crops a year, covers 32% of the arable area.

Gajbhiye and Mandal (2000) reported that India has heterogeneous landforms and variety of climatic conditions such as the lofty mountains, the raverine deltas, high altitude forests, peninsular plateaus, variety of geological formations endowed with temperature varying from arctic cold to equatorial hot, and rainfall from extreme aridity with a few cm (<10 cm) to per humid with world's maximum rainfall (1120 cm) of several hundred cm. This provides macro relief of high plateau, open valleys, rolling upland, plains, swampy low lands and barren deserts. These varying environmental situations in the country have resulted in a greater variety of soils. Therefore, the systematic appraisal of agro-ecological regions has tremendous scope in grouping relatively homogenous regions in terms of soil, climate, physiography and conducive moisture availability periods (length of growing season) in planning appropriate land use. Depending upon the soil, bioclimatic type and physiographic situations, the country has been grouped into 20 agro-eco regions (AER) and 60 agro-eco sub regions (AESR). Each agro-eco sub region has further been classified into agro-eco unit at district level for developing long term land use strategies. The constraints and potentials with appropriate ameliorative measures have been suggested for each region for better understanding and adoption for formulating the plans to suggest crop/cropping system, which are supposed to minimize the deterioration of land quality controlled by soil physical conditions, nutrient availability and organic carbon pool.

MACRES (Malaysian Centre for Remote Sensing) has conducted a study on agro-ecological zoning of South West Selangor using the integration of remote sensing and Geographic Information System Loh *et al.,* (1997) five parameters; land cover/use, landform, terrain, soil and climate were used for agro-suitability assessment adopting the procedure published in the UN Food and Agriculture Organization (FAO) document entitled 'Agro-ecological zoning'. The land cover/use, landform and soil layers were generated from visual interpretation of satellite data accompanied by intensive ground verifications. The terrain layer was produced from a Digital Elevation Model (DEM) derived from digitized contour lines. Two climatic layers; duration of dry season and annual rainfall distribution were generated through interpolation of point files digitized in the GIS. Crop requirements data were taken from the FAO guideline with modifications to suit the Malaysian environment setting. Four crops; rubber, oil palm, cocoa and paddy were assessed because of their socio-economic significance to the state of Selangor, Malaysia. The agro-ecological zone (AEZ) map was produced using overlay analysis technique in the GIS. The agro-land suitability map was generated by matching the crop requirements with the land characteristics in each AEZ unit through cross-tabulation method, giving due considerations to the present agricultural land use.

Stanley *et al.,* (1997) workedout the Agro-ecological aspects of Agricultural R&D and concluded that Agro-ecology has a real role to play in designing and evaluating agricultural research and development strategies. In recognition of that potential, the Chhattisgarh system is also moving to the use of Agro-ecological criteria as explicit factors in its institutional structure and in the strategic deployment of its research resources.

Patel *et al.,* (2000) found that Agro-ecological zoning (AEZ) through remote sensing is an alternative to delineate areas having similar Agroclimatic and Agro-edaphic conditions for better assigning crop yield potentialities. This AEZ concept includes representation of land in layers of spatial information and their combination using geographical information system (GIS). A GIS based model for Agro-ecological zoning was developed and optimal land use was suggested for a watershed in Uttarakhand, India measuring 50 thousand hectares area. Satellite database on physiography, soil, land use/land cover and Digital Elevation Model (DEM) derived slope along with Agrometeorological parameters and ground water table information were collected during field survey form basic input. Ten Agroecological zones and 23 Agroecological sub zones and their production potential were identified. This zoning revealed that 27% and 14% of the study area could be allocated for irrigated double cropping (sugarcane and wheat) and sole sugarcane cropping, respectively.

Sombroek *et al.,* (2000) studied the Macro and Micro Ecological-economic zoning in the Amazon Region and concluded that Macro-zoning for agricultural occupation requires better information on the characteristics and the requirements of the different feasible land use types or lively-hood systems.

Quiroz *et al.,* (2000) reported that Agro-ecological zoning is a method that uses biophysical attributes of the land to cluster land-use type into more homogenous areas. This exercise facilitated planning for the sustainable use of natural resources. The application of AEZ limited by the lake of geospatial data, particularly in mountainous areas, the remote sensing and process based models for both climates interpolation and crop and livestock production were used in a watershed above 3800m. With the incorporation of this new tool, AEZ can become a dynamic and more robust method.

Patel (2002) reported that sustainable agricultural development requires a systematic effort towards the planning of land use activities in the most appropriate way, apart from several other institutional and policy programme initiatives. Agro-ecological zoning (AEZ) is one of the most important approaches for agricultural developmental planning because survival and failure of particular land use or farming system in a given region heavily relies on careful assessment of Agro-climatic resources. This approach is used to categorize Agroclimatically uniform geographical areas for agricultural developmental planning and other interventions. Modern tools such as satellite remote sensing and Geographical Information System (GIS) have been providing newer dimensions to effectively monitor and manage land resources in an integrated manner for Agroecological characterization. The application of AEZ is limited by lack of geospatial data, particularly in mountainous areas. He demonstrated incorporation of new tools to extend applicability of AEZ in mountainous areas like Kumaon, Himalayas, India.

Ekanayake *et al.,* (2003) attempted to use the available spatial information for the identification of suitable areas for forest plantations in the University of Peradeniya, Sri Lanka. According to the results of the study, it can be concluded that there was a very low potential for forest plantations in the university lands. Perhaps, a different land use scenario would be better suited for these lands and further studies need to be formulated to identify the best land use options for these lands in the university.

Agro-ecological zoning and GIS Applications in Asia with special emphasis on land degradation assessment in dry lands (LADA). Messrs *et al.,* (2005). They concluded that the AEZ methodology is well implemented in some countries in Asia. Owing to economic development, increasing pressure on natural resources and related environmental degradation have become important problems constraining development in all the countries of the region. As the range of practical applications of the AEZ concept and characterization for land use analysis and planning has been broadening, it is necessary to extend and modify the AEZ procedures to meet new requirements, such as AEZ/GIS in poverty mapping and natural disaster management combining biophysical and socio-economic information to delineate vulnerable areas for intervention purposes. This includes the need to improve institutional capacity and build a resilient society to handle disaster prevention and mitigation through better land-use planning, land management and drought preparedness.

Materials and Methods

CHAPTER - III

MATERIALS AND METHODS

In the present chapter of the research work on "Agro-climatic and Agro-ecological characterizations of Chhattisgarh" the materials collected along with the sources and the methodologies adopted are discussed.

3.1 General description of study area

Chhattisgarh, India's 26th state carved out of Madhya Pradesh is a newly formed state and shares borders with Maharashtra, Madhya Pradesh, Uttar Pradesh, Orissa, Jharkhand and Andhra Pradesh. Chhattisgarh state is situated in east-central India and is larger than Punjab, Haryana and Kerala state put together. It is spreading over of area of 13.51 million hectares with a gross cropped area of 5.8 million ha. It comprises of 18 districts divided in to 3 agro-climatic zones. About 74% area of Chhattisgarh plains, 97% of Bastar plateau and 95% in Northern hills are rainfed, having the paddy as leading crops. It is chiefly a mono cropped area with some amount of *Rabi* crops supported by meager irrigation facilities. The cropping intensity of the state is 121%. The climate of Chhattisgarh is dry sub-humid. Nearly 90% of the annual average rainfall occurs from June to September due to southwest monsoon.

Chhattisgarh is endowed with different types of soils varying in nature. Variations in most soil property in the region are closely related to their position on the landscape. Their extent and development depends on the environment setting in which they have been evolved. Moving down the slope there is an

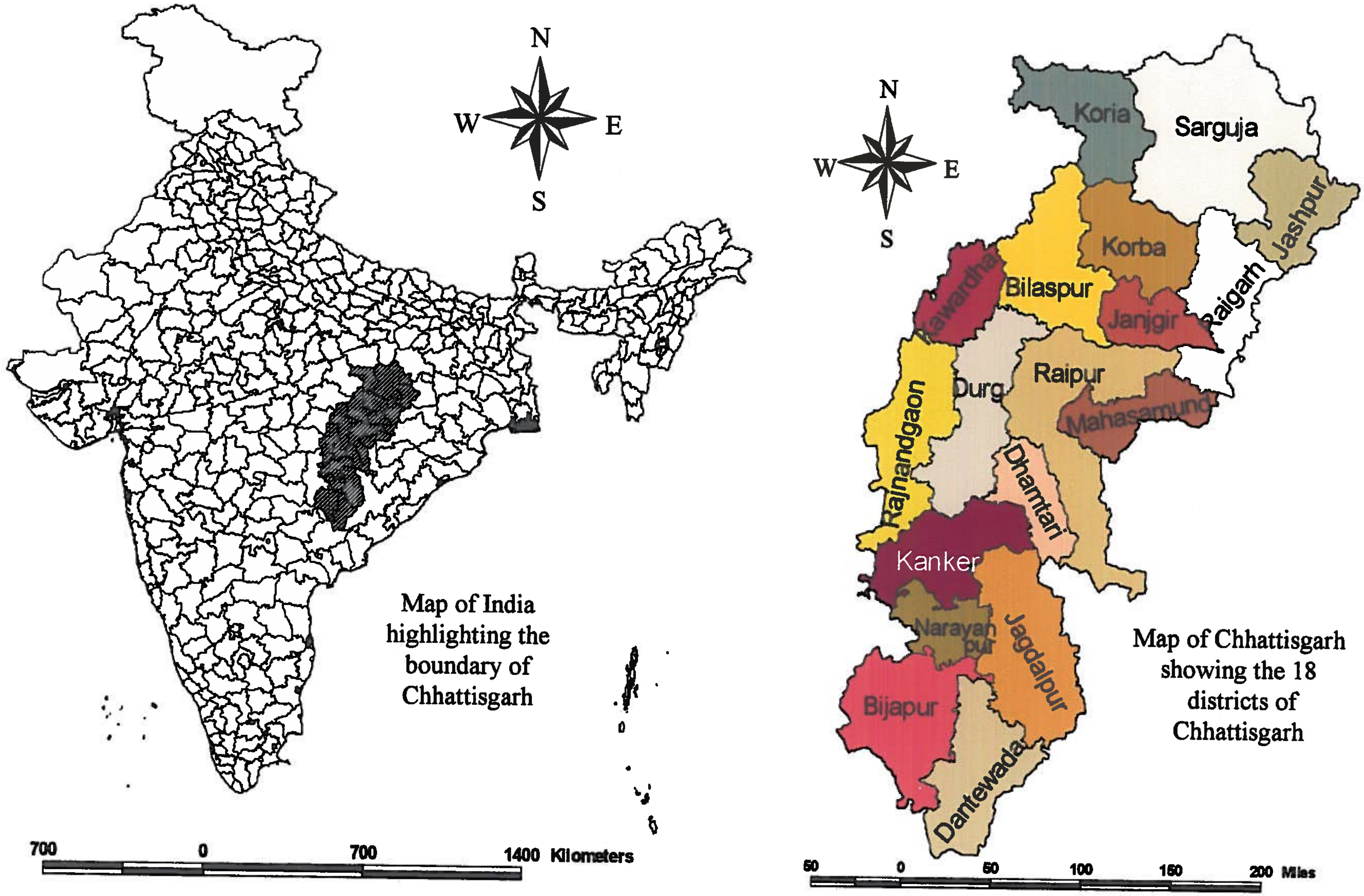

Plate 3.1. Location of study area.

increase in soil depth, water holding capacity and dominance of calcium and magnesium ions on exchange sites. Soils of Chhattisgarh are classified in to four major orders: Entisols (*Bhata*), Inceptisols (*Matasi*), Alfisols (*Dorsa*) and Vertisols (*Kanhar*).

3.2 Methodology

The basic work regarding the Agro-climatic and Agro-ecological characterization of Chhattisgarh includes the screening of different Agro-climatic parameters, thus Agro-ecological database of the state was prepared.

3.2.1 Data base used

Various data sets of Chhattisgarh state were used during the study course. The basic data, which were collected and used during the work, were: Soil type, soil depth, soil physiography, digital elevation map, temperature, precipitation, wind speed, relative humidity, radiation intensity, length of growing period, land use/land cover map, administrative boundary.

3.2.2 Collection of data

These preliminary data were collected by visiting various areas concerned of the state. The very first data collected were the maps related to soil resource of Chhattisgarh. Such data include maps showing the soil type, soil depth and soil physiography of the state. These soil resource maps were then digitized to prepare the digital soil resource database. The second most important set of parameters, which were collected included the different meteorological data like rainfall and temperature from different meteorological stations. The stations visited for the data collection were:

- Revenue Department of Chhattisgarh
- College of Agriculture Raipur, Bilaspur, Ambikapur, and Jagdalpur.

For the computation of water balance of different parts of Chhattisgarh, the rainfall data for those areas as well as, temperature, humidity, wind speed, radiation data of the related areas were also collected. Apart from all these data the land use land cover map of the Chhattisgarh state was also generated. In addition to that the SRTM (Shuttle Radar Topography Mission) data of the state for DEM preparation were also collected.

3.2.3 Data generation

Using the weather data of recent 30 years the spatial surfaces of the rainfall, temperature, humidity, mean wind speed and radiation intensity were generated in ARC-view 3.1 GIS software using the Inverse Distance Weigtage (IDW) algorithm. A pixel size of 0.015^{0} was used for interpolation of point data.

Steps of data generation

A. Digitization of primary maps of Chhattisgarh-

All the primary maps of Chhattisgarh collected from the different sources were geo referenced and digitized using ARC-view 3.1 GIS software.

B. DEM preparation

Digital Elevation Model is the map by which continuous surface such as terrain surface can be represented. Actually the DEM is used to interpolate elevation at arbitrary location using limited number of three dimensional terrain points. DEM for the Chhattisgarh was prepared through SRTM (Shuttle Radar Topography Mission) and was utilized to generate a more precise three-dimensional map of Chhattisgarh. The elevation zones, slope classes and slope-aspect for the hilly- undulating as well as nearly plain surfaces were derived from this DEM of the Chhattisgarh.

C. Slope aspects of the state

Slope has a direct control on the runoff, infiltration etc., and thus on the water storage potential of that area as well as its recharge capacity. A Digital Elevation Model (DEM) derived slope map was generated for the study area i.e., Chhattisagrh. The slope map was generated from the DEM and reclassified into three slope groups as gentle (0–5%), moderate (5–10%) and high (>10%). A DEM serves in a climate interpolation not only as a regular three-dimensional topographic surrogate, but also as key for estimating climate conditions. Thus, the development of a DEM at a fine spatial resolution is the first step towards accurate climate estimation.

3.3 Agro-climatic zoning

The agro-climatic regime map was prepared by GIS aided integration of thermal regimes, rainfall zone, moisture adequacy and available soil water capacity regimes.

3.3.1 Delineation of climatic regimes

Using the interpolated spatial surfaces of different meteorological parameters like the temperature, precipitation and moisture the state was delineated into different regimes depending upon the parameters such as:

Thermal zones – Thermal zones describe the temperature regime available for crop growth during the growing period. They are usually defined based on ranges

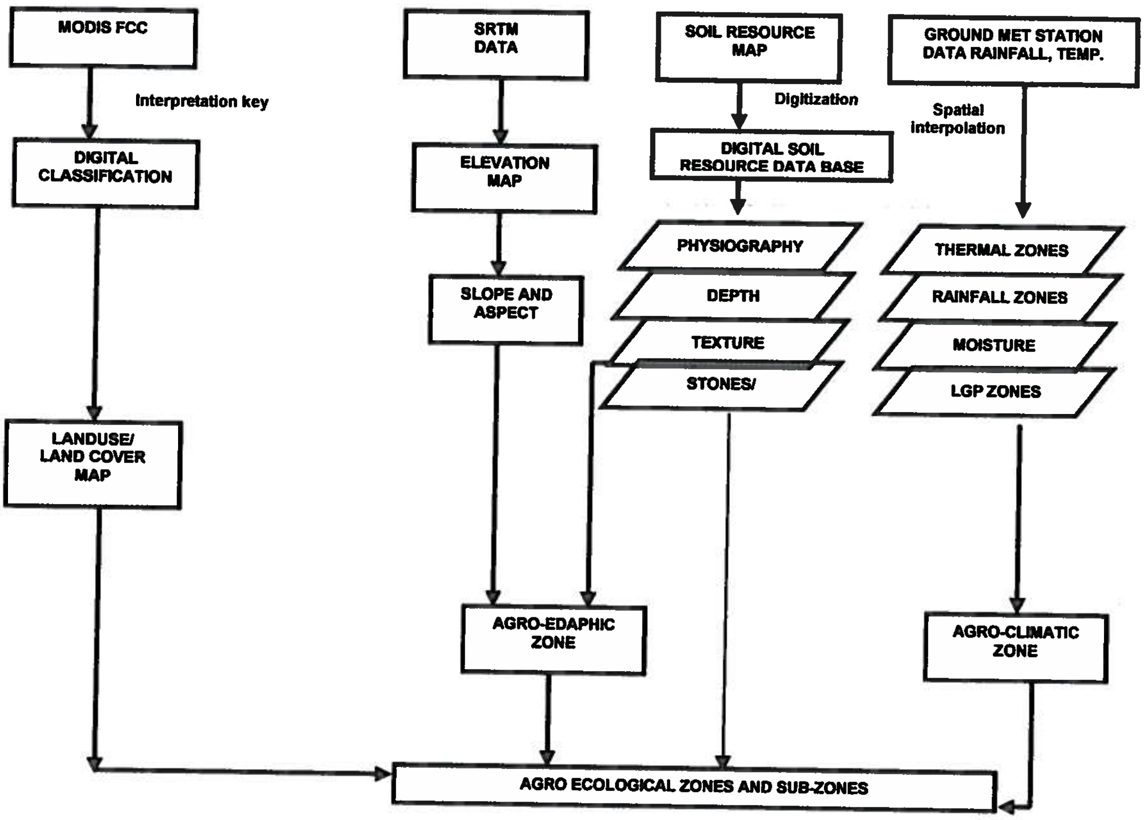

Fig. 3.2 flow chart showing the different steps for the Agro-ecological zoning of Chhattisgarh

Agroclimatic Zones of Chhattisgarh

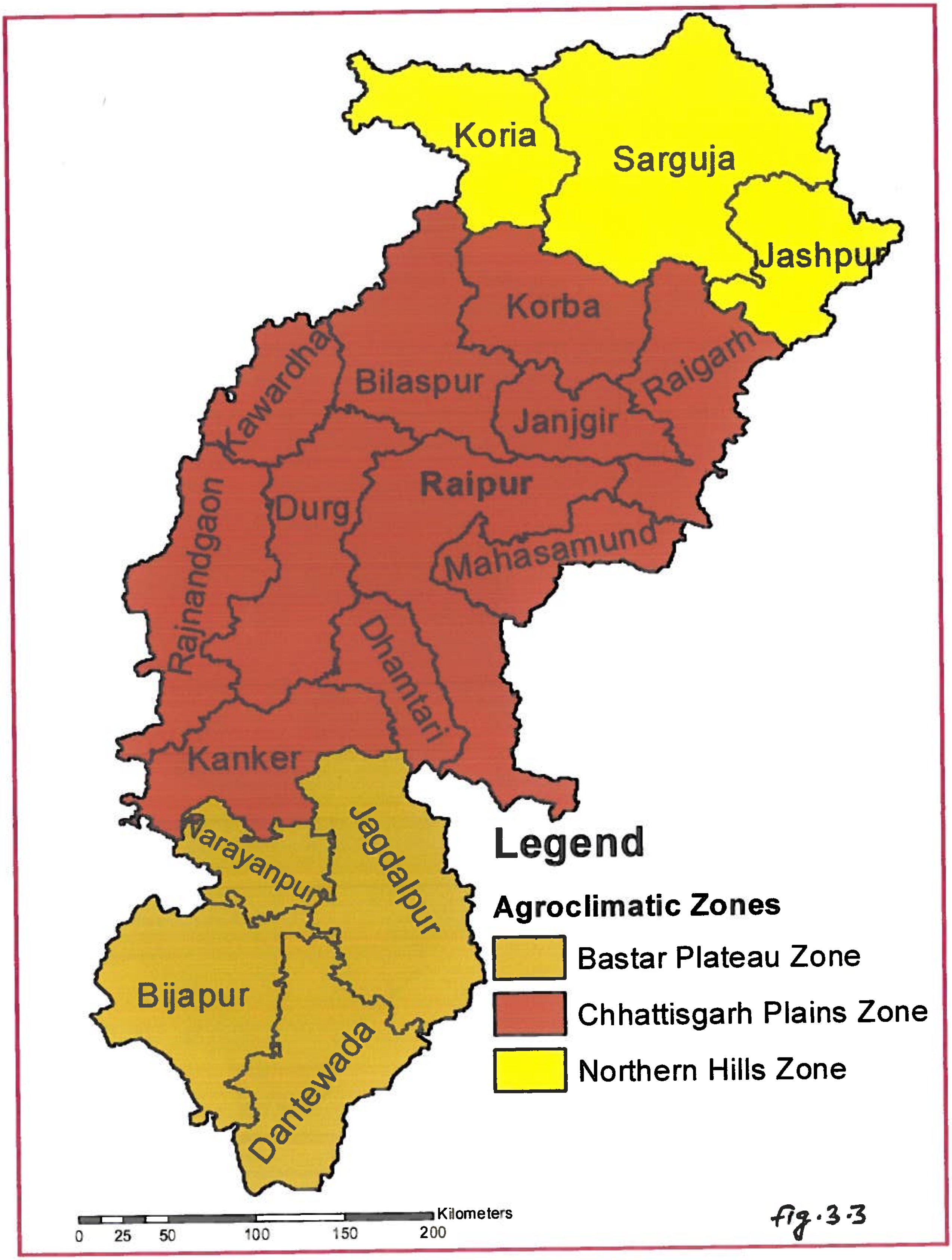

Fig. 3.3

of mean temperature. For creating thermal zones Inverse Distance Weightage method was used in the ARCVIEW 3.1 GIS software. The pixel size used for the above mentioned work was 0.015^0. In this temperature data of different parts of Chhattisgarh were compiled. We created different maps showing the annual mean temperature, temperature during Rabi season, temperature during Kharif season etc., of the state.

Rainfall zones – For creating rainfall zones Inverse Distance Weightage method in ARCVIEW GIS 3.1 was used. In this step the rainfall data of different parts of Chhattisgarh were compiled. We created different rainfall maps like annual rainfall, rainfall during Rabi season, rainfall during Kharif season of the state.

Moisture Zone – The moisture zones of the state were also created using the Inverse Distance Weightage method in ARCVIEW GIS 3.1. in this step the moisture data of different parts of Chhattisgarh were compiled. We created different maps related to moisture regimes of the state like annual moisture zone, moisture zone during Rabi season, moisture zone during Kharif season of the state.

Length of growing period - Length of growing period is the continuous period of the year when precipitation exceeds half of Penman evapotranspiration plus periods required to evapotranspire an assumed soil moisture reserve and when mean daily temperature exceeds 6.5^0 C. In our study length of growing period was computed by the adoption of the following steps:

Computation of water balance

The meteorological parameters used for the computation of water balance are: the climatic water balance for different stations and for different year, worked out by using the book-keeping procedure of Thornthwaite and mathar (1955). In the water balance computations, the inputs were rainfall and potential evapotranspiration and the outputs were soil moisture storage, actual evapotranspiration, water deficit and water surplus. The PET values required for the water balance computation were estimated using Penmen (1948) equation. By using this equation the PET for 90 different stations of Chhattisgarh were computed. Also then water balance of these respective stations was further computed using Thornthwaite method.

Computation of length of growing period

Length of growing period for all the above mentioned 90 stations was calculated. Using this value further the LGP Zones were delineated. These Zones were used for the whole of Chhattisgarh for the preparation of climatic regimes of Chhattisgarh state.

Determination of Agro-climatic zone

All the spatial layers viz., thermal regime, precipitation regime, moisture regimes, length of growing period and Evapotranspiration regimes were imported in ENVI 42 software and the zoning was done using the TREE classification Algorithum.

3.4 Agroedaphic Zoning

The soil texture and properties derived from the soils resource database generated earlier was used along with the slope and presence of stone in soil aspect of Chhattisgarh derived from DEM, were used to delineate different edaphic zones of the state, which was finally used up for Agroedaphic zoning.

3.5 Agro-ecological zoning

The final step of the work was Agro-ecological zoning which included the compilation of the two previously prepared database namely - agro-climatic zones and agro-edaphic zones. It is basically a bio-physical assessment of land and climatic parameters, resulting in zones of similar soil, climate, terrain and land form characterization.

Results and Discussion

CHAPTER- IV
RESULTS AND DISCUSSION

The annual average data of 30 stations falling in Chhattisgarh and surrounding states of Madhya Pradesh, Maharastra, Orissa, Uttar Pradesh, Jharkhand and Andhra Pradesh have been collected from the literature published by India Meteorological Department (IMD) (Climatological tables 5^{th} addition 1999). The average climatic data of whole India is routinely published by IMD considering the weather data of past 30 years. Beside this the rainfall data of 90 stations falling in teritory of Chhattisgarh have also been collected from Revenue Department of Chhattisgarh government in order to account for the large spatial variability in rainfall pattern. The spatial surfaces of the all meteorological parameters were generated in ARC-View 3.1 GIS software using the IDW (Inverse Distance Weightage) algorithm.

AGRO-CLIMATIC AND AGROECOLOGICAL CHHARECTERIZATION

4.1 Rainfall

4.1.1 Annual average rainfall

The entire state has been divided in to five major categories namely very high rainfall zone (rainfall >1900 mm), high rainfall zone (1600-1900 mm), medium rainfall zone (1300-1600 mm), low rainfall zone (1000-1300 mm) and very low rainfall zone (<1000 mm).

The spatial distribution of annual rainfall shows that north part of Kanker comes under very high rainfall zone, while some part of Sarguja, Jashpur, Korba

Annual Rainfall

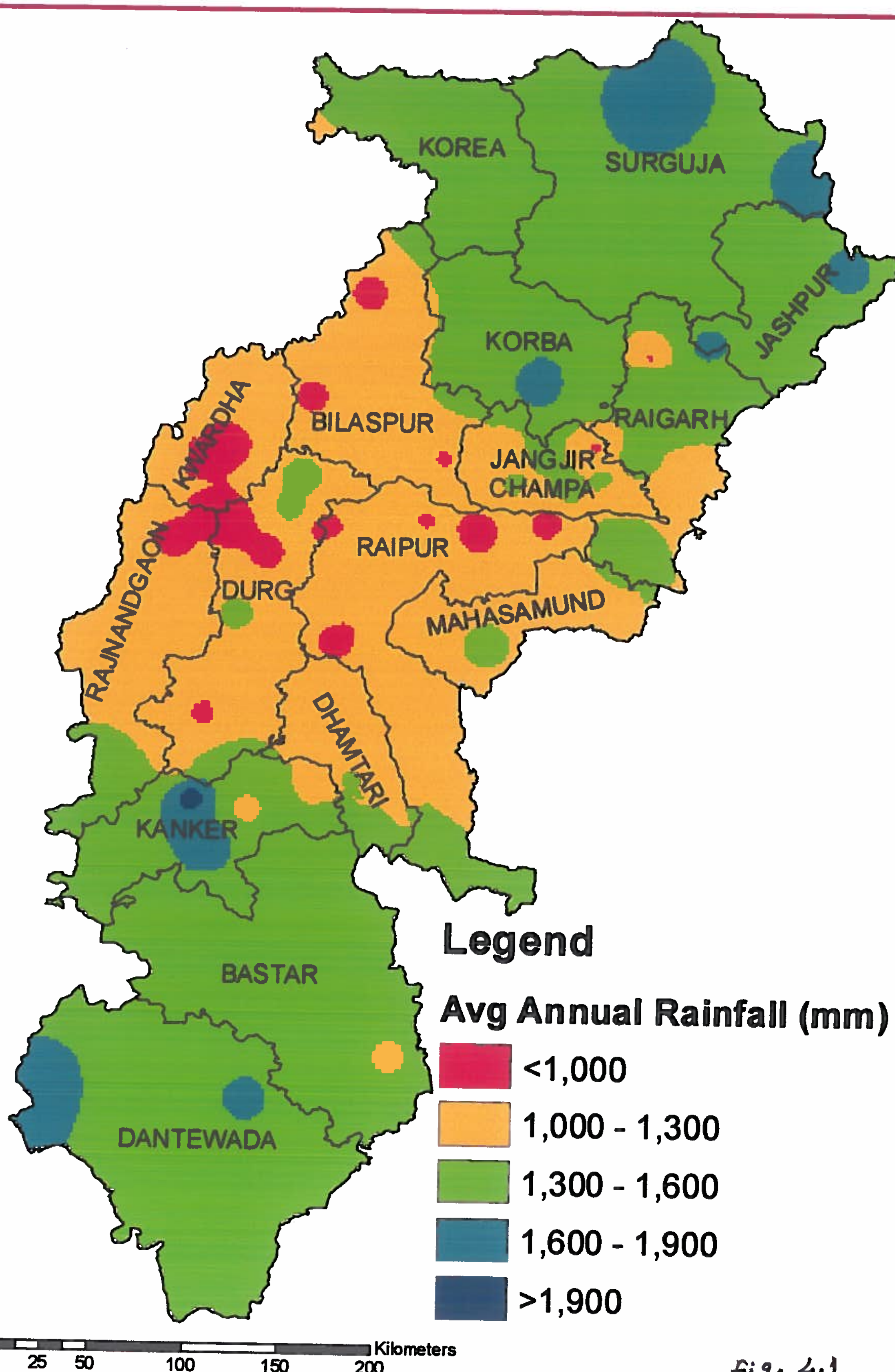

Fig. 4.1

Dantewara, Kanker come under high rainfall zone. Most part of Korea, Sarguja, Jashpur, Raigarh, Korba, Kanker, Bastar and Dantewada, and some part of Durg, Janjgir-champa, Raigarh, Mahasamund, Dhamtari, Raipur and Bilaspur receive medium rainfall. Most geographical area of Bilaspur, Raipur, Durg, Rajanandgaon, Kawardha, Janjgirchampa, Mahasamund, Dhamtari, some part of Raigarh, Kanker, Bastar come under low rainfall zone, while some parts of Kawardha, Rajanandgaon, Durg, Raipur, Bilaspur come under very low rainfall zone.

4.1.2. Rainfall during *Kharif* season

Maximum rainfall occurrence in the state takes place in between July to September months of the year, which corresponds to the *Kharif* season. Like as average annual rainfall, state has been divided into 5 major categories namely very high rainfall zone (>1900 mm), high rainfall zone (1600-1900 mm), medium rainfall zone (1300-1600 mm), low rainfall zone (1000-1300 mm) and very low rainfall zone (<1000mm) on the basis of rainfall received during *kharif* season.

The spatial distribution of rainfall during *kharif* season shows that only a small part of Kanker comes under very high rainfall zone while some parts of Kanker, Korea and Sarguja fall under high rainfall zone. Most geographical area of Korea, Sarguja, Jashpur, Korba, Kanker, Bastar, Dantewara, some part of Raigarh, Rajanandgaon, and small parts of Durg, Janjgir-champa witnessed the medium rainfall. Almost whole geographical area of Mahasamund, Dhamtari, Janjgir-champa more than half area of Bilaspur, Raigarh, Durg, Rajanandgaon, Raipur, Bastar and some parts of Korea, Jashpur, Sarguja, Kanker, Dantewada

Rainfall during Kharif season

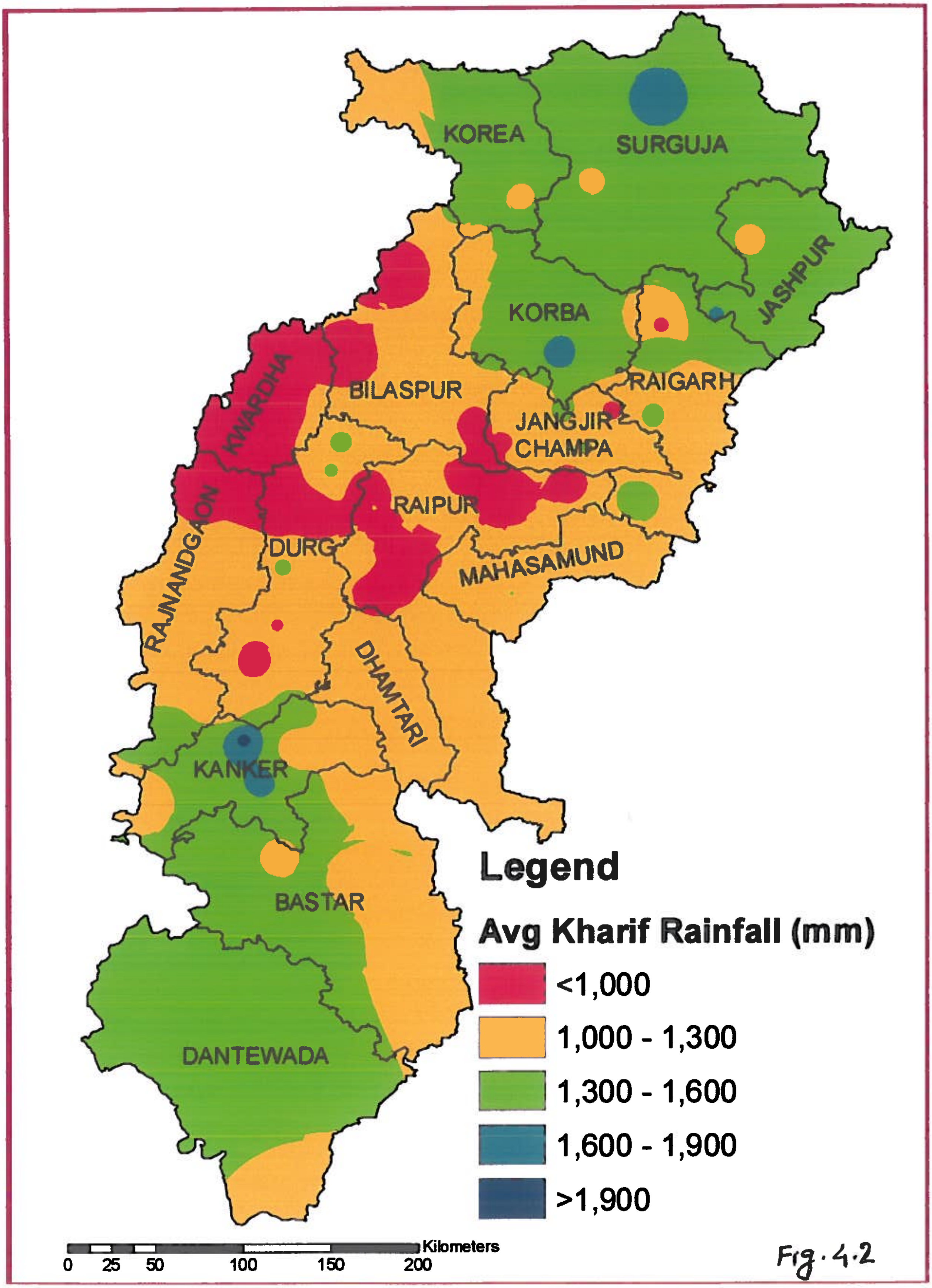

Fig. 4.2

come under low rainfall zone. Almost whole area of Kawardha comes under very high rainfall zone but some part of Rajanandgaon, Bilaspur, Raipur, Durg and small part of Janjgir-champa, Raigarh also come under very high rainfall zone.

4.1.3 Rainfall during *Rabi* season

As mentioned above maximum rainfall of the state occurs in *Kharif* season, rainfall during *Rabi* season receives between 80 mm to 160 mm. Most part of Chhattisgarh plain, northern hill zone and northern part of Bastar plateau falls under very low rainfall (< 85 mm) during *Rabi* season.

Maximum part of western part of Northern hill zone, some part of south east and south west region of Sarguja and Jashpur district and some pats of Chhattisgarh plain comprises Near about 50% of Korba (Pali, Katghora and Piparia) and parts of Bilaspur (Achanakmarg, Lormi, Kota, Tkhatpur and Ratanpur), Kawardha (Pandaria), Mahasamund (Bagbahra and Suarmar), Raipur (Chhura, Gariaband, Rasela and Mainpur), Rajnandgao (Dogergaon, Ambagarh chauki, Mohala and Manpur), Durg (Dhallirajhara and Dondi), Dhamtari (Siphonpara and Nagri), Kanker (Antagarh and Bhanupratappur) comes under low rainfall (85-100 mm) also including some parts of Bastar plateau like Jagdalpur (Parasgaon and Dongar) and Koylibera of Narayanpur district.

Eastern part of Northern hill zone and parts of Chhattisgarh plain comprising of Bilaspur (Pendraroad, Parasi, Keonchi, Kotmei and Marvahi), southern Raipur, Pasan part of Korba, Dhamtari (Bora, Umargao and Parasgaon) and Kanker (Pkhanjur) and maximum part of Bastar plateau come under medium rainfall of 100-130 mm .

Rainfall during Rabi season

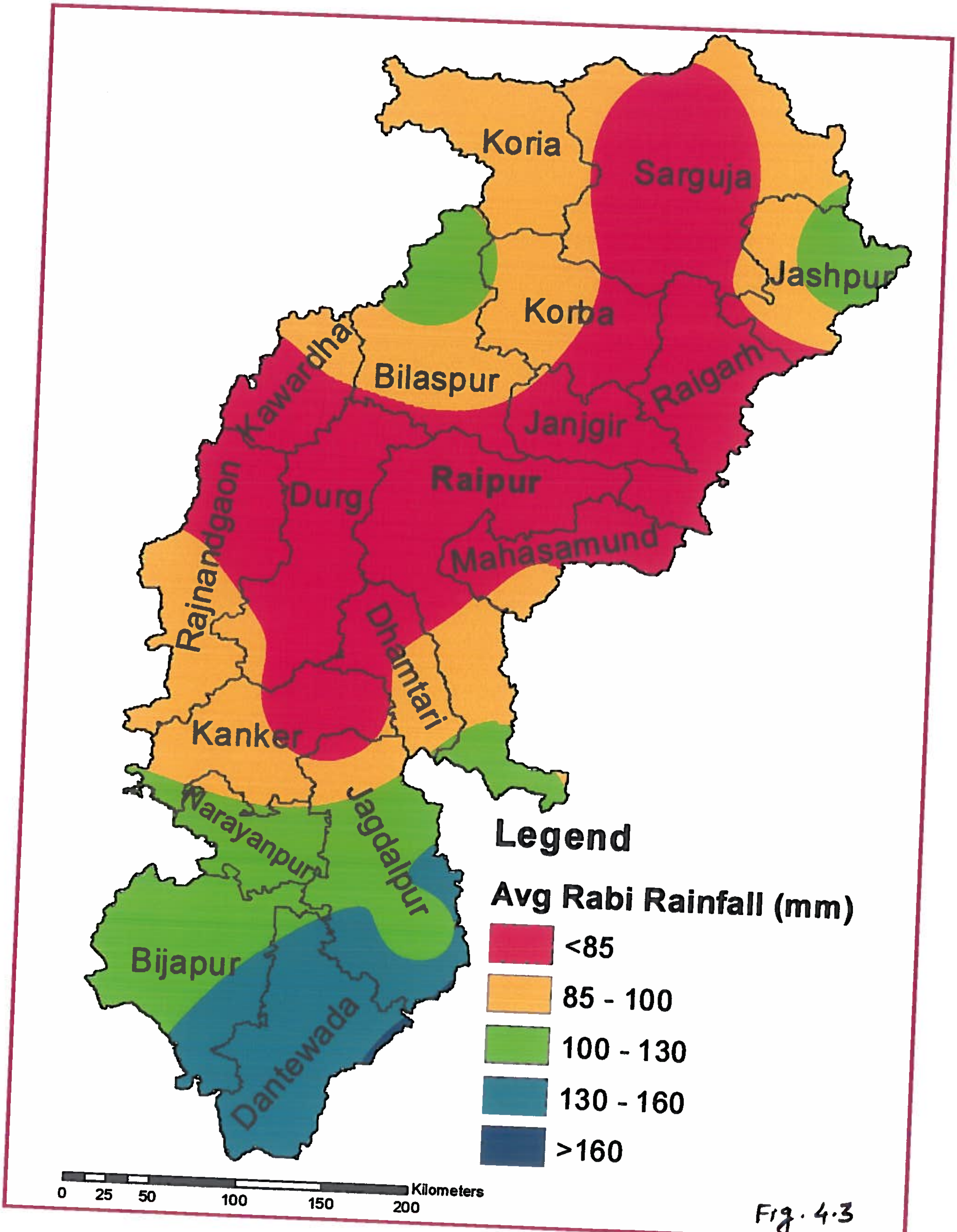

Fig. 4.3

Only small part of state comes under high (130-160 mm) to very high (>160 mm) rainfall categories in *Rabi* season comprises only part of Bastar plateau regions.

4.2 Temperature

4.2.1 Annual mean temperature

The entire state has been divided in to five major categories namely very low temperature zone (<23^0 C), low temperature zone (23-24^0 C), medium temperature zone (24-25^0 C), high temperature zone (25-26^0 C) and very high temperature zone (>26^0 C).

The annual average temperature shows that very low temperature recoded only at Jashpurnagar of Jashpur district. Where as most part of Northern hill zone comprising of Sarguja (Ambikapur and Kusumi), Jaspur (Amakona, Sakardih, Raikera and Kunkuri) with low temperature of (23-24^0 C). Along with remaining part of northern hill zone includes Sarguja (Ramanujganj, Wadrafnagar, Sarguja, Semaria, Ramkola and Barbaspur), Jaspur (Bagicha, Tapkara and Bandachua) and Koriya, northern and eastern Chhattisgarh plane falls in medium temperature zone. The whole districts of Bijapur, Dantewada, Jagdalpur, Narayanpur of Bastar plateau and maximum area of Kanker, Durg (Gurur, Dondi and Balod), Dhamtari (Nagri and Dhamtari), Raipur (Mainpur, Tauranga, Indagaon), Rajnandgao (Mohala and Manpur), Kawardha (Pandaria), Bilaspur (Achanakmar, Mungeli Tkhatpur, Kota, Ratanpur and Bilaspur) along with some patches of Janjgir, Korba, Raigarh, comes under high range of temperature region. Southern part of

Annual Mean Temperature

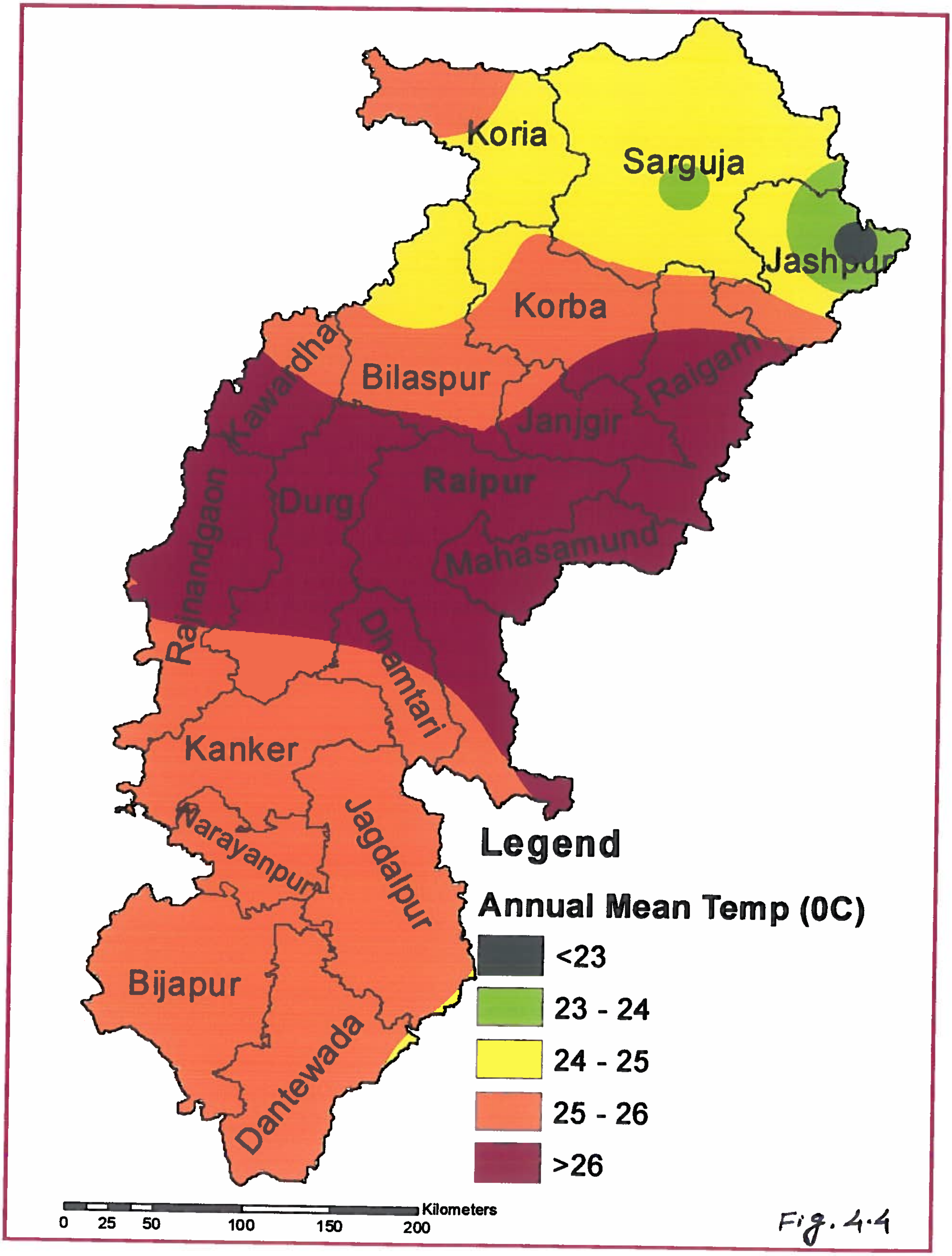

Fig. 4.4

Sarguja district like Parsa, Bhakurma and Bharatpur. Janakpur, Taloli, Kotadol regions of Korea also comes under this zone. Due to less vegetation and more human habitat and high industrialization maximum area of Chhattisgarh plain falls under high annual mean temperature.

4.2.2 Mean temperature during *Kharif* season

As like annual mean temperature, mean temperature of The Jaspur district during *Kharif* season is below 26^0C except some parts like Amakona, Kunkuri, Raikera which comes under low temperature (26-27^0C) zone along with eastern Surguja of northern hill zone and parts of Bastar plateau (southern Jagdalpur, eastern part of Dantewara) during *Kharif* season.

Maximum part of Bastar plateau comes under medium temperature zone (27-28^0C) which comprises the whole Bijapur, Narayanpur, more than 70% of Dantewara, Jagdalpur and Kanker comes under this range and also some parts of plains includes Kanker, Raipur (Gariaband, Rajim, Mainpur and Tauranga), Dhamtari (Nagri and Dhamtari), Durg (Gurur, Balod and Dondi), Rajnandgaon (Manpur and Mohala), Korba (Piparia, Pasan and Ahirpara), Bilaspur (Parasi, Pendraroad and Marwahi). 80% area of Surguja (except Kusumi, Parsa and Bhakurma), Koriya (Ramgarh, Sonhat, Baikunthpur and Manendragarh) and Jashpur (Ghatmunda, Pathalgaon and Konpara) also comes under this temperature range.

North western part of northern hill zone and part of Chhattisgarh plains consists of Rajnandgaon (Dongargaon, Dongargarh, Rajnandgaon and Chhuikhadan), Kawardha (Pandaria and Chilpi), Bilaspur (Lormi, Kota, Tkhatpur,

Mean Temperature during Kharif season

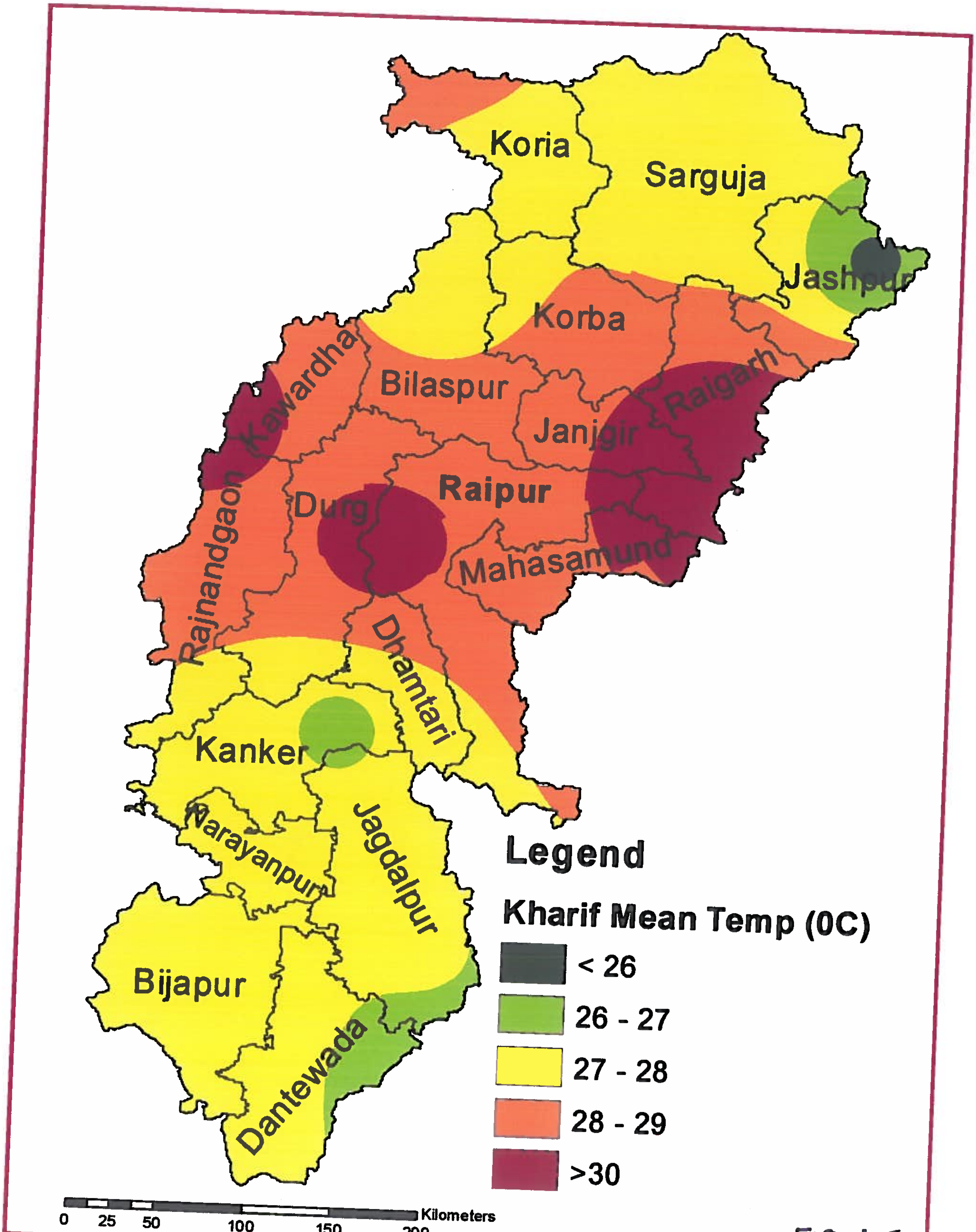

Fig. 4.5

Mungeli and Bilha), Janjgir (Baloda, Champa and Akaltara) Raipur (Bhantapara, Balodabazar, Kasdol, Palari, Deobhog, Simga, Abhanpur, Rajim and Gariaband), Mahasamund (Sirpur, Patewa, Pithora, Bagbahra, Suarmar and Mahasamund), except Doundi, Gurur, Balod and Bhilai other part of Durg, more than 50% area of Korba (Pali, Korba, Katghora and Kartala) Raigarh (Dharmjaygarh and Lailunga) and Dhamtari (Kurud and Dhamtari) comes under zone with high mean temperature of 28-29 ^{0}C during kharif season. Bhakurma, Parsa regions of Surguja and Pathalgaon tehsil of Jaspur district also comes under this range.

Remaining parts of Chhattisgarh plain (parts of Kawardha, Rajnandgaon, Raipur, Raigarh, Janjgir and Korba) are comes under zone of mean temperature during kharif season is above than 30^{0}C.

4.2.3 Mean temperature during *Rabi* season

Most part of northern hill zone comes under low temperature zone below 21^{0}C during *Rabi* season consists of Jashpur (Jashpurnagar, Kunkuri and Amarkantak), Sarguja (Kusumi block, Lundra, Ambikapur, Tulsi and Rajpur) mean temperature during *Rabi* season is 21-22 ^{0}C, where as remaining areas of this zone comes under medium temperature(22-23°C) along with some part of Chhattisgarh plain includes Bilaspur, Kawardha (Pandaria), Korba (Piparia, Pasan, Ahirpara, Katghora, Pali, Shying and Jilda) and Raigarh (Bhojpur and Bhakurma). Whole zone of Bastar Plateau (Dantewara, Bijapur, Jagdalpur and Narayanpur) comes under high temperature (23-24^0 C) zone. This temperature zone also includes parts of Chhattisgarh planes; Kanker, Rajnanadgaon, Kawardha, Durg (Nawagarh, Bametara, Dondi and Balod), Dhamtari (Nagri and Siphonpara)

Mean Temperature during Rabi season

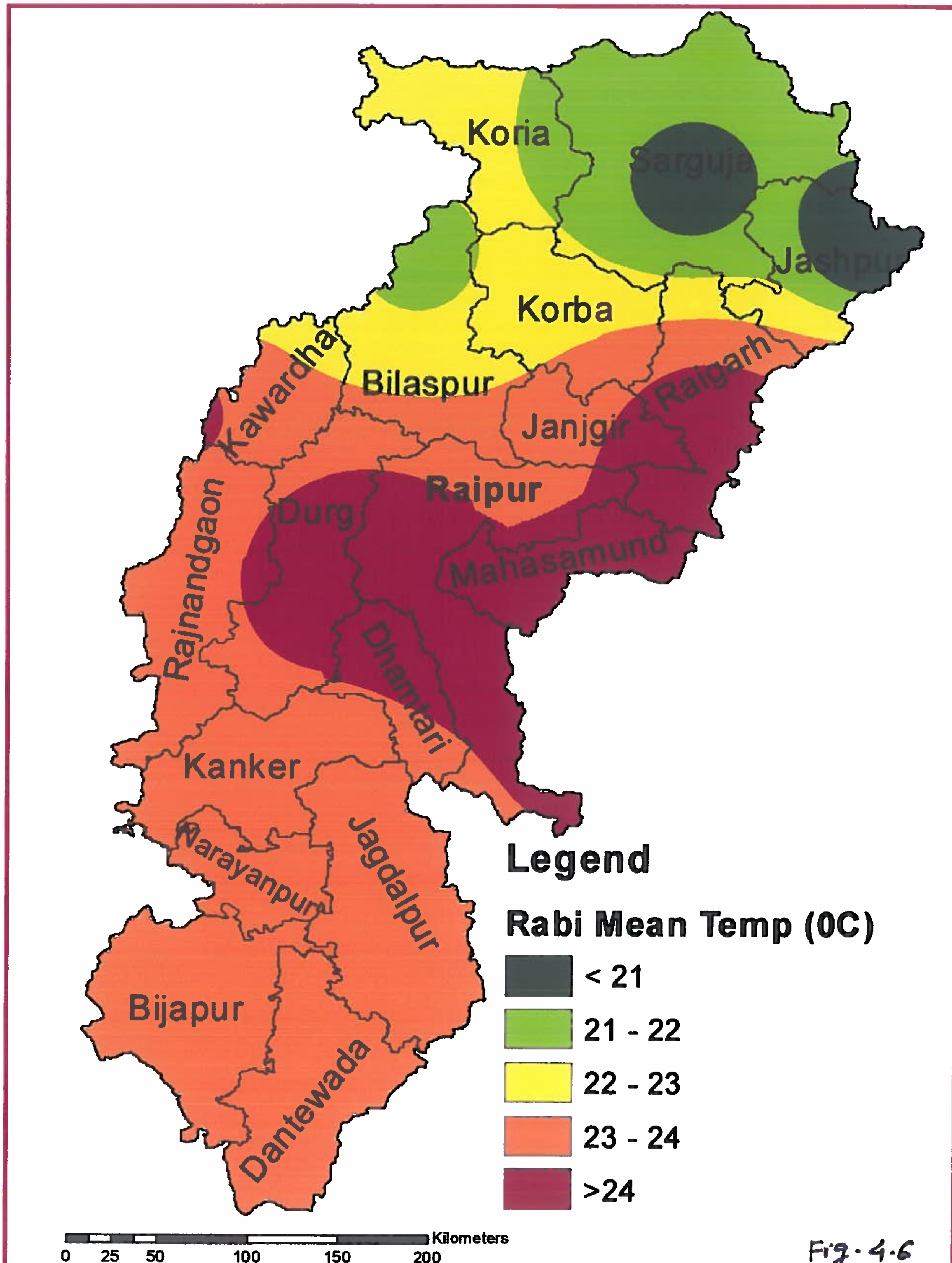

Fig. 4.6

Raipur (Tauranga, Bhatapara, Balodabazar and Kasdol), Bilaspur (Mungeli, Tkhatpur, Bilha and Bilaspur), Janjgir (Baloda, Akaltara, Champa, Pamgarh, Nawagarh and Janjgir), Korba (Korba, Kartala and Nonbira), Raigarh (Dharmjaygarh, Sithra and Lailunga), and remaining part of plain zone having temperature more than 24 ^{0} C during Rabi also.

4.3 Relative humidity

4.3.1 Annual relative humidity

Based on annual mean relative humidity distribution, whole state is divided into five major categories namely very low humid region (< 56%), low humidity region (56-58%), medium humidity region (58-60%), high humid region (60-62%) and very high humid region (> 62%).

Due to industrialization temperature increasing because of green house gases, annual relative humidity become very low in areas like Bhilai, Durg, Raipur and Raigarh. Remaining part of Chhattisgarh plains except southern pert comes under low humid region which also cover whole area of northern hill zone. Southern part of Chhattisgarh plain and western part of Bastar plateau comes under medium humid region. Most of Bastar Plateau comes under high humid region except Bastar, Jagdalpur and Kutumsar of Bastar and Kanker of Dantewara which falls under very high humid region.

4.3.2 Relative humidity during *Kharif* season

As explained above in *Kharif* season also relative humidity Durg, Rajnandgao, Bhilai, Raipur, and Raigarh is less than 66.5%, and remaining part of Chhattisgarh plains comes under low humid (66.5-68%) region with some parts

Annual Relative Humidity (%)

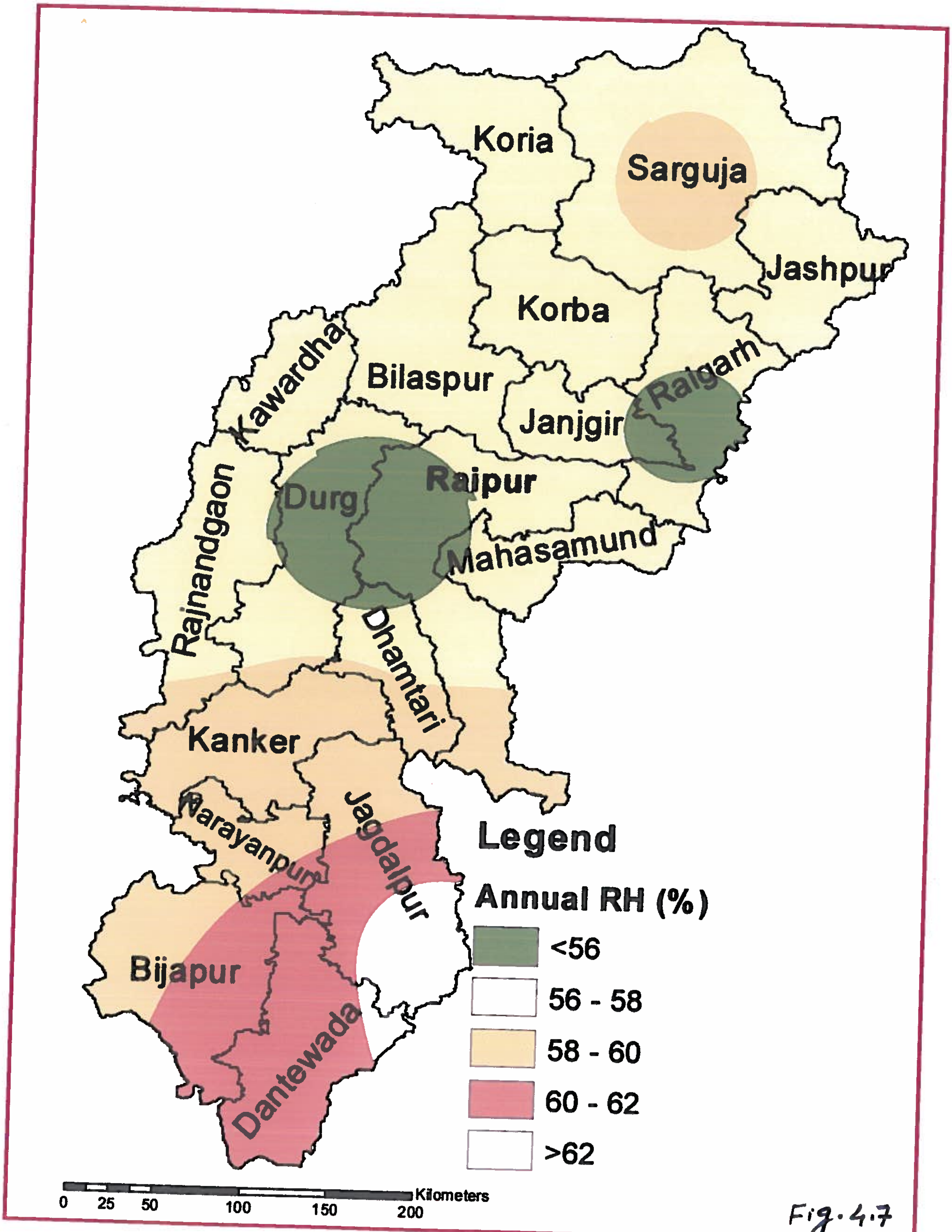

Fig. 4.7

Relative Humidity during Kharif season

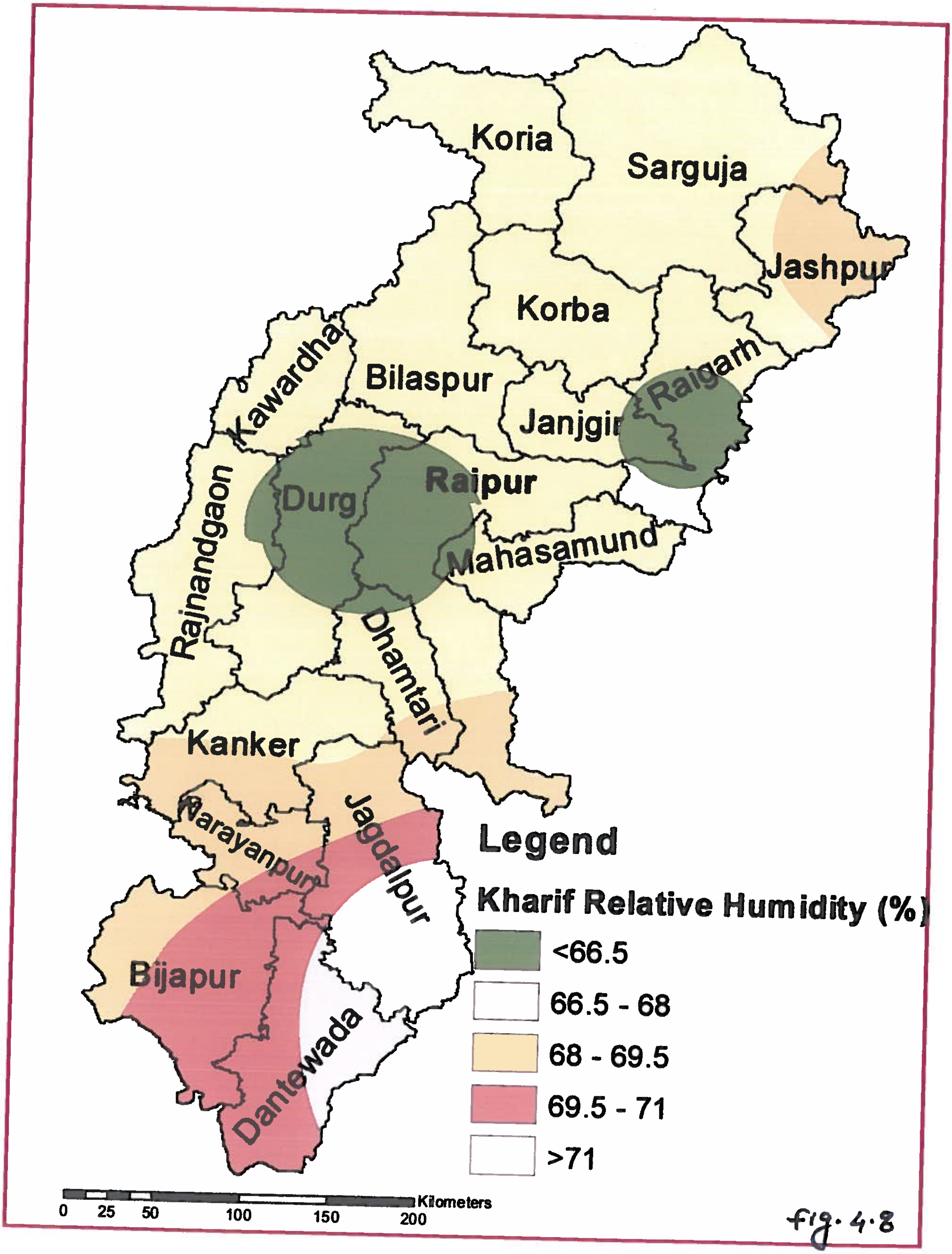

fig. 4.8

Kanker (Charma and Bhanupratappur) and Jaspur (Mahnai, Bagicha and Pathalgaon). Remaining part of northern hill zone and 50 % of Narayanpur and Bijapur (Pasewara, Bandepar, Annapur and Bhopalpattnam) comes under relative humidity of 68-69.5 % during *Kharif* season.

Most of Bastar plateau falls in high humid (69.5 – 71 %) region excluding Jagdalpur (Jagadalpur and Suklapara), Dantewara (Rokela, Sukma, Penta and Kukaner) which comes under very high relative humidity (> 71 %) during *Kharif* season.

4.3.3 Relative Humidity during *Rabi* season

As like *Kharif,* relative humidity during *Rabi* season is very low (below 45%) in areas like Durg, Raipur, Dhamtari and Pendraroad of Bilaspur. Relative humidity during Rabi season in most of Chhattisgarh plain and parts of northern hill zone like Koriya (Manendragarh and Devadand), Jaspur (Patthalgao and Kotawa) and Jashpurnagar of Jaspur ranges between 45-47%. Remaining part of Northern hills and Chhattisgarh plain comes under medium relative humidity (47-49%). Most part of Bastar plateau and Ambikapur region of Sarguja comes under high relative humid (49-51%) region, where as some part of Bastar plateau includes Bastar (Gorenga, Chitrakote, Jagdalpur, Bastar, Shuklapara and Darba) Dantewara (Kukanar, Dantewara, Shukma, Konta and Penta) and some part of eastern region of Bijapur falls under very high relative humidity(> 51%) during *Rabi* season.

Relative Humidity during Rabi season

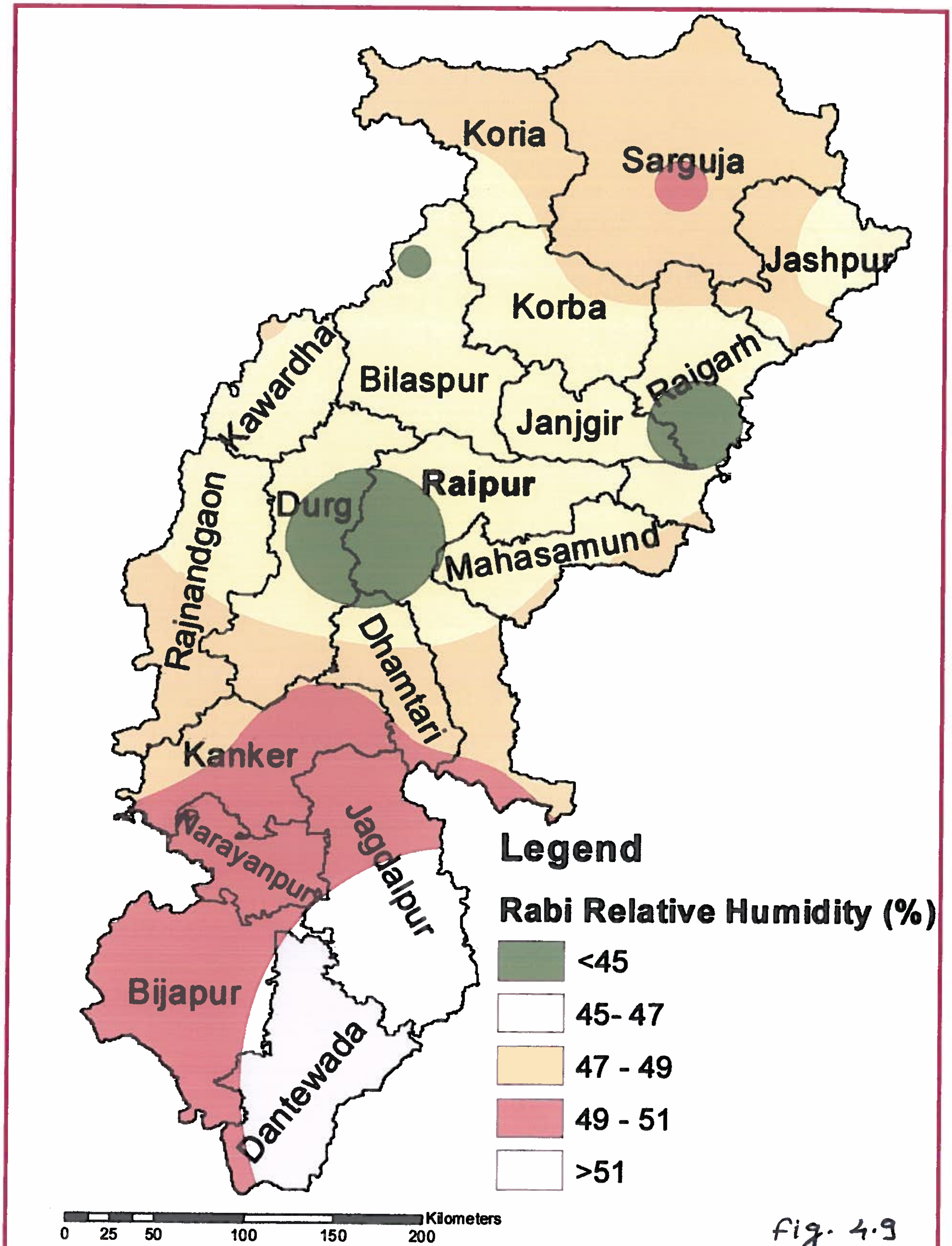

fig. 4.9

4.4 Cloud cover

4.4.1 Annual cloud cover

Based on annual cloud cover data obtained the state has been classified into very less (less than 3 octa), less cloud cover region (3-3.5 octa), medium (3.5-4 octa) and high cloud cover region (4-4.5 octa).

Only small part of state faces less than 3 octa annual cloud cover that is in some parts of Sarguja and Jashpur districts where as maximum part of Northern hills zone consists of Sarguja, Koriya having low annual cloud cover and also parts of Chhattisgarh plain include Korba, Raigarh, Saraipali tehsil of Mahasamund, southern region of Raipur comes under this range. Where as remaining part of Chhattisgarh plain and part of Northern Bastar plateau comes under medium cloud cover with 3-4 octa. Remaining area of Bastar plateau enjoys annual cloud cover is 4-4.5 octa.

4.4.2 Cloud cover during *Kharif* Season

During high cloud cover during *Kharif,* the state has been categorized into five classes very less (< 4.5 octa), less (4.5-5 octa), medium (5 – 5.5 octa), high (5.5-6 octa) and very high cloud cover (>6 octa). Eastern part of Northern hills had very less cloud cover and other part is classified in to less cloud cover region and some part of north eastern area of Chhattisgarh plains.

Maximum part of Chhattisgarh plains includes Bilaspur, Korba, Raipur, Korba, Janjgir, Raigarh, Durg, Rajnanadgaon and Dhamtari and also Jagdalpur (Keskal and Parasgao), Narayanpur (Koilibera, Parankot and Sonpur), Bijapur (Pasewara. Bhopalpattnam, Bhadrakali and Kusur), Dantawara (Kistaram,

Annual Cloud cover (okta)

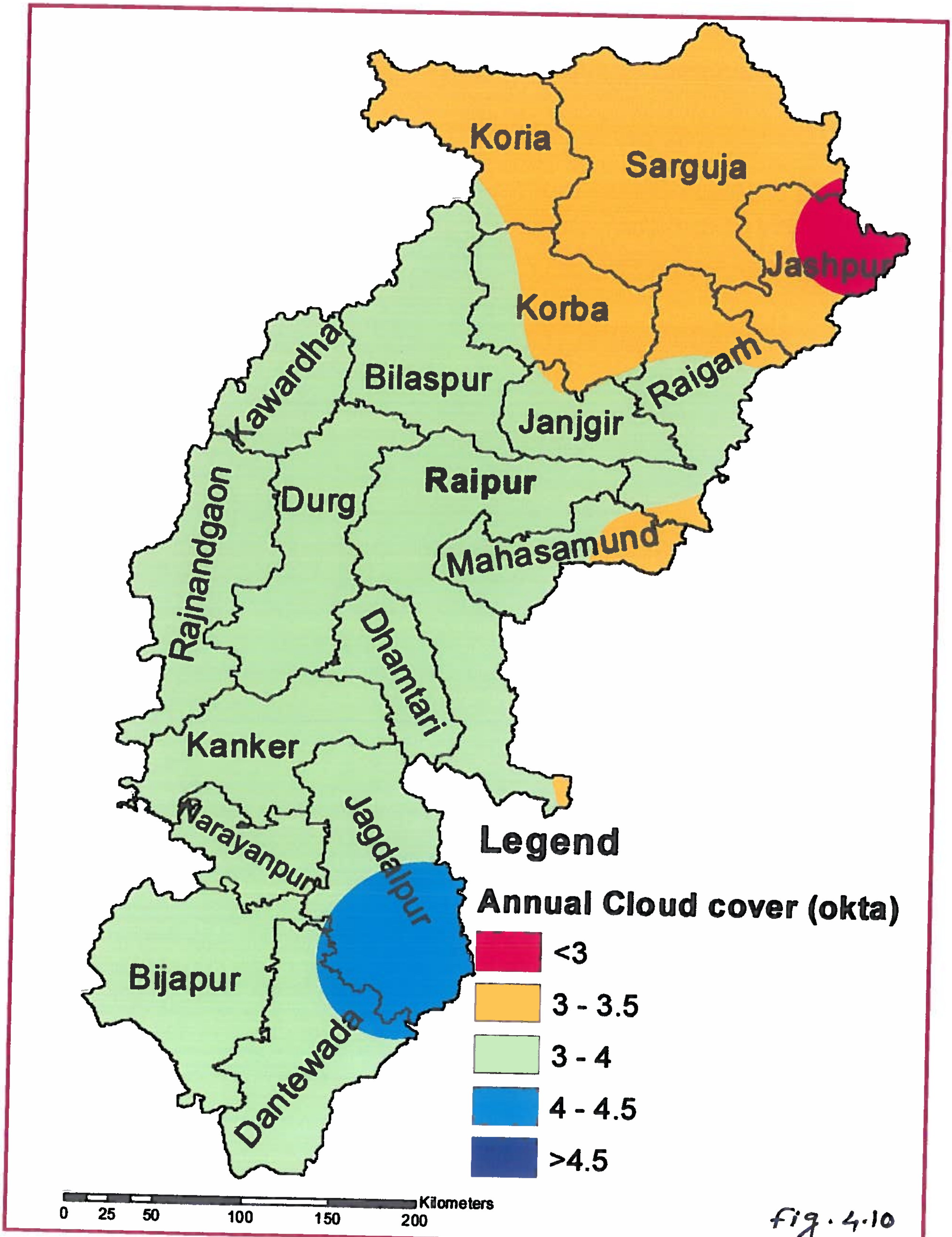

fig. 4.10

Cloud cover during Kharif season

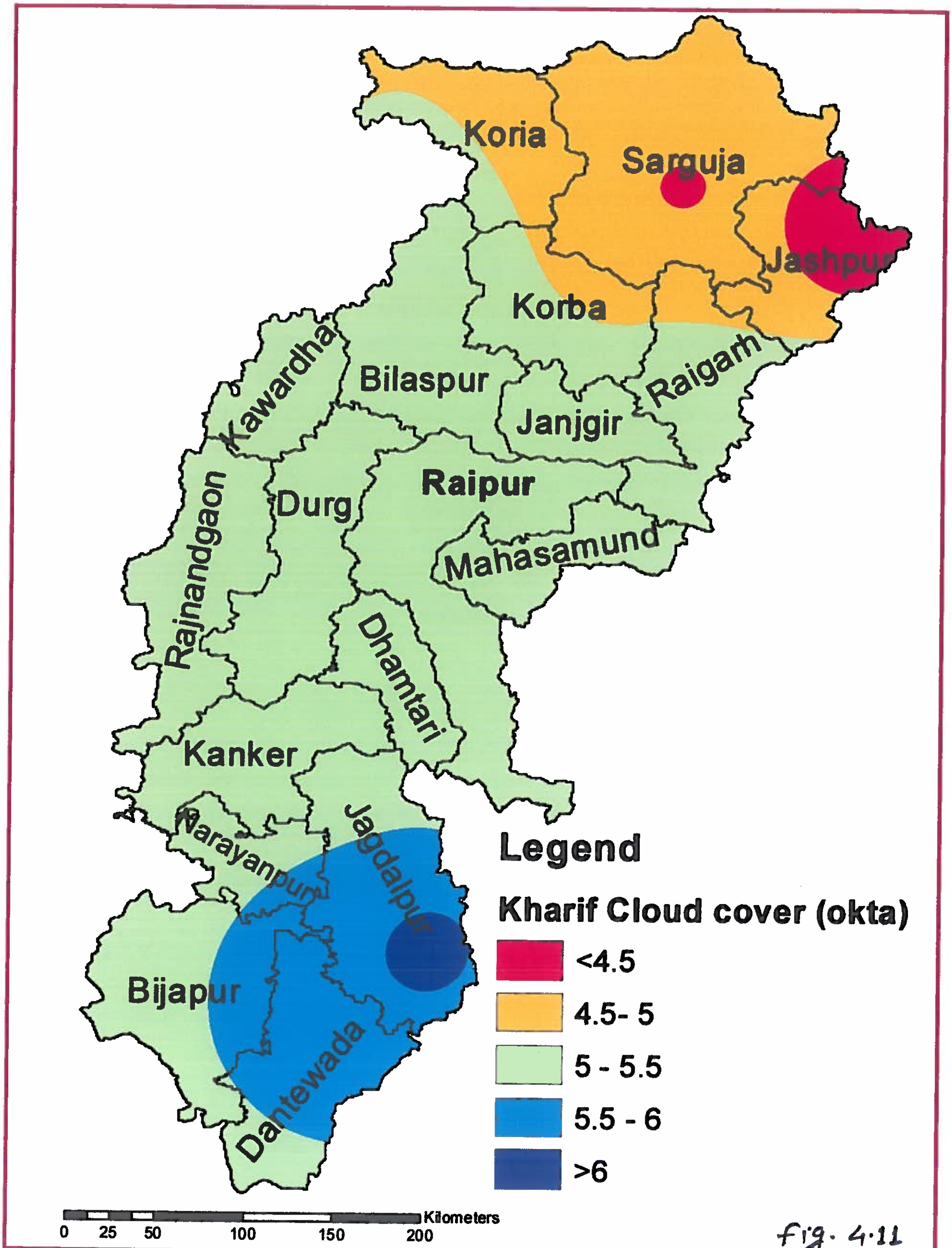

Fig. 4.11

Golapali and Konta) comes under medium cloud cover during *Kharif* season. Most of Bastar plateau comes under High humid region except Jagdalpur and Bastar regions of Bastar which are having high cloud cover during *Kharif.*

4.4.3 Cloud cover during *Rabi* season

Only Jaspur (Rupsera, Jashpurnagar and Raikera) comes under less then 1.5 octa cloud cover region of the state. Whole Northern hill zone and most part of Chhattisgarh plain zone like Raigarh, Janjgir, Korba, western Mahasamund, Bilaspur, Durg (Nandghat, doundilohara, Balod, Daundi and Gurur), Kanker (Bhanupratapur, Antagarh, Charama, Kanker and Sarona), Dhamtari (Nagri and Dhamtari), Rajnandgao (Ambagarhchouki, Mohala and Manpur), Raipur (Bilaigarh, Balodabazar, Kasdol, Bhatapara, Palari, Chhura, Gariaband, Mainpur and Deobhog) comes under medium cloud cover (1.5-2 octa). Cloud cover during Rabi season whole Bastar plateau, Rajnandgao (Chhuikhadan, Dongargarh, Rajnandgao and Chichola), Durg (Arjunda, Gunderdehi, Durg, Patan, Saja, Bametara and Nawagarh), Dhamtari (Kurud), Raipur (Rajim, Abhanpur, Raipur, Tilda and Simga), Bilaspur (Pendraroad, Lormi, Achanakmarg and Chilpi), Korba (Pasan and Ahirpara) comes under high cloud cover (2-2.5 octa) category, where as Surrounded area of Jagdalpur and Bastar region of Bastar district comes under cloud cover of 2.5-3 octa during *Rabi* season.

4.5 Rainy Days

4.5.1 Annual rainy days

Rainy days is one of the criteria of classification rainfall (intensity), the day must be more than 2.5 mm is comes under rainy day. Based on this data collected

Cloud cover during Rabi season

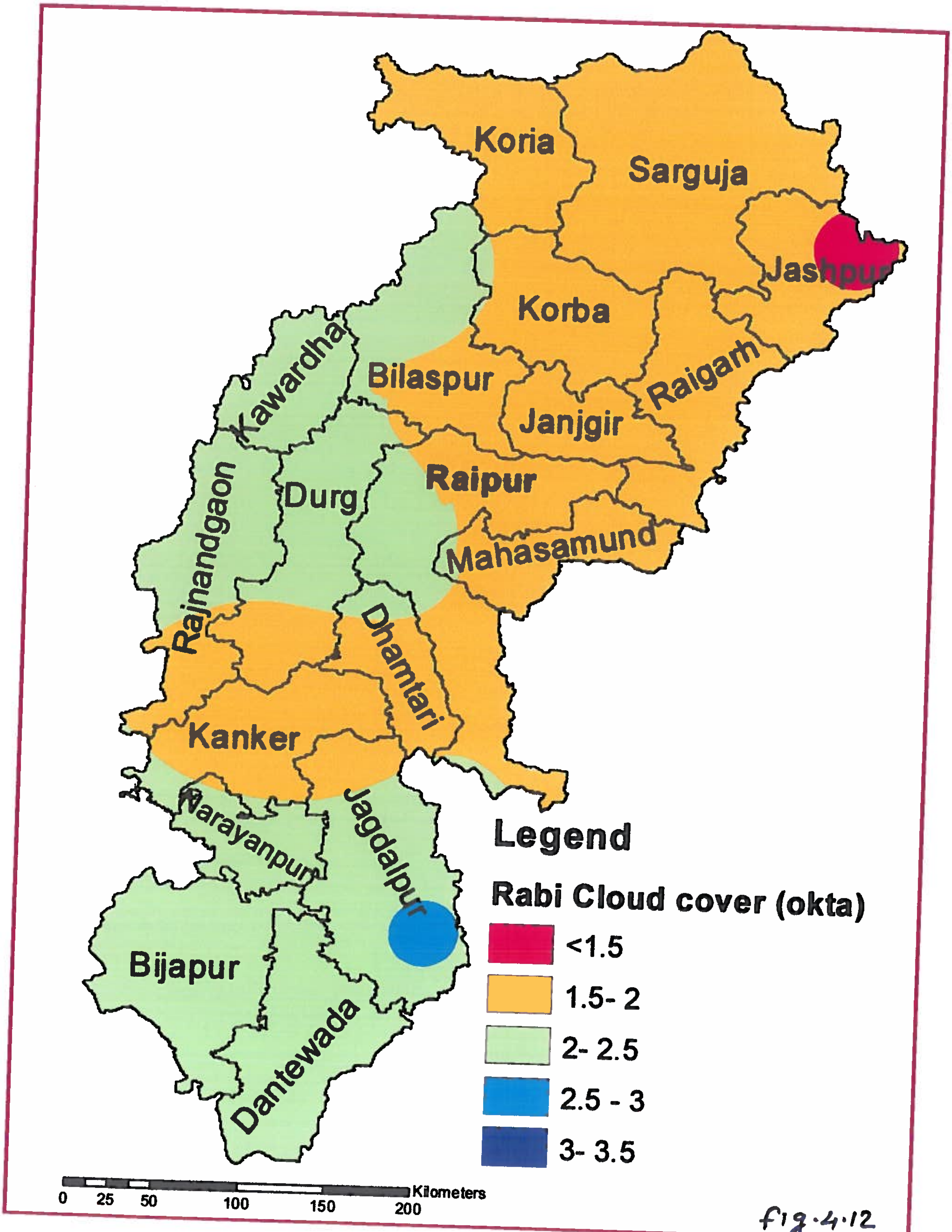

fig. 4.12

Annual Rainy days

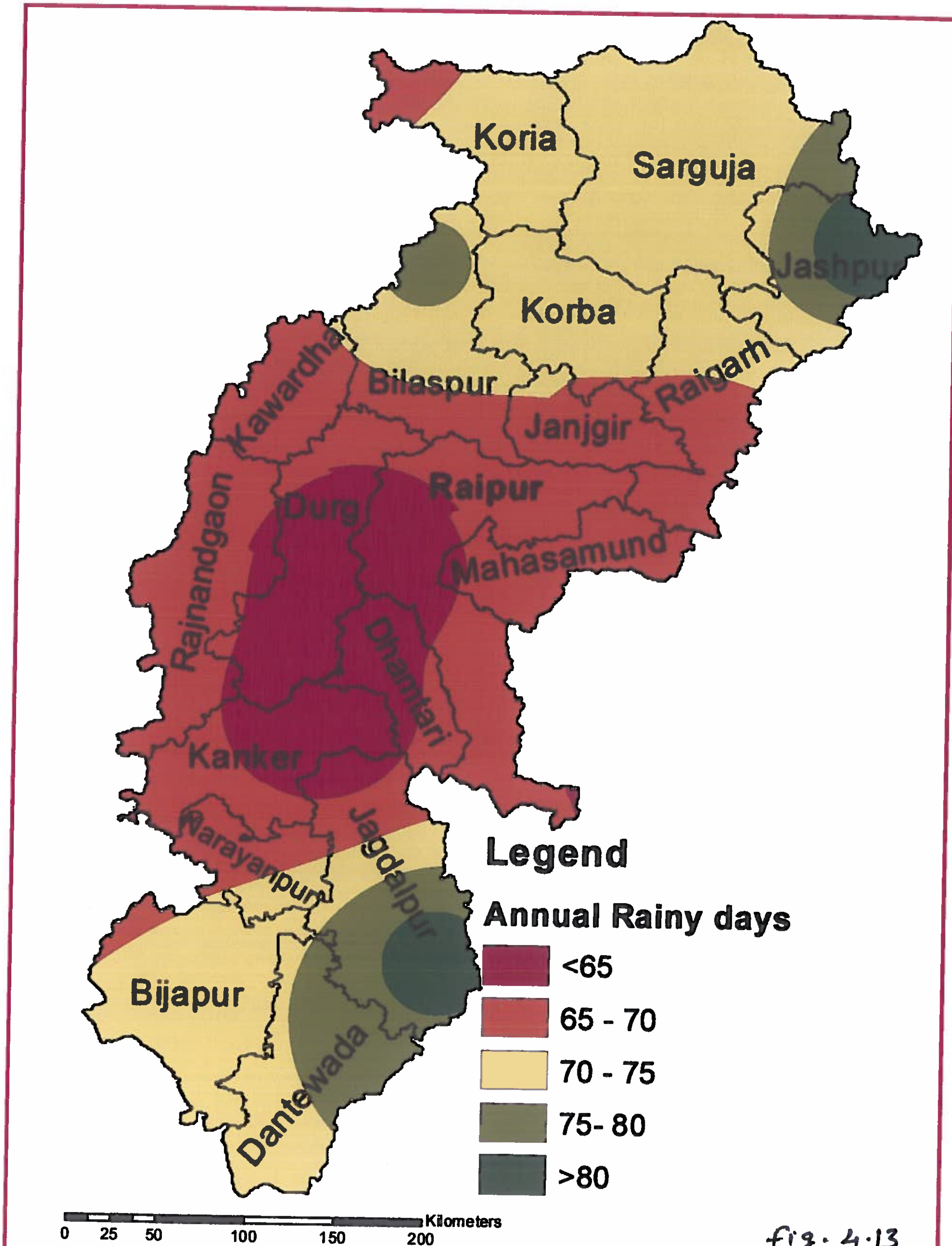

fig. 4.13

from different stations, the state has been categorized into five classes namely very less annual rainy days zone (below 65 days), less rainy days zone (65-70 days), medium (70-75 days), more (75-80) and more rainy days zone (more than 80 days).

Most part of Chhattisgarh plain consists of Raipur, Mahasamund, Dhamtari, Kanker, Durg and Rajnandgao are located at very less annual rainy days zone. Parts of Chhattisgarh plain like Kawardha, Durg, Bilaspur (Mungeli and Bilha), Janjgir, Korba, Raigarh (Kharsia, Raigarh and Sarangarh), Mahasamund, Raipur (Balodabazar, Palari, Kasdol, Bilaigarh, Gariaband and Deobhog), Kanker (Antagarh and Pakhanjur), Koriya (Bharatpur) Jagdalpur (Kondagaon), Dhamtari (Nagri) and northern part of Bastar plateau Narayanpur (Koylibera and Narayanpur), Bijapur (Pasewara), comes under less rainy days of state.

The maximum area of the state come under medium rainy days zone in which most part of Northern hill zone consists of Surguja, Jashpur (Mahnai and Pathalgaon), Koriya, and some parts of Chhattisgarh plain like Raigarh (Dharmjaygarh), Korba (except Nonvira Bilaspur (Parasi, Achanakmar, Lormi and Kota), Janjgir (Balodabazar), and also some parts of Bastar plateau like Bastar (Kondagaon), Narayanpur (Bhairamgarh), Bijapur, Dantewada (Kota, Aranpur and Koriras).

Where as eastern portion of Northern hill zone; Surguja (Samri) Jashpur (Bagicha and Kunkuri) along with Bilaspur (Pendraroad) and eastern part of Bastar plateau includes Bastar (Amravati and Chitrakote), east and north east part of Dantewada comes under more rainy days zone. Only part of Jaspur (Jashpurnagar) and Jagdalpur (Jaitgiri, Bastar and Jagdalpur) comes under very more rainy days zone.

4.5.2 Rainy days during *Kharif* Season

Maximum area of southern Chhattisgarh plain zone receives maximum rainfall in very short period of time with less rainy day during *Kharif* season (less then 60 days). This zone covers Rajnandgao, Durg, Dhamtari and northern Kanker, Kawardha (Kawardha, Mohgaon and Gandai), Raipur (Bhatapara, Tilda, Simga, Raipur, Arang, Abhanpur, Chhura, Gariaband and Deobhog), Mahasamund (Mahasamund and Sirpur) and also northern part of Jagdalpur (Keskal and Bisrampur) and Narayanpur.

Maximum part of the state comes under medium rainy days (60-65 days) zone during *Kharif* season which includes most part of Northern hill zone Koriya, Sarguja (Wadrafnagar , Chiraikund, Surajpur, Ambikapur and Bhakurma), and some parts of Chhattisgarh plain, Janjgir, Raigarh, Korba (except Pasan and Ahirpara), Bilaspur (except Marwahi and Pendraroad), Kawardha (Pandaria), Raipur (Balodabazar, Kasdol, Bilaigarh, Mainpur and Gariaband), Mahasamund (Saraipali, Basna and Pithora), southern Dhamtari and Kanker (Bhrenda, Kolar and Pakhanjur) and some areas of Bastar plateau like Jagdalpur (Makari and Kondagaon), Narayanpur (Narayanpur, Sonpur, Chotadongar and Hoinar), Bijapur (Pasewara, Annapur, Bhopalpattnam and Koturu).

Maximum part of Bastar plateau falls in zone having more rainy days (65-70 days) covers Dantewara (accept Gidam), Bijapur (Jarikaker and Basaguda), Southern Narayanpur, Bastar (Kondagaon, Rajagaon, Makri , Amaravati and

Rainy days during Kharif season

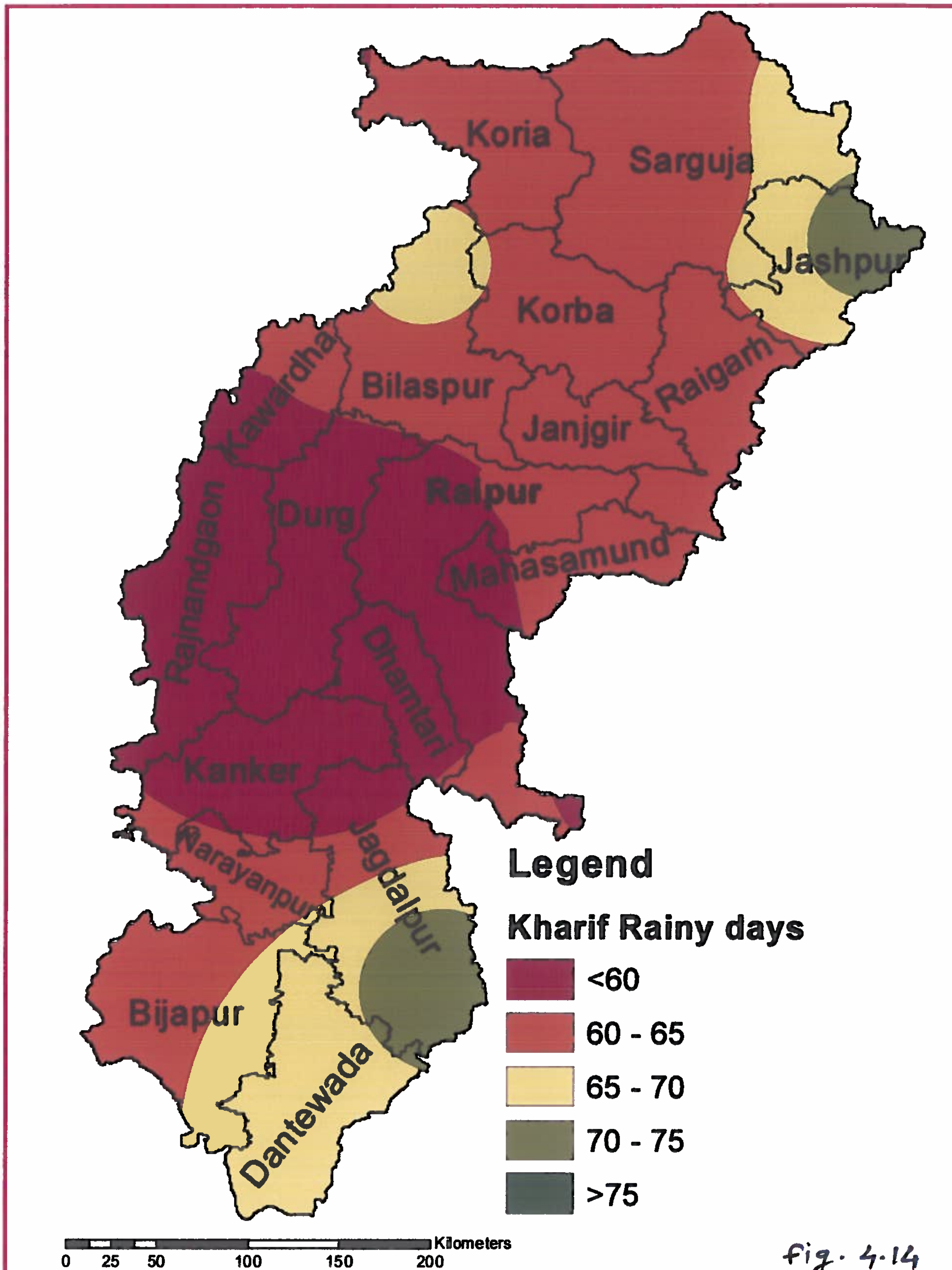

Fig. 4.14

Garanga) along with some parts of Bilaspur (Marwahi and Pendraroad), Korba (Ahirpara and Pasan), Sarguja (Sitapur and Samri), Jashpur (Champa, Mahnai, Bagicha, Ghatmunda, Tapkara, and Pathalgaon). Remaining part of state like Sarguja (Kusumi), Jaspur (Rupsera, Jashpurnagar, Raikera, and Kunkuri), Jagdalpur (Jaitgiri, Bastar, Jagdalpur and Chitrakote), Dantewara (north east region like some part of Gidam) receives more rainy days (70-75 days) during *Kharif* season.

4.5.3 Rainy days during *Rabi* season

Maximum rainfall of the occurs during *Kharif* season only small portion of rain occurs during Rabi season, based n which state has been divided mainly in to five categories. Only small portion of Raipur (Deobhog) falls in class having very less rainy days (less than 6 days).

Most part of Chhattisgarh plain falls under class less rainy days (6-7 days) during Rabi season which includes Rajnandgao, Kanker, Dhamtari, Mahasamund, Raipur, Durg (except Nawagarh), Raigarh (Dharmjaygarh, Gharghoda, Kharsia, Raigarh and Sarangarh), Janjgir (Sakti, Malkhroda Nawagarh, Dabra and Jaijepur), Korba (Nonbira and Kartala) and Kawardha (Mohgaon and Gandai). Also part of Northern Jagdalpur and Narayanpur comes under this range.

Remaining part of Chhattisgarh plain like Raigarh (Bhojpur and Bhakurma) Korba (Kendai, Arsia, Jilda, Syang, Katghora, Korba and Pali), Koriya (Bharatpur, Kotadole, Ramgarh, Sonhat), Janjgir (Baloda, Champa and Akaltara), Bilaspur (Ratanpur, Kota, Lormi, Bilaspur, Mungeli and Bilha), Kawardha (Pandaria) and part of Northern hill zone, Sarguja (except Samri and Sitapur), Jashpur

Rainy days during Rabi season

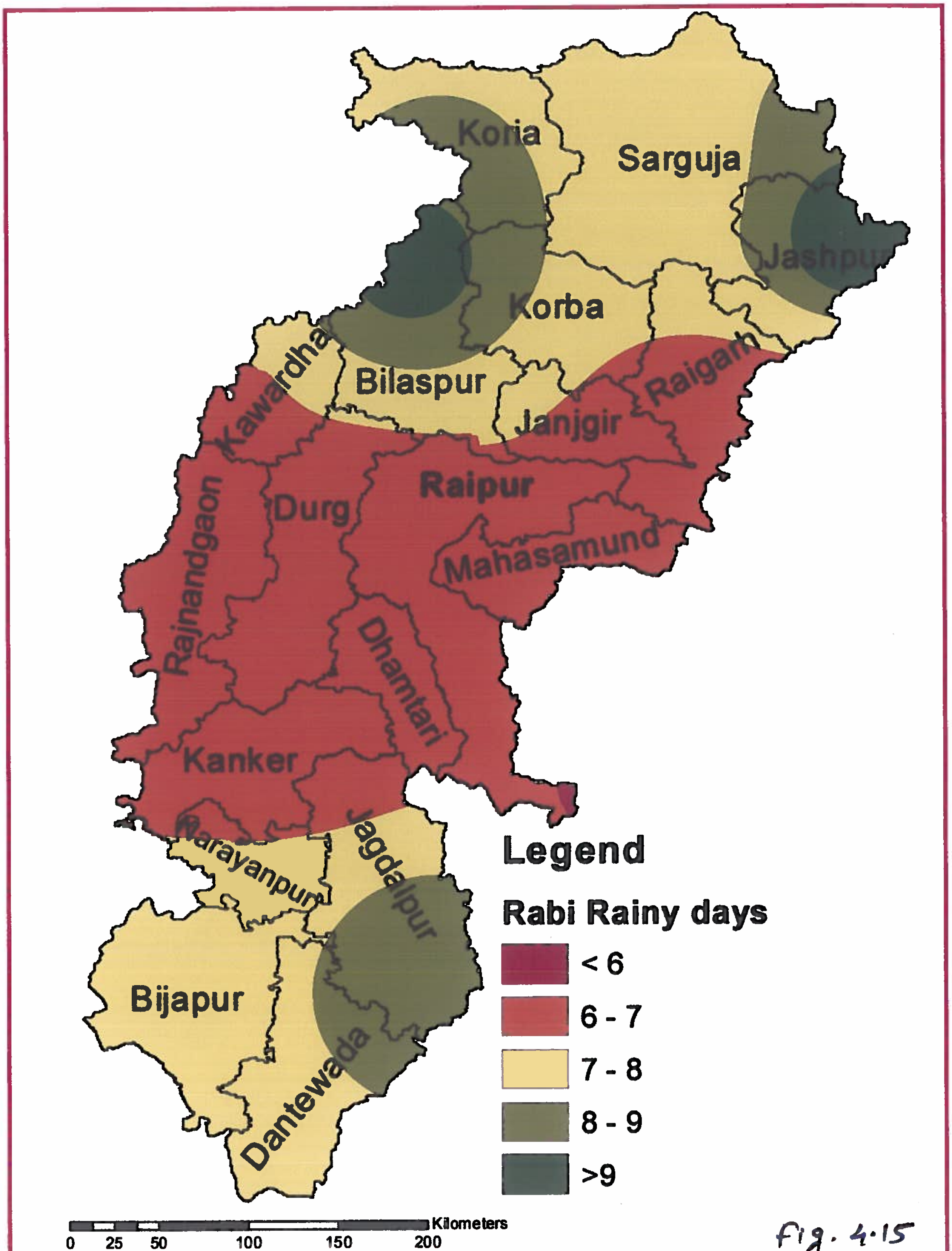

Fig. 4.15

(Pathalgaon and Kotaba), and also parts of Narayanpur, Bijapur, Northern part of Dantewara comes under medium rainy days (7-8 days) zone during *Rabi* season. Most part of Bastar plateau, Southern Jagdalpur, East and North East of Dantewara (Giddam, Baghmundi, Sukma) had high rainy days (8-9 days) during *Rabi* season. This also includes Koria (Baikunthpur, Manendragarh and Kalahari), Samri, Champa, Kwai, Bagicha, Bandarchua of Sarguja district, Kunkuri of Jashpur and parts of Chhattisgarh plains like Bilaspur (Parasi, Lormi and Achanakmarg) and Piparia, Ahirpara, Nagoi of Korba district.

Remaining portion of the state like Kusmi of Sarguja, Rupsera, Sakardi, Aamakona, Jashpurnagar and Raikera region of Jashpur, Pandraroad tehsil of Bilaspur and Pasan of Korba district the rainy days during Rabi season is more than 9 days.

4.6 Wind speed

4.6.1 Annual wind speed

Only Deobhog of Raipur had annual wind speed below 3 km per hour, Where as Tauranga and Indagaon of Raipur, whole Dantewada and southern part of Jagdalpur district having annual wind speed of 3-4 km per hour. Raigarh, Sarangarh of Raigarh, Dabra of Janjgir, Saraipali, Suarmar of Mahasamund, Gariaband, Nawagarh of Raipur of Chhattisgarh plain comes under medium wind speed (4-5 kmph) region along with Kondagaon, Jagdalpur of Jagdalpur district, Dantewada tehsil of Dantewada district, Bijapur and Narayanpur districts.

Most part of state comes under region of high wind speed zone (5-6 kmph) includes Koriya (Bharatpur), Surguja (Samri), Jashpur, Raigarh (Dharmjaygarh,

Annual Wind speed (km/h)

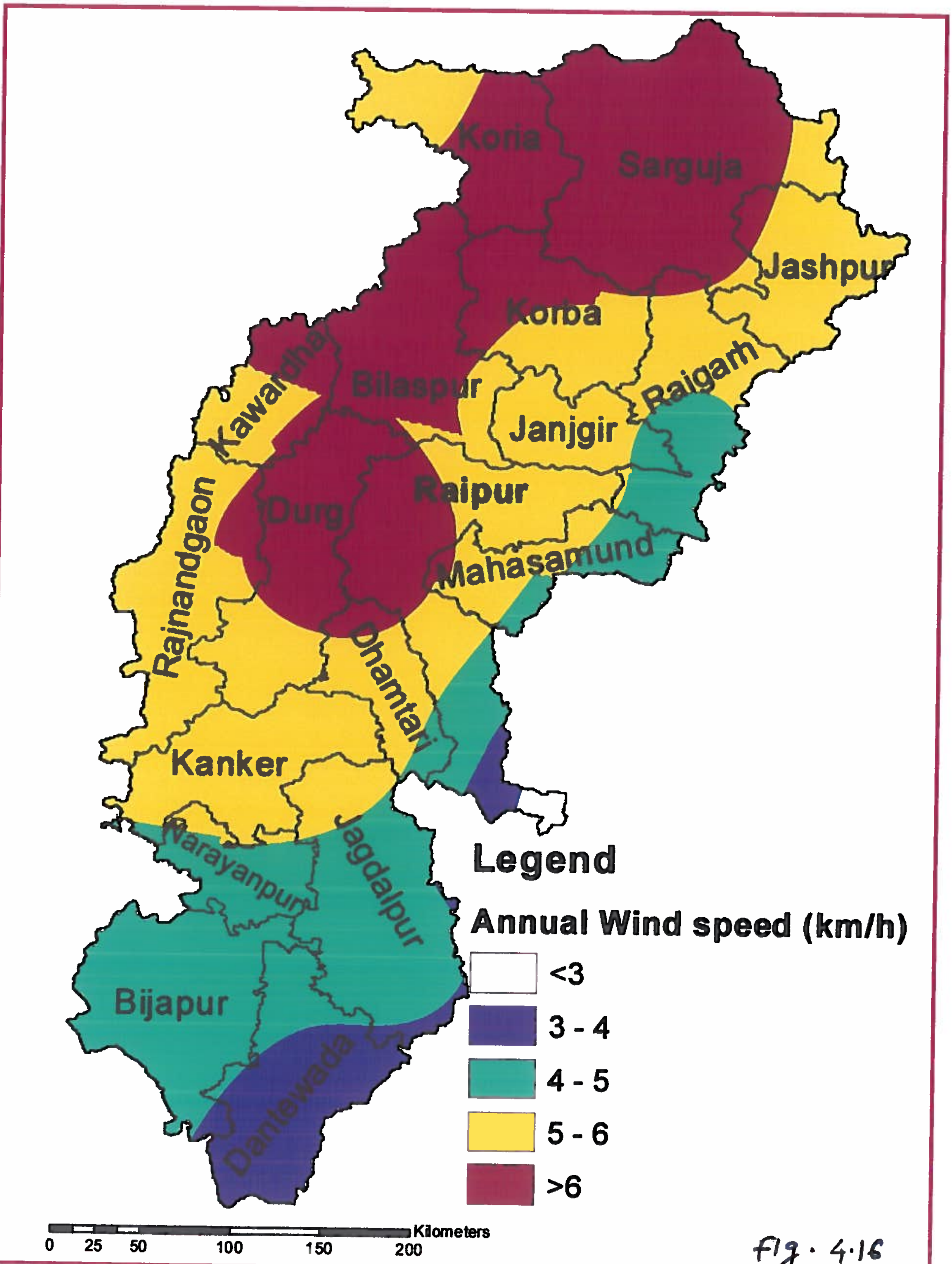

Fig. 4.16

Gharghoda and Kharsia), Janjgir, Korba (Katghora, Kartala and Korba), Bilaspur (Bilha, Ratanpur), Raipur (Bhatapara, Balodabazar, Kasdol, Bilaigarh, Rajim, Gariaband), Mahasamund (Pithora, Jagdishpur, Bagbahra), Dhamtari (Siphonpara and Dhamtari), Kawardha (Gandai and Kawardha), Rajnandgao, Durg (Balod, Doundilohara, Gurur and Doundi) and Kanker. Some part of Bastar plateau like Narayanpur (Koylibera and Dhanora) and Keskal of Jagdalpur district also comes under this range.

Remaining portion of Sarguja, Jaspur (Mahnai), Raigarh (Bhojpur), Koriya (Bharatpur), Korba (Piparia, Pasan, Ahirpara and Kendai), Bilaspur (Marwahi, Pendraroad, Lormi, Achanakmar, Mungeli and Tkhatpur), Kawardha (Pandria) Nawagarh, Bametara, Saja, Baraga of Durg, Raipur (Simga), Dhamtari (Kurud) comes under annual wind speed of more then 6 KM per hour.

4.6.2 Wind speed during *Kharif* season

Maximum area of Chhattisgarh plains like Raipur, Koriya, Sarguja, Korba, Bilaspur, Kawardha, Durg, Rajnandgao, Kanker, Dhamtari, Janjgir (Dabra and Malkhroda), Mahasamund (Saraipali, Basna and Bagbahra)and Raigarh (Raigarh, Kharsia, Sarangarh and Gharghoda) facing high wind speed during *Kharif* season of above 6 km/hour. Parts of Narayanpur (Koylibera, Narayanpur and Paraskote), Bastar (Keskal and Parasgaon) and Jashpur (Rupsera, Raikera and Jashpurnagar) also comes under this range of wind speed.

Most part of Bastar plateau like Narayanpur (Chotadonger and Hoinar), Jagdalpur (Makari, Sonpur, Kondagaon, Chitrakote and Bastar), Dantewara (Barsur and Gidam), and Pasewara Sundra, Bijapur, Bhiramgarh, Bandarkholi,

Wind speed during Kharif season

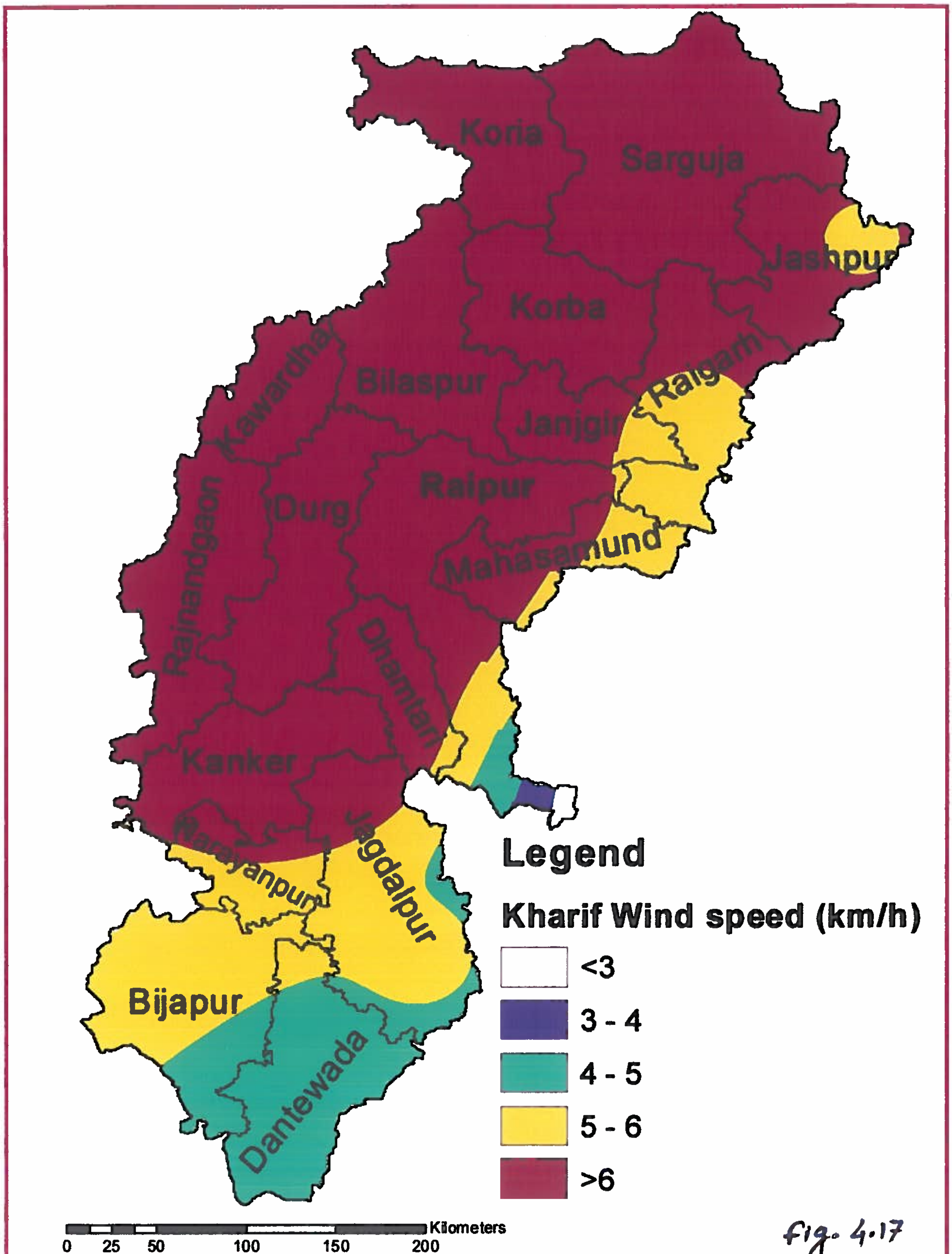

fig. 4.17

Bhopalpattnam regions of Bijapur district comes under wind speed 5-6 km/hours during kharif season. This class also includes other parts of state like Jashpur (Raikera), Raigarh (Gharghoda, Kharsia, Raigarh and Sarangarh), Janjgir (Malkhroda, Jaijepur and Dabra), Saraipali, Basna and Bagbahra region of Mahasamund, Sirsiwa, Chhura and Gariaband region of Raipur district.

Remaining part of eastern and central part of Bastar Plateau like Dantewara, Bijapur (Pujarikaker, Usur, Avupalli and Basaguda), Suklapara, Darba, Kotamsar Caves, Balega, Amrvati and Garenga region of Bastar district and also Mainpur, Tauranga region of Raipur district comes under region having wind speed of 4-5 km/hours during kharif season. Few parts of Raipur like Gohrapdar and Deobhog comes under region having Wind speed of 3-4 km/hours and less than 3 km/hours respectively during Kharif season.

4.6.3 Wind speed during *Rabi* season

As explained above only Deobhog region of Raipur district in *Rabi* season also having very low wind speed of below 2 km/hours. The areas of Mainpur, Badula, Indagaon and Gohrapdar of South East Raipur, Dantewara (Kukanar, Sukma, Penta, Beri and Konta) having wind speed of 2-3 km/hours.

Most part of Bastar plateau like Dantewara, Jagdalpur, Narayanpur and Bilaspur having wind speed of 3-4 km/hours. This also includes Kanker, Dhamtari (Siphonpara and Nagri), Raipur (Chhura, Rasela, Gariaband, Lipipara and Dhawalpur), Mahasamud (Suwarmar, Bagbahra, Bundeli, Basna and Saraipali) and Baramkera, Sarangarh, Tatla of Raigarh district also comes under this range.

Wind speed during Rabi season

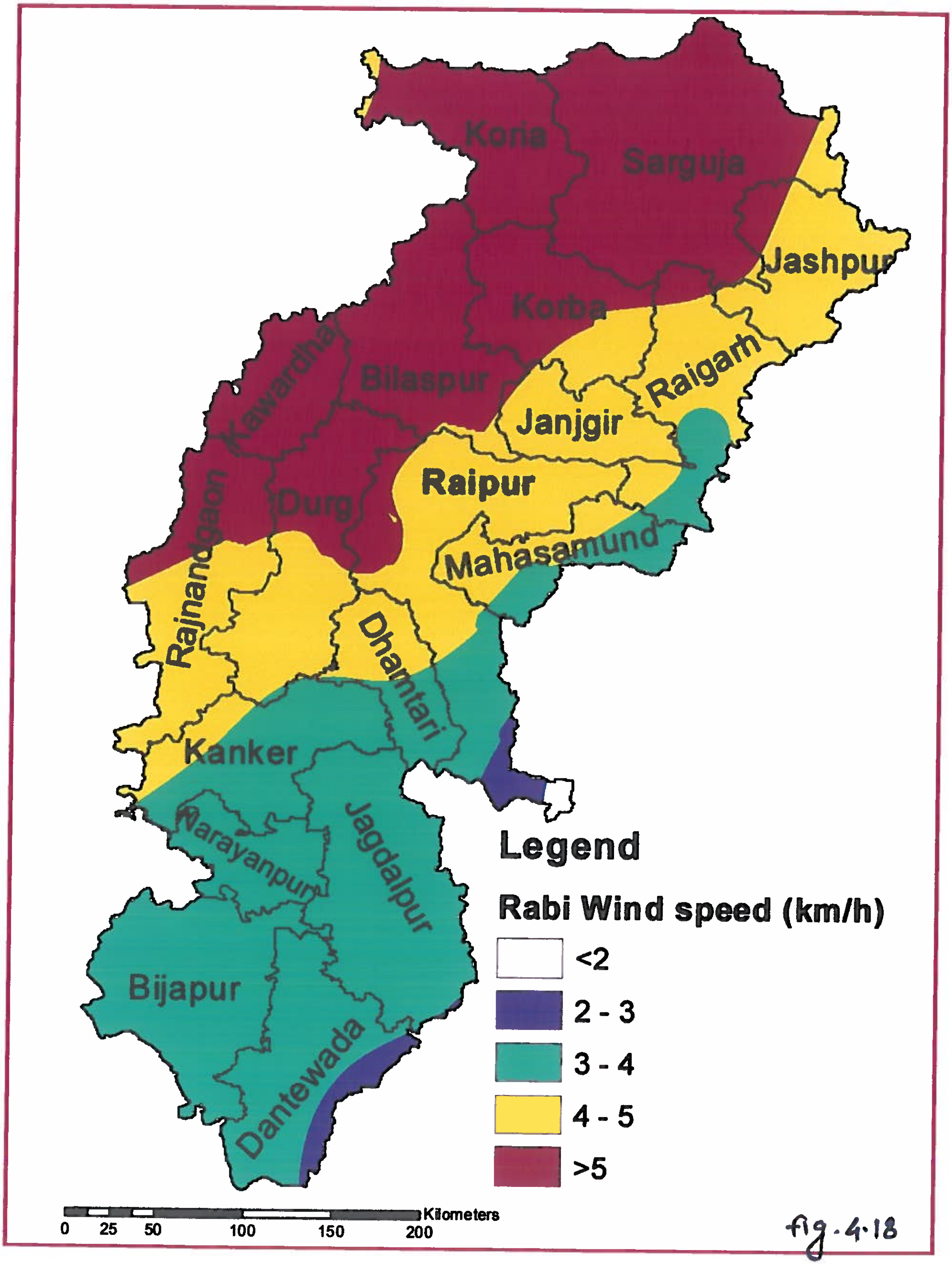

fig. 4.18

Wind speed (4-5 km/hours) during *Kharif* season have been recorded in many areas like Kanker (Kurshokorhi, Hanker and Bhanupratappur), Manpur, Mohala Ambagarhchoki, Dongargaon and Rajnandgao regions of Rajnandgao district, Doundilohara, Balod, Doundi, Gurur, Gunderdehi and Patan of Durg, Dhamtari (Kurud and Dhamtari), Abhanpur, Rajim, Chhura, Arang, Bangoli, Tilda, Palari, Bhatapara Balodabazar, Kasdole, Bilaigarh, Sirsiwa and Tola region of Raipur, Mahasamund (Sirpur, Patewa, Jagdishpur, Basna and Mahasamund), Janjgir, Bilha region of Bilaspur, Raigarh (Dharmjaygarh, Lailunga and Gharghoda), Korba (Kartala and Korba) Pathalgaon, Tapkara, Kunkuri, Jashpurnagar, Sakardih, Rupsera of Jashpur, Samari of Sarguja, Koriya (Bharatpur).

Remaining portion includes Sarguja, Koriya, Mahnai region of Jashpur, Bilaspur, Korba (Piparia, Pasan, Ahirpara, Kendai, Arsiya, Nagai, Katghora and Pali), Bhojpur region of Raigarh, Kawardha, Chhuikhadan of Rajnandgao, Nawagarh, Bametara, Saja, Barela, Durg (Bhilai), Raipur (Tilda, Simga and Raipur) regions recorded high wind speed of more than 5 wind km/hours during Rabi season.

4.7 Radiation intensity

4.7.1 Annual radiation intensity

On the basis of average annual radiation intensity, the state has been categories in five classes. These data were collected from WMO which are available on internet (www.wmo.ch). The classes with less than 18 mj/m^2 is categorized as very low radiation intensity, 18 -18.5 as low, 18.5 – 19 medium, 19 – 19.5 high an areas with more than 19.5 were categorized as very high radiation intensity zone.

Average Radiation Intensity

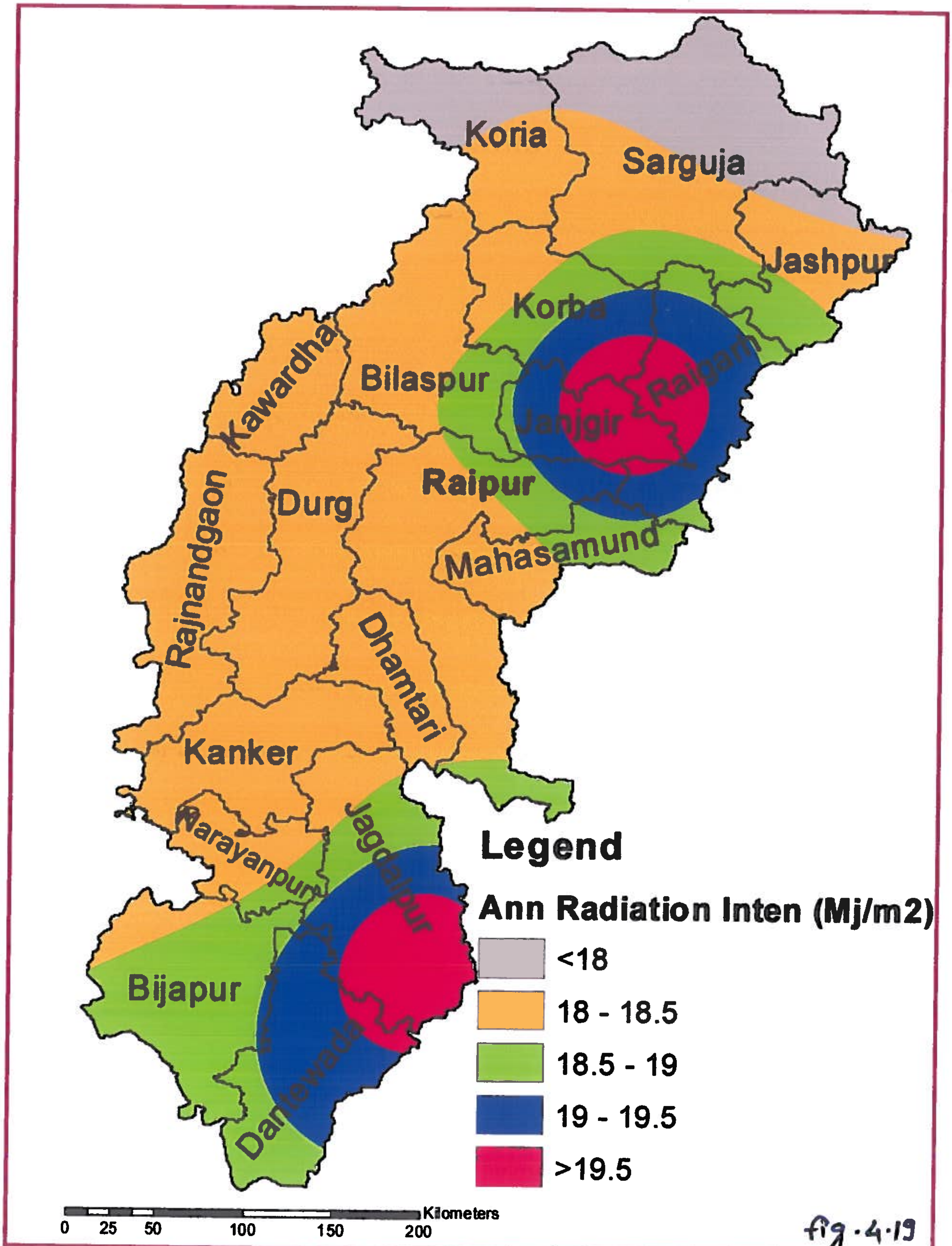

fig. 4.19

Northern part of the state which was categorized Northern hill having very low annual radiation intensity were as most part of Chhattisgarh plains and Southern part of Northern hill with some part of Narayanpur are having 18 – 18.5 annual radiation intensity. Part of North East Chhattisgarh plain Mahasamund (Saraipali and Basna), Raipur (Bilaigarh, Deobhog, Balodabazar, Indagaon, Kashdol and Tala), Bilaspur(Bilaspur, Bilha and Ratanpur) Korba(Chaitma, Pali, Kendai and Arsia), and some part of Sarguja (Parsa, Bhakurma, Sitapur and Kalnai), Jaspur (Pathalgaon, Kotaba, and Konpara), and most part of Bijapur and some areas of Jagdalpur (Bastar, Baghdera and Kondagaon), Dantewada (Gallipoli, Penta and Beri) are comes under medium radiation intensity zone. Some part of Jagdalpur (Amravati and Rajagaon) and Dantewada (Aranpur, Sukma, Elmagonda, Koriras, Porokameli and Barsur) and part of Raigarh (Bhakurma, Telta, Lailunga, Raigarh and Dharmjaygarh). Korba (Kartala, Madanpur, Fulsari and Syang), Janjgir (Champa, Akaltara, Baloda and Jaijepur) comes under high radiation intensity zone whereas the area surrounded by high radiation intensity zone like Southern part of Jagdalpur, Raigarh, Janjgir (Malkhroda, Sakti and Dabra) are categorized as areas having very high radiation intensity zone.

4.7.2 Radiation intensity during *Rabi*

During *Rabi* season the radiation intensity in North part of Northern hills and Northern Bilaspur are categorized into areas of very low radiation intensity zone. During *Rabi* remaining part of Sarguja, Northern part of Jashpur, Kawardha, Northern Rajnandgaon, Durg, part of Bilaspur (Tkhatpur, Kanteli, Chilpi, Mungeli and Kota), Korba (Kendai, Ahirpara and Nagai) are falls under less radiation

Radiation Intensity during Rabi

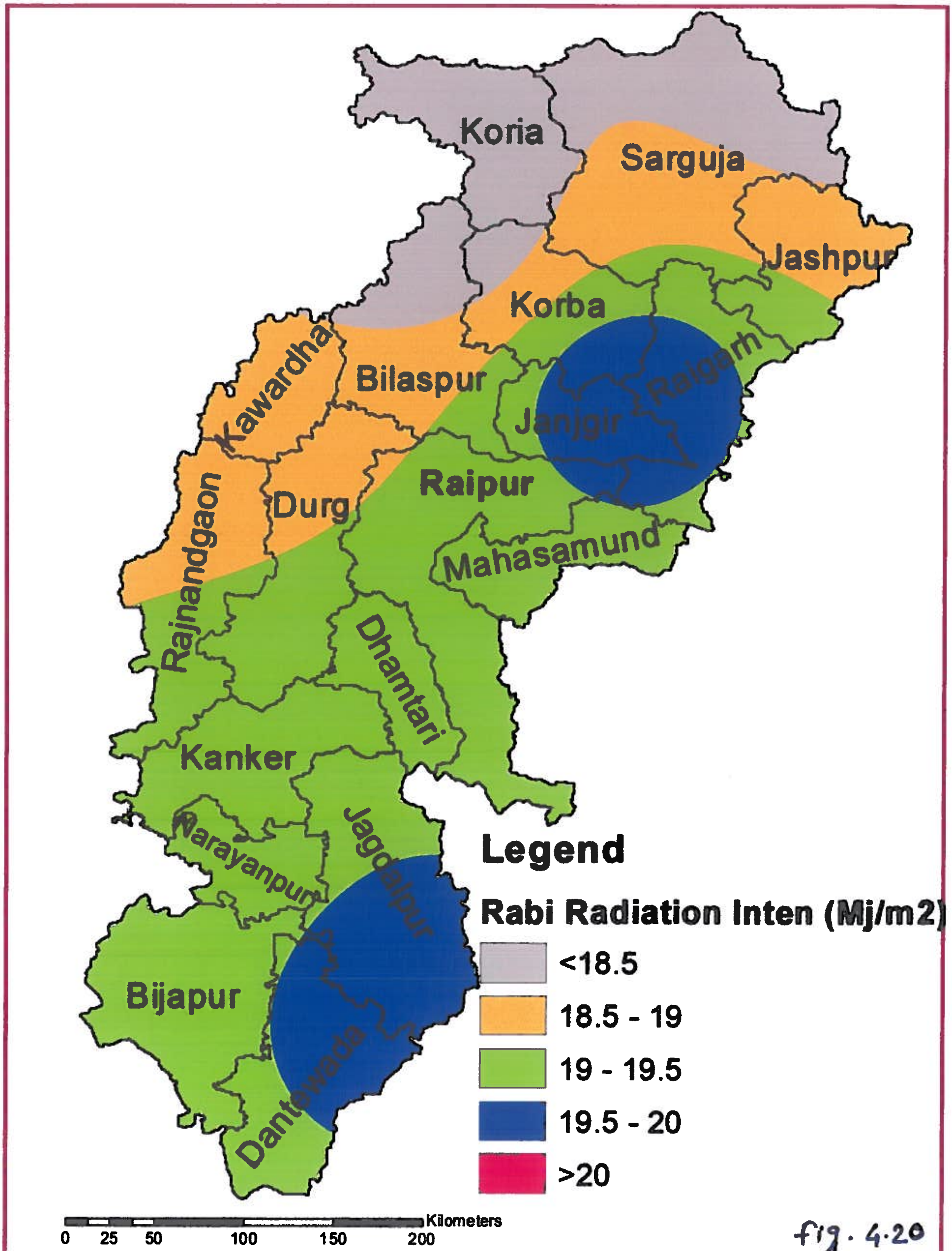

fig. 4.20

intensity zone. Whole part of Bastar plateau except southern Jagdalpur (Suklapara, Darba, Bastar, Amravati, Baghdeva), Dantewada (Gidam, Barsur, Malaiwara, Jirampam and Aranpur) and most part of Chhattisgarh plain like Kanker, Dhamtari, Mahasamund, Raipur, Durg (Durg, Bhilai, Dondi, Gurur, Dilhirajhar and Balod), Rajnandgaon (Ambagarh chauki, Mohala and Manpur) and little part of Korba (Madanpur and Syang) and North part of Raigarh categorized as medium radiation intensity zones. Southern Jagdalpur (Suklapara, Darba, Bastar, Amravati), Dantewada (Gidam, Barso, Malaiwara, Jirampam and Aranpur), Raigarh (Chal, Tetla, Bhakurma, Lailunga, Raigarh and Dharmjaygarh), Korba (Kartala, Madanpur, Fulsari and Syang) Janjgir (Champa, Akaltara, Baloda and Jaijaipur) comes under high radiation intensity zone. During Rabi the radiation intensity shows less than 20 only there is no part of state having very high intensity areas.

4.7.3 Radiation intensity during *Kharif* season

During *Kharif* season, Radiation intensity in Chhattisgarh state has been divided in the following categories, they are below 17 very low, 17 – 17.5 low, 17.5 – 18 medium, 18 – 18.5 high, > 18.5 very high. Bharatpur area of Koriya district comes under very low range of Radiation intensity. Some part of Koriya (Kotadol, Bargaon and Taloli) and Sarguja (Sonwal, Ramanujganj, Wadrafnagar, Chandanpur, Samari and Kusmi) comes under low range. Remaining part of Koriya (Devsil, Ramgarh, Baikunthpur, Manendragarh and Dewadand) and most part of Rajnandgaon(Chhuikhadan, Dongargarh, Chauki, Mohala and Tilai), Durg (Nawagarh, Bametara, Bairla, Dhamdha, Bhilai, Patan, Gunderdehi, Dondilohara

Radiation Intensity during Kharif

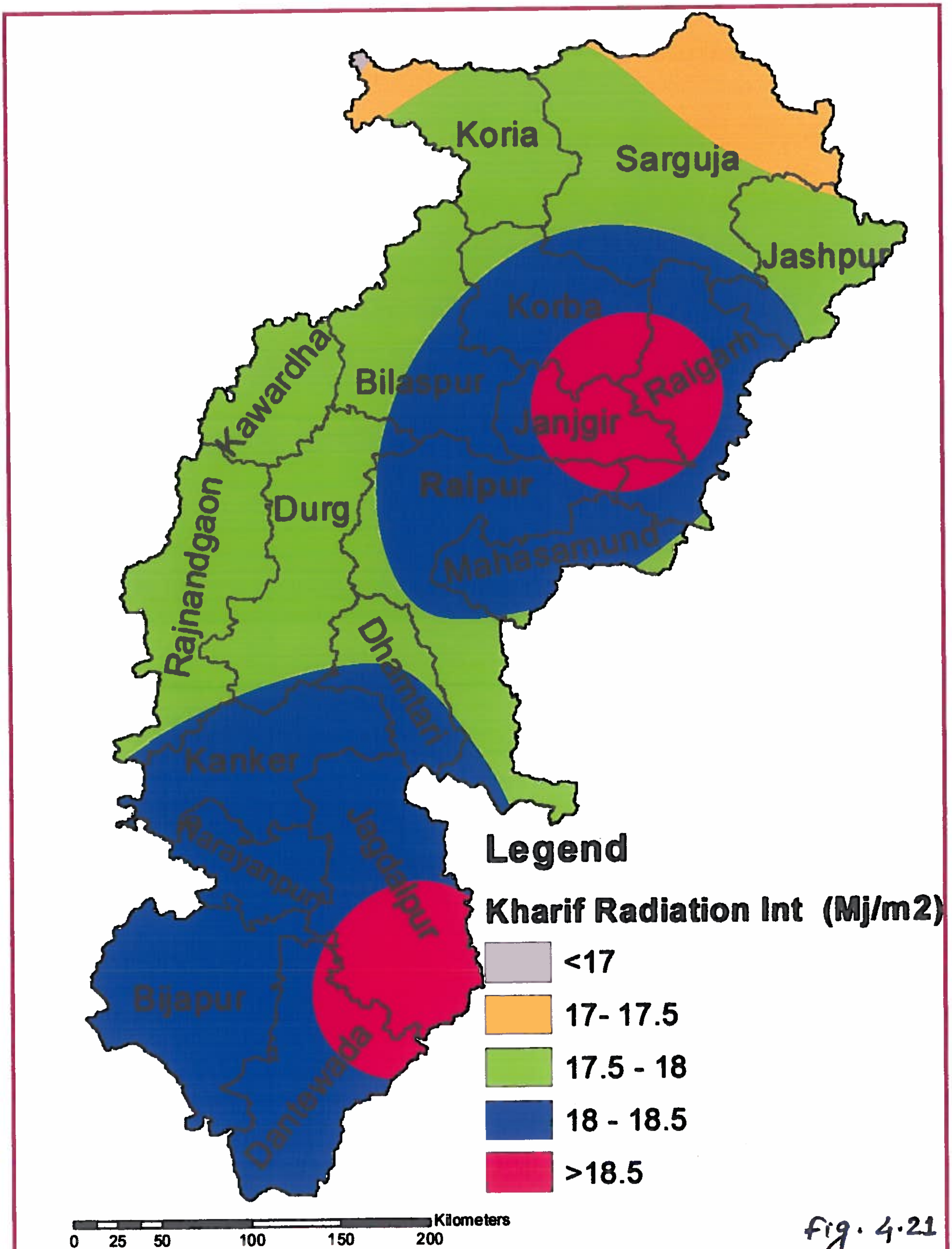

Fig. 4.21

and Balod), Sarguja (Chiraikund, Pendari, Ramkola, Kudurgarh, Dipadih, Rajpur and Ambikapur), Jashpur (Kawai, Bagicha, Jashpurnagar, Narayanpur, Kunkuri and Rupsera), Bilaspur (Parasi, Gaurela, Pendraroad and Achanakmarg), Raipur (Rajim, Gariaband, Mainpur and Deobhog), Dhamtari (Kurud and Chhati) and some part of Korba(Piparia and Pasan) fall under range of medium radiation intensity but Kawardha district completely comes under medium radiation intensity range. The whole area of Bijapur, Narayanpur, Kanker is constituted under high range radiation intensity but a large part of Mahasamund (Sirpur, Saraipali and Pithora), Korba (Chaitama, Katghora, Pali, Phulsari and Kartala), Raigarh (Bhojpur, Lailunga, Gharghoda, Singhanpur and Tetla), Dantewada (Gidam, Aranpur, Penta, Sukma and Konta), Jagdalpur (Keskal and Kondagaon), Dhamtari (Nagari and Birgudi) and remaining part of Rajnandgaon (Manpur), Durg (Dhallirajhra), Sarguja (Ramgarh and Sitapur), Janjgir Champa (Baloda and Champa) comes under high radiation intensity range. Large area of Janjgirchampa (Shakti, Pamgarh, Jaijaipur and Dabra), Jagdalpur (Amraoti and Dabra), Raigarh (Kudumkela and Sarangarh) and remaining part of Korba, Raipur, Dantewada and Jagdalpur is included under very high radiation intensity range.

4.8 Potential evapotranspiration

4.8.1 Annual potential evapotranspiration

When we observed annual potential evapotranspiration of Chhattisgarh state we find out that the state has been divided into five categories of annual potential evapotranspiration areas. They are following:- below 1500 mm (very low), 1500-1550 mm (low), 1550-1600 mm (medium),1600-1650 mm (high) and more than 1650 mm (very high) zone. Maximum part of

Annual Potential Evapotranspiration

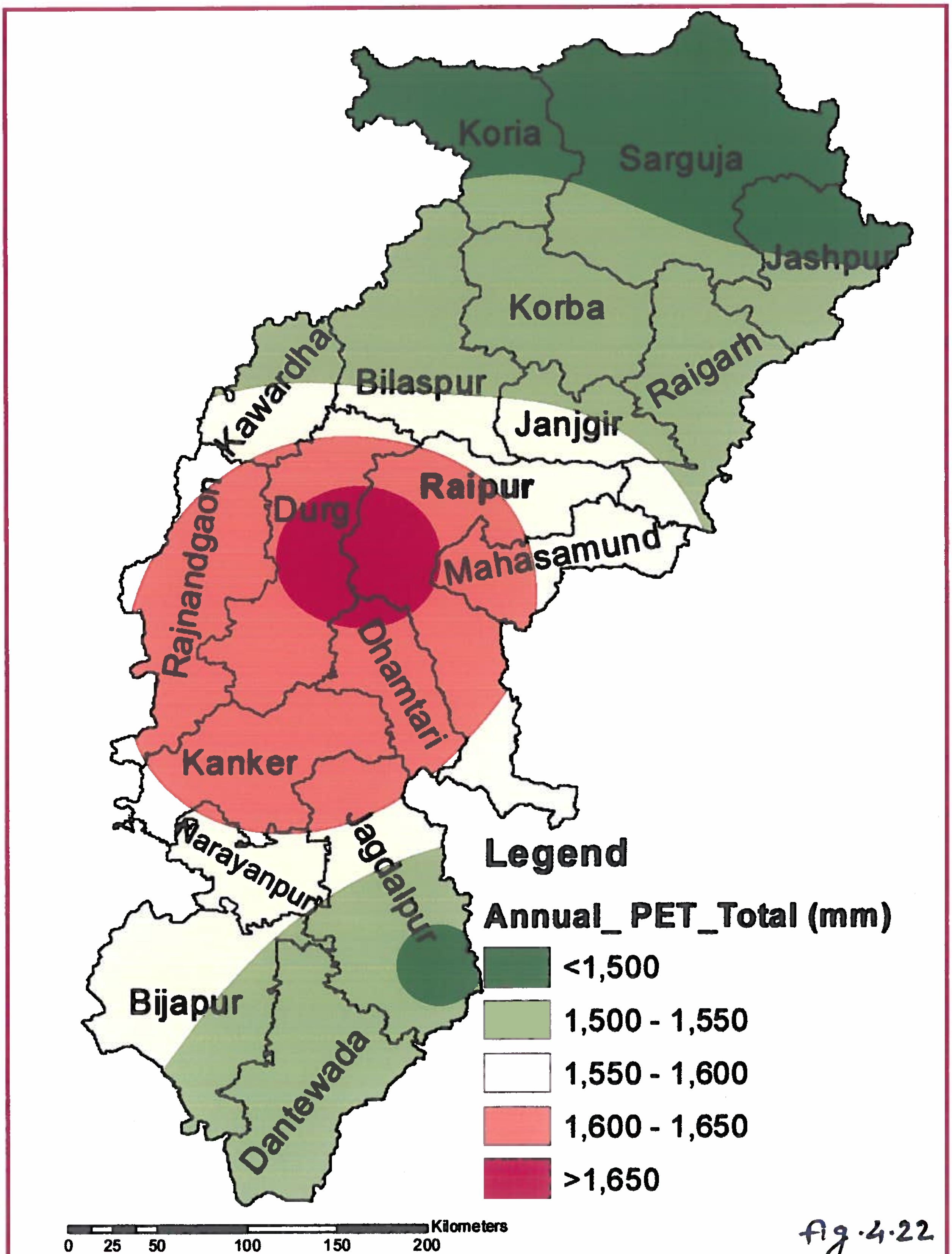

Fig. 4.22

Koriya (except Manendragarh), 80% of Sarguja (except Sitapur and Parsha), northern part of Jashpur (Bagicha and Jashpurnagar) and surrounded region of Jagdalpur city comes under very low potential evapotranspiration zone. South part of Koriya, Sarguja, Jashpur (Manendragarh, Sitapur, Parsa, Pathalgaon and Kunkuri),whole Korba, maximum part of Raigarh (except Sarangarh), north and north east part of Janjgir (Champa, Sakti, and Dabra), 70 percent area of Bilaspur (Pendra road, Kota and Lormi), northern part of Kawardha (Pandaria), whole part of Dantewara, Sotu and eastern part of Bijapur (Pujarikaker and Gangalur), Maximum part of Jagdalpur (Kondagaon, Chitrakote and Dabra) District comes under low annual potential evapotranspiration zone. South part of Kawardha (Gandai and Lohara), south region of Bilaspur (Mungeli and Bilha), Janjgir (Pamgarh, Nawagarh and Jaijepur), Raipur (Kasdol, Bilaigarh, Balodabazar, Tauranga and Deobhog), Raigarh (Sarangarh), Mahasamund (Saraipali, Basna and Pithora), Rajnandgaon (small part of Chhuikhadan and Chichola), Kanker (Pakhanjur), Narayanpur (except Koylibera), Jagdalpur (Parasgaon and Makri), Bijapur (Bhopalpatnum, Pasewara and Koturu) comes under medium annual potential evapotranspiration zone. Raipur (Simga, Bangoli, Arang, Rajim and Gariaband), Mahasamund, Dhamtari (except Kurud), Durg (Saja, Bametara, Balod and Doundi), Rajnandgaon (Dongargarh, Ambagarh chauki and Mohala), Kanker (except Pakhanjur), Jagdalpur (Keskal) comes under high annual potential transpiration zone. Surrounded Raipur city, Durg city, Dhamtari (Kurud) comes under very high annual potential evapotranspiration zone.

4.8.2 Potential evapotranspiration during *Kharif*

Potential evapotranspiration during *Kharif* season in Chhattisgarh state has been categorized in following categories:-Below 830 mm very low, 830-860 low, 860-890 medium, 890-920 high and more than 920 mm very high zone. Koriya (Bharatpur), Jagdalpur (Chitrakote, Bastar and Dabra), Dantewada (Gidam and Sukma) comes under very low transpiration zone. Whole Sarguja, Jashpur, Korba, Raigarh, Bijapur, Narayanpur, Koriya (Baikunthpur, Manendragarh and Sonhat), Janjgir (Champa, Sakti and Dabra), Bilaspur (Pendraroad, Lormi, Kota), Kawardha (Pandaria), Mahasamund (Saraipali), Raipur (Tauranga and Deobhog), Dhamtari (Birgudi), Kanker (Sarona, Kanker, Pakhanjur and Antagarh), Jagdalpur (Keskal and Kondagaon), Dantewada (Konta and Jagargunda) comes under low potential evapotranspiration zone. South part of Kawardha (Gandai and Lohara) small part of Bilaspur (Mungeli and Bilha), south west part of Janjgir (Pamgarh and Nawagarh), Raipur (Bilaigarh, Balodabazar, Kasdol and Gariaband), Mahasamund (Basna and Pithora), maximum part of Rajnandgaon (Chhuikhadan, Dongargarh, Ambagarh Chauki and Manpur), north and south part of Durg (Nawagarh, Balod and Dondi),centre pert of Dhamtari (Dhamtari and Siphonpara), Charma, Narharpur, Bhanupratappur region of Kanker District comes under medium potential evapotranspiration zone. Simga, Tilda, Arang, Abhanpur region of Raipur district, western part of Mahasamund, North Dhamtari (Kurud), central part of Durg, eastern part of Rajnandgaon comes under high potential transpiration zone. Surrounded region of Raipur and Bhilai city comes under very high potential evapotranspiration zone.

Potential Evapotranspiration during Kharif season

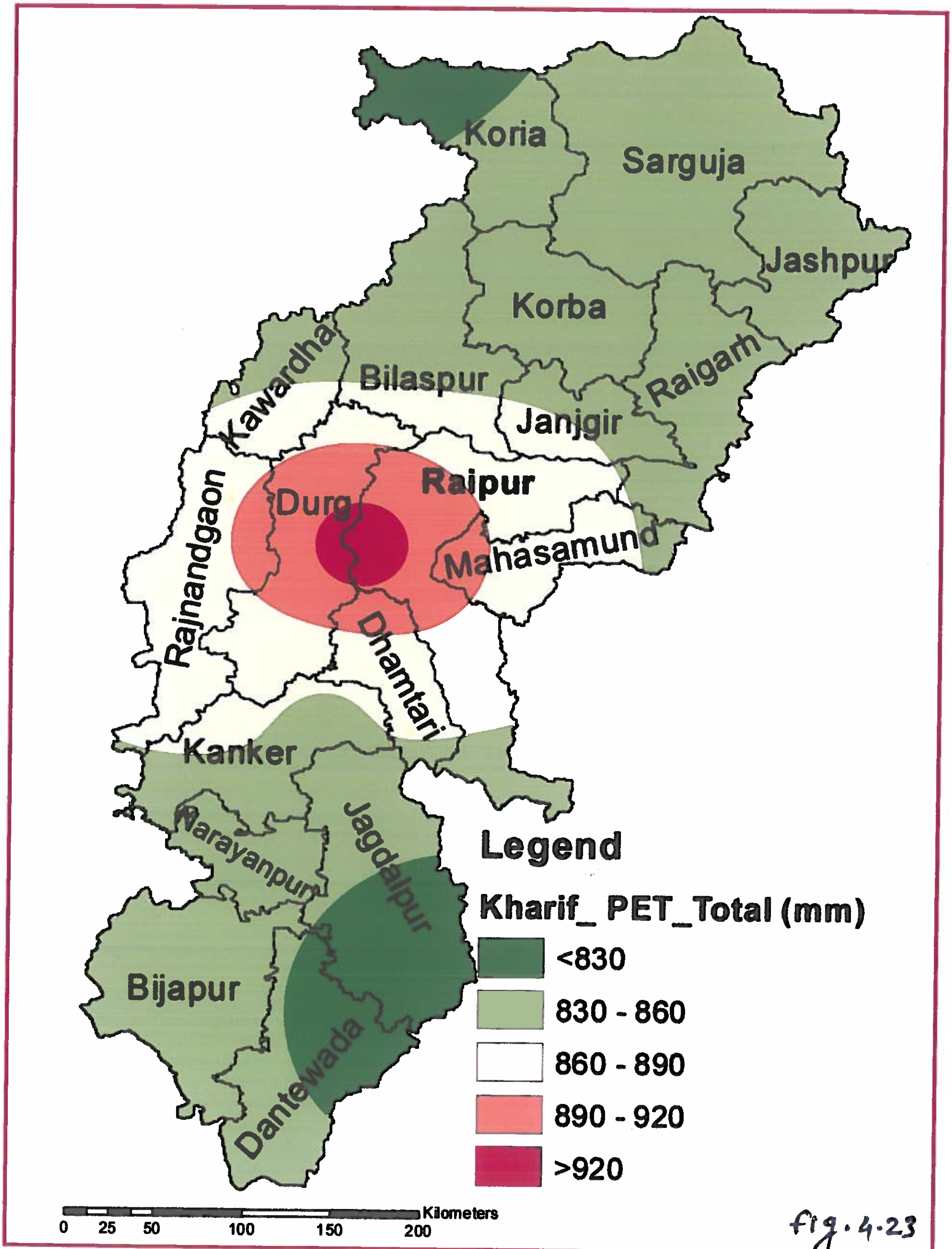

fig. 4.23

4.8.3 Potential evapotranspiration during *Rabi* season

Potential evapotranspiration during *Rabi* season in Chhattisgarh region has been divided in following categories:- below 640 mm very low, 640-680 mm low, 680-720 mm medium, 720-760 mm high, more than 760 mm very high potential transpiration zone, north eastern part of Sarguja (Ramanujganj, Wadrafnagar and Samri), north part of Jashpur (Champa) comes under very low Potential transpiration zone. Whole part of Koriya, maximum part of Sarguja (except Ramanujganj, Wadrafnagar, Samri) except Champa region whole Jaspur, northern part of Raigarh (Dharmjaygarh), Korba (Piparia, Nagai, Katghora), northern part of Bilaspur (Pendraroad, Lormi and Kota) Kui Region of Kawardha district comes under low potential evapotranspiration zone. Whole part of Dantewada, Janjgir, Raigarh (Kharsia, Gharghoda and Sarangarh) Korba (Kartala) Bilaspur (Bilha, Mungeli and Tkhatpur) except Kui region whole Kawardha district, Small part of Chhuikhadan region of Rajnandgaon, Jagdalpur (Kondagaon, Suklapara and Darba) except northern part of whole Bijapur, Raipur (Kasdol, Bilaigarh and Deobhog) Mahasamund (Saraipali and Basna) comes under medium potential evapotranspiration zone. Ninety percent part of Rajnandgaon (except Chhuikhadan) maximum part of Durg (except Nawagarh and Dondi) more than ninety percent part of Dhamtari (except eastern part) maximum part of Raipur (Simga, Abhanpur, Gariaband and Arang), Kanker (Pakhanjur and Antagarh) Jagdalpur (north part of Kondagaon) comes under high potential evapotranspiration zone. Eastern part of Dhamtari, south part of Durg (Dondi and

Potential Evapotranspiration during Rabi season

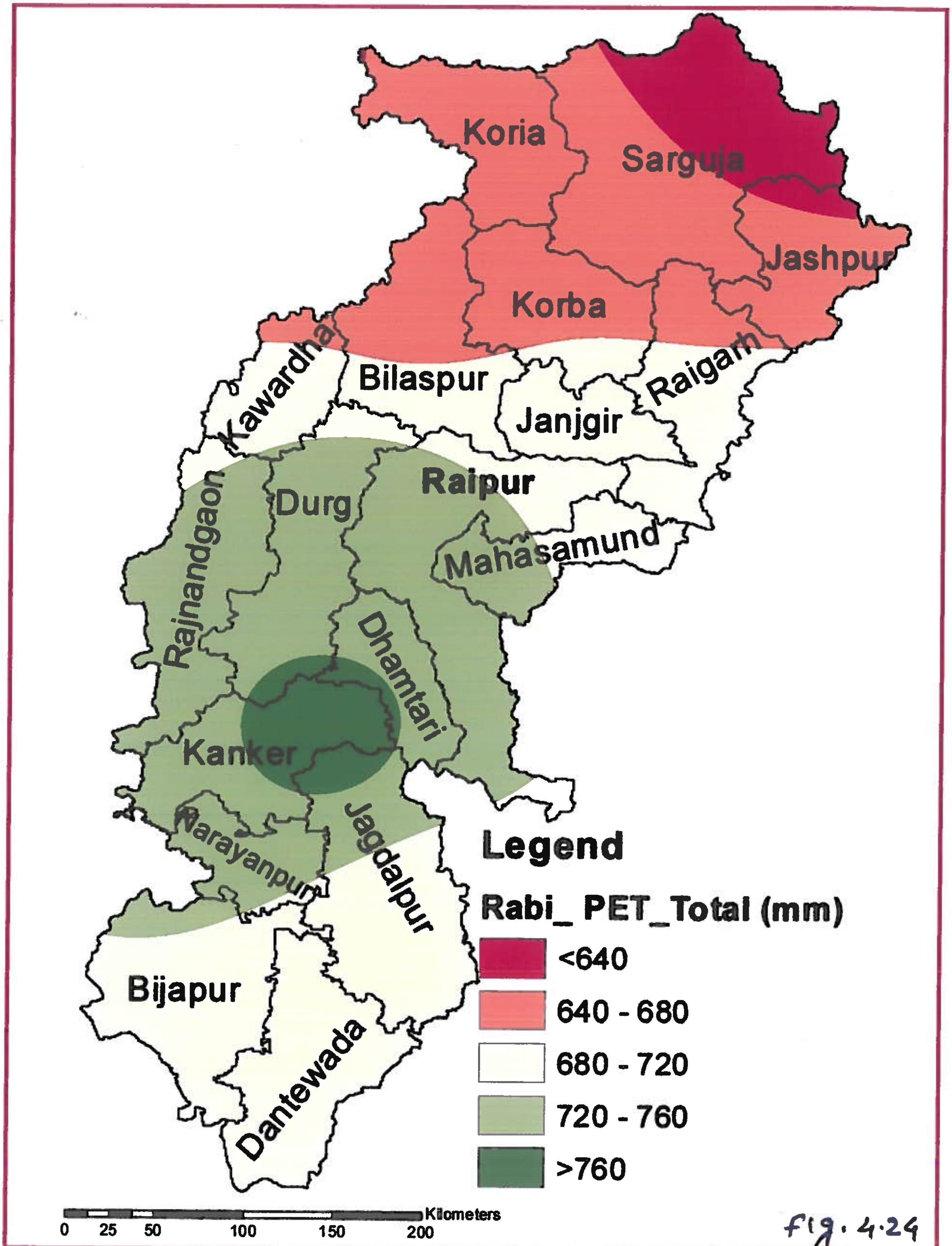

fig. 4.24

Gurur), eastern part of Kanker (Charama, Kanker and Narharpur) north part of Jagdalpur (Keskal) comes under very high potential transpiration zone.

4.9 Length of growing period

4.9.1 Length of growing period with 100 mm soil moisture

Length of growing period is defined as the period during the year when prevailing temperature are conductive to crop growth and precipitation plus moisture stored in the soil profile exceed half the potential Evopo-transpiration for obtaining the length of growing period we have taken 100 mm soil moisture. The state has been categorized into five categories like less than 105 day very low length of growing period zone, 105-110 days categories as low LGP zone, 110-115 as medium LGP and 115-120 as high LGP and the zone having more than 120 days was categories as very high LGP zone. Only part of Kawardha is having very low and low LGP areas like Kawardha block, Bhoramdev, Chilpi, Borla, Lohara. Most of the Chhattisgarh plain area comes under medium LGP zone like whole district of Durg, Rajnandgao, Kawardha, Northern Raipur, North part of Dhamtari and Korba and remaining part of Chhattisgarh plain, whole Northern hills zone comes under high LGP zone. Except southern Raigarh, Janjgir (Dabra, Malkhroda and Champa), Bilaspur (Lormi, Parasi and Pendra), Kanker, Dhamtari (Nagri, Siphonpara and Birgudi)and small part of Raipur (Indagao and Tauranga) which comes under high LGP categories along with whole area of Bastar Plateau.

4.9.2 Length of Growing Period with 150 mm soil moisture

When we take 150 mm soil moisture state has been divided in five categories. The area having (<116 days) were categories in to very low LGP zone,

Length of Growing Period: 100 mm

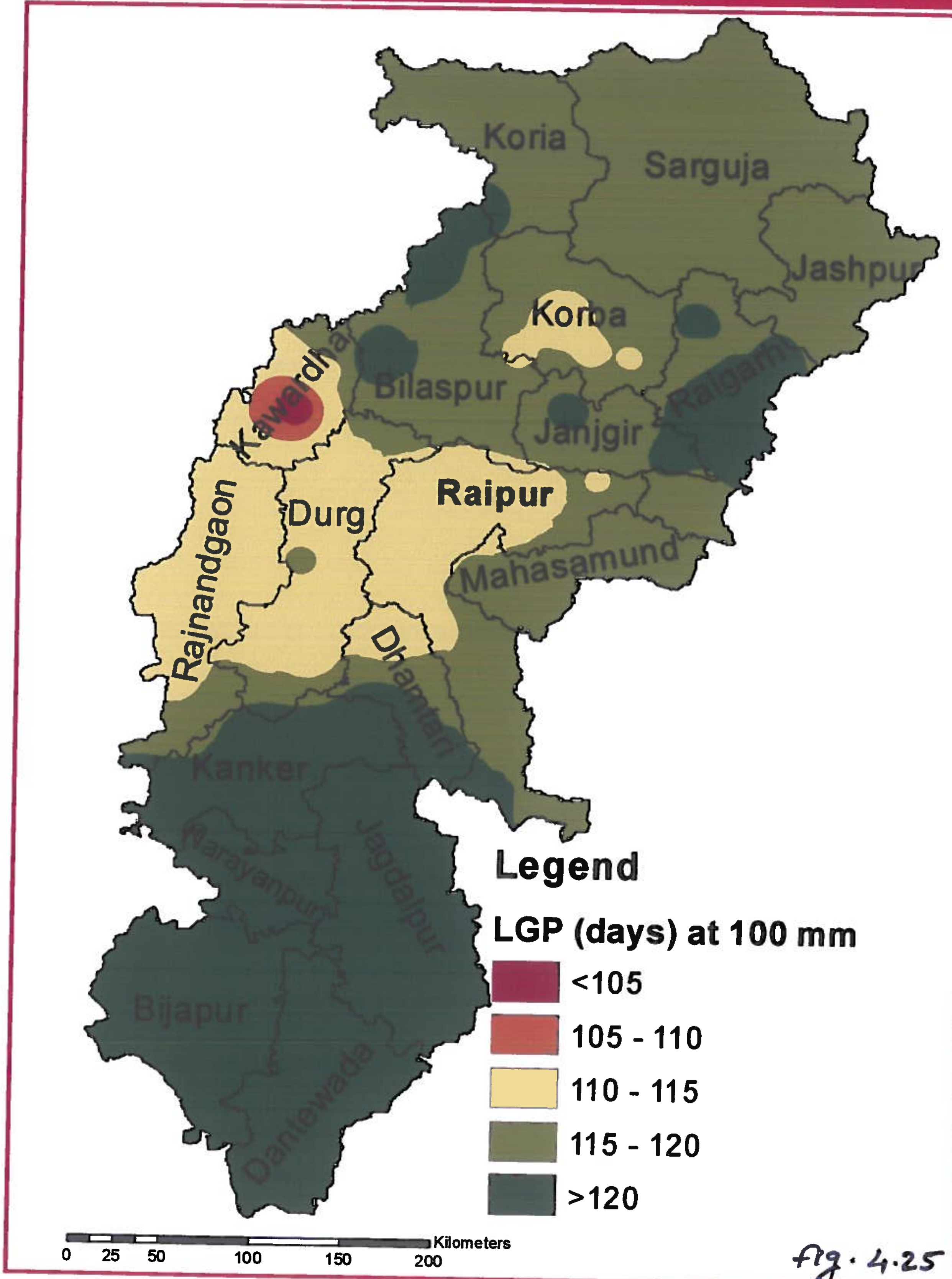

Fig. 4.25

Length of Growing Period: 150 mm

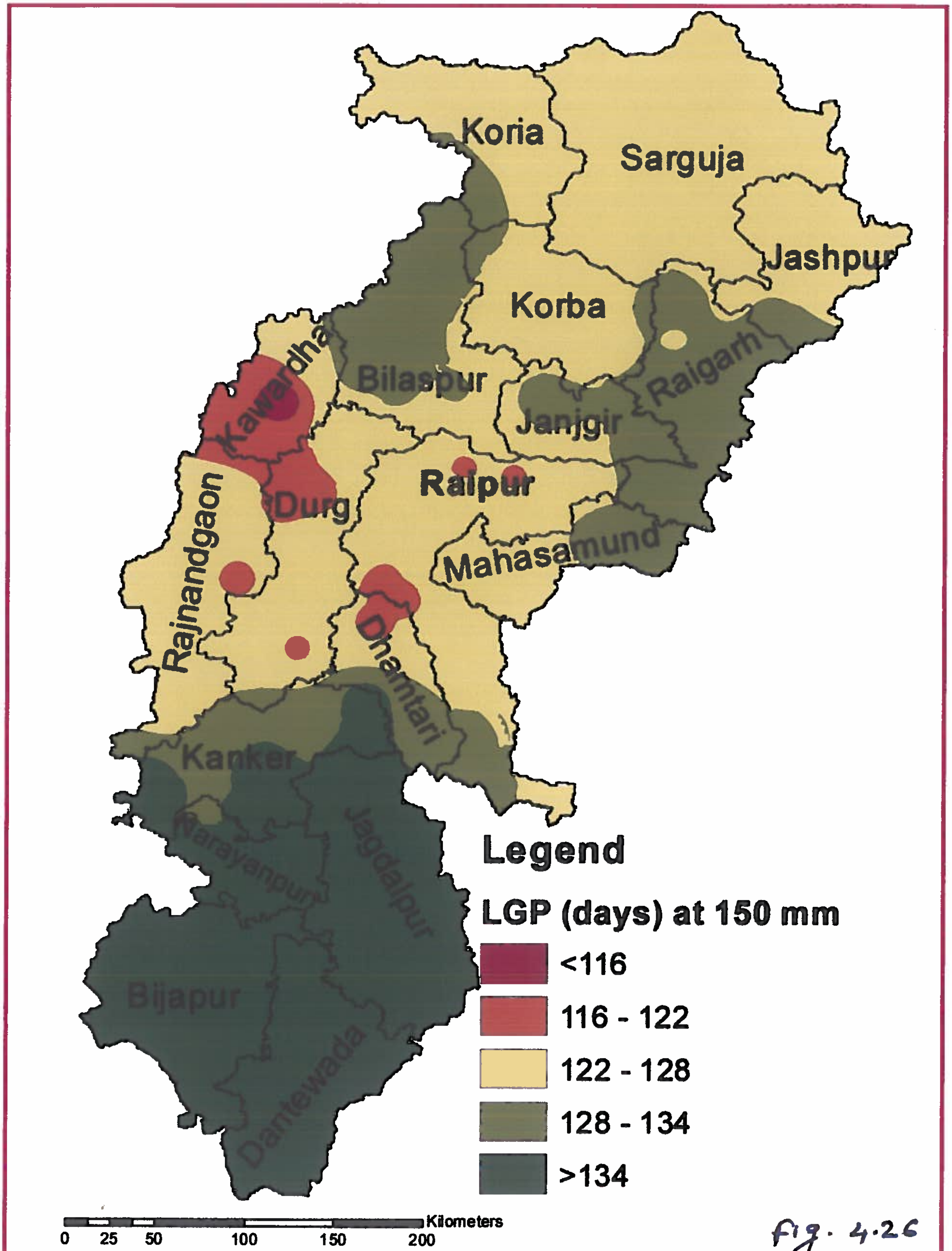

Fig. 4.26

(116-122 days) has low LGP zone, (120-128 days) medium LGP zone, (128-134 days) high LGP zone and areas having (>134 days) categories in to very high LGP zone. Some as like with 100 mm soil moisture Kawardha comes under very low LGP zone and remaining southern part of Kawardha, Durg (Saja and Kodwa), small part of Raipur (Rajim), Dhamtari (Kurud), and part of Rajnandgao are categories has low LGP zone. Most part of Northern hills along with Korba, Raipur, Rajnandgao, Durg, half of Mahasamund are comes under medium LGP zones. Where as Raigarh, East part of Mahasamund, Janjgir and most part of Bilaspur, Dhamtari, Kanker categories as high LGP zone and Whole part of Bastar plateau and southern Kanker are comes under very high LGP zone.

4.10 Land use/ Land cover of Chhattisgarh

There is a varied land use and over of the state demographically. It is the 17 the largest state of the country with the geographical area of approx 13.5 m ha. The most common type of land over found in the large part of the state is its forest cover Chhattisgarh is rich in forest resources. According to 1999- 2000 census Chhattisgarh had 6 million hectares of forest which was approx 45% of total reported area of the state. Due to rapid urbanization, the forest cover has decreased mark-ably in the state, but is still makes up the largest state of the country. Presently about 35.94% of the total geographical area of the Chhattisgarh is covered by forest. Demographically forest cover makes up about 2/3 of the state. The state is famous for its sal forest in the whole country.

The fallow land of Chhattisgarh is also mark-ably high when compared to its total area. It is about 28.08% of the total geographical area of the state. The

Land cover Map of Chhattisgarh

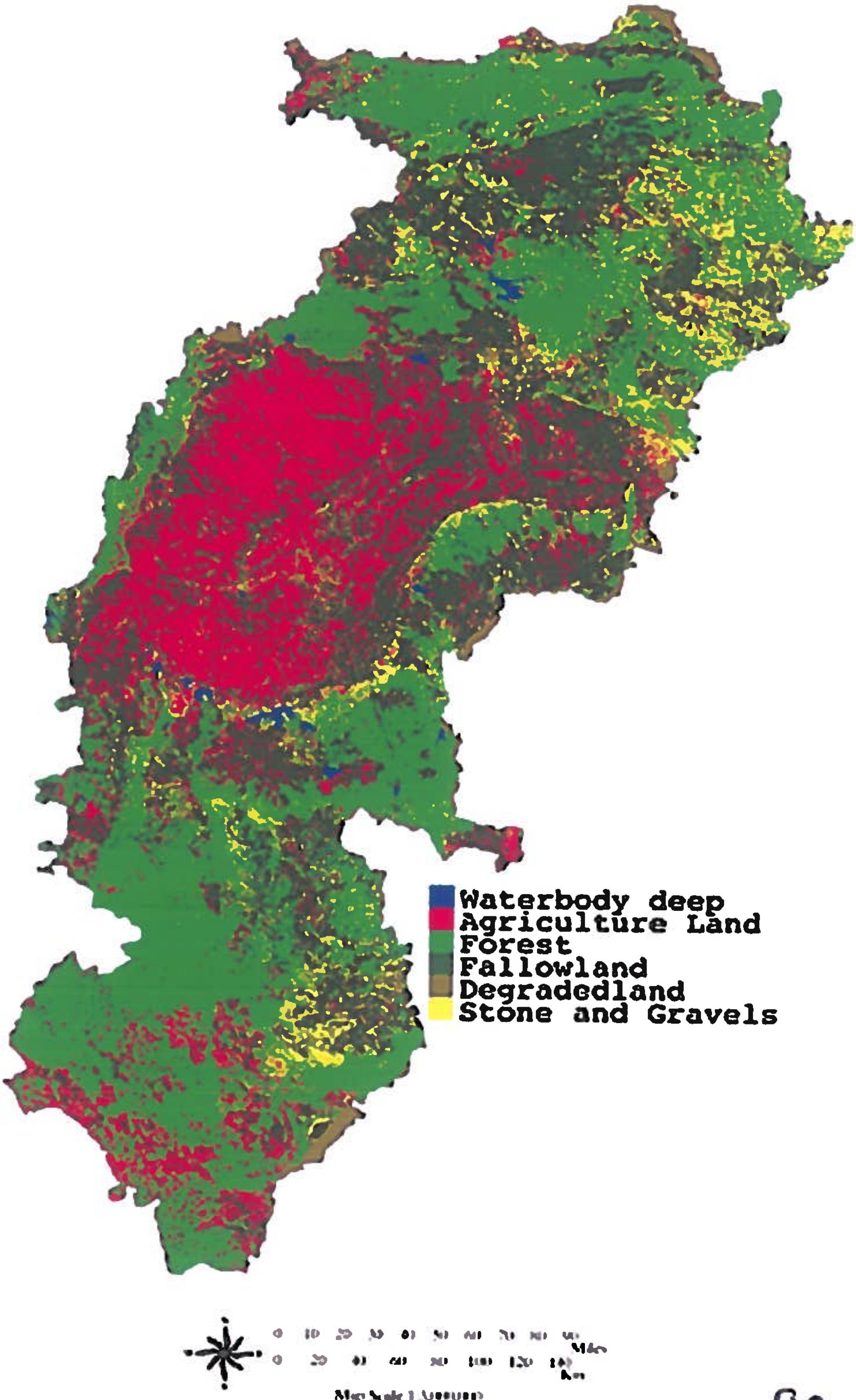

Fig. 4.27

major feature of fallow land is that they are found in most of the area along the degraded land which cover around 4.98% of the state area.

These are most widely distributed in the district of the Koriya, Sarguja, Raigarh however it is found in small patches all over the state.

Chhattisgarh is an agricultural province, having 21.12% of its geographical area under agriculture. As the most of the population of the state is resides largely in the Chhattisgarh plains. A very small portion of the state is exposed to the deep water bodies. Only about 0.46% of the total area of the state is covered by deep water bodies. Most of the deep water bodies are found in the central part of the state. However, Bastar, Dantewada, Jashpur, Raigarh & Janjgir-Champa districts do not have any remarkable water bodies.

Apart from all these some portions of the state is covered by stone and gravels. About 9.45% of the reported area of Chhattisgarh is covered by such covering. However Rajnandgaon, Kawardha, Narayanpur and Bijapur districts are devoid of covering.

4.11 Soil depth of Chhattisgarh

The soils of the state have originated from a wide variety of parent rocks, formed over different geological periods. Thus, a variety of soils with different depths are present in the state of Chhattisgarh.

The deep soils are the predominant type in the state as a whole and in Chhattisgarh plain in particular. These soils are characterized by their depth which is more than 100 cm. Generally, the deep soils are more supportive to the ground

Depth of Soil in Chhattisgarh

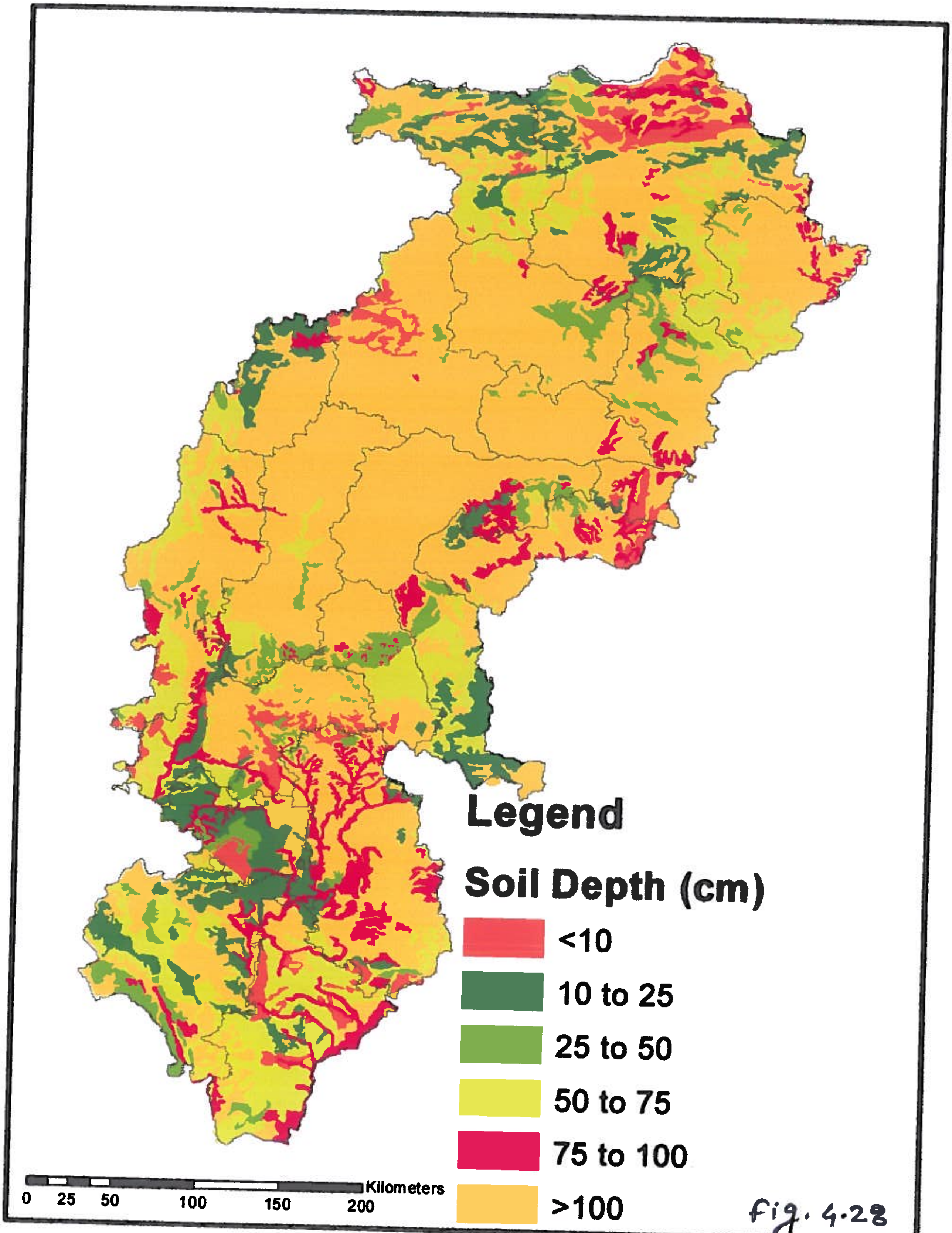

Fig. 4.28

water recharge. Considering the soil depth, these soils are most favorable for the artificial ground water recharge.

The soils having depth of 75-100cm are mostly found in the districts of Northern hills and Bastar plateau. However some small patches of Dhamtari, Rajnandgaon, Raipur, Kawardha, Durg, Mahasamund, Janjgir-Champa, Bilaspur, Raigarh, and Korba also exhibit such soil depth. These soils are very good from artificial ground water recharge point of view.

The soil depth of 50-75 cm is predominant in the soils of Dantewada and Narayanpur districts, while the soils of Bilaspur and Janjgir-Champa rarely show such soil depths, a remarkable area of Northern hills and some small patches of all other districts exhibit such soil depths. Considering the soil depth, soils of such depths are good in favoring artificial ground water recharge.

The medium depth of soil ranging between 25-50 cm is exposed in the portions of Bijapur, Narayanpur, Bastar, Dantewada, Kanker, Dhamtari, Durg, Raipur, Mahasamund, Korba, Raigarh and in very small patches in the Janjgir-Champa, Bilaspur, Kawardha, Sarguja, Rajnandgaon, Jashpur and Koriya districts. These depth of soils moderately support the artificial ground water recharge.

The predominant depth of soil in Narayanpur, Bijapur of Bastar plateau ranges from 10-25cm. However, some considerable area of Raipur, Kanker, Bastar, Kawardha and Koriya districts also exhibit such soil depths. Other districts have also such soil depths in small patches to a limited extent, except Korba, Janjgir-Champa, Bilaspur, Jashpur, and Dhamtari districts. These soils are poor from artificial ground water recharge point of view.

Very shallow soil, of less than 10 cm depth are found in a significant amount in the parts of Surguja, Bilaspur, Mahasamund, Raigarh, Kanker, Bastar, Bijapur and Dantewada districts. However, as very small patches such soil depths are also found in Dhamtari, Rajnandgaon, and Koriya districts. These shallow soils are underlain generally by hard rock and thus in the absence of any remarkable aquifers, fractures or faults, the artificial ground water recharge is not possible here.

4.12 Distribution of Soil in Chhattisgarh

In India, soil groups commonly recognized are Red soil, Laterites and lateritic soils, Black soils, Alluvial soils, Forest and hill, Desert, Saline and alkaline, Peaty and marshy

According to US Soil taxonomy, the major 12 orders of soil are Histosol, Antisol, Inceptisol, Alfisol, Ultisol, Mollisol, Aridisol, Spodosol, Vertisol, Oxysol, Andisol and Gelisol.

Out of 12 orders only 4 orders, *viz.*, Vertisol, Ultisol, Inceptisol and Alfisol are found in Chhattisgarh. The soil orders in U.S. The distribution of different soil types are shown in fig. and are discussed below:

The central part of Chhattisgarh is covered mainly by deep black and medium black soils (Vertisol). Areas coming under this order are parts of Durg, Rajnandgaon, Kawardha, Bilaspur, Raipur, Surguja and Dhamtari districts. Vertisol is a soil in which the content of clay size particles is 30% or more by mass in all 3 horizons (layers) of the upper half meter of the soil particle. They are characterized by a high content of expanding and shrinking clay known as

Distribution of Soil in Chhattisgarh

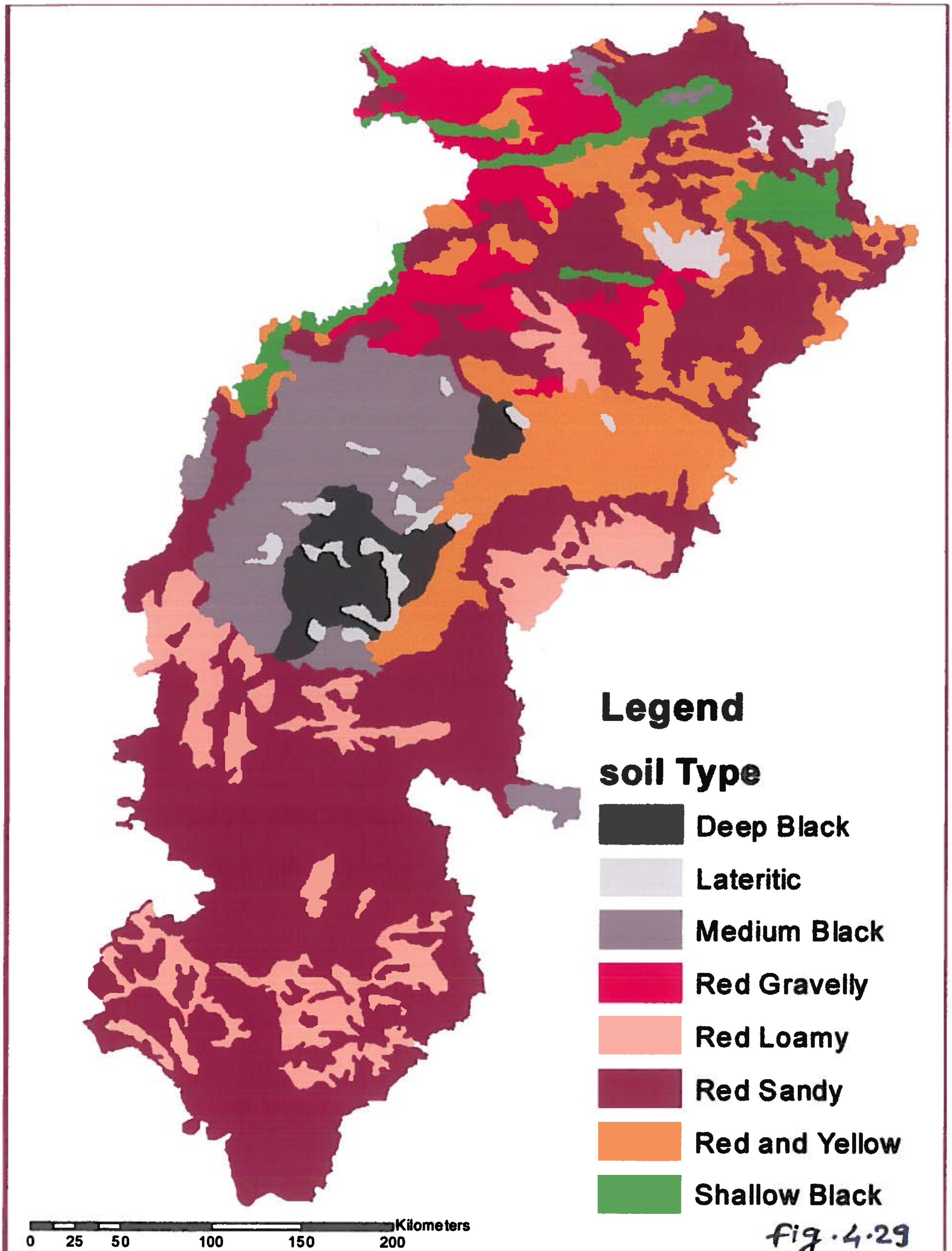

Fig. 4.29

Montmorillonite that forms deep cracks in certain seasons. They are typically found on level or mildly sloping topography in climatic zones that have distinct wet and dry seasons. These soils are almost impermeable when saturated.

The soils scattered in small portions of Chhattisgarh plains and Northern hills are the Ultisol. The Indian equivalent of Ultisols which are available in this state are lateritic soils and red and yellow soils. They mainly occupy as patches of the west-central parts and Northern part of the state. They are distributed in parts of Janjgir-Champa, Raipur, Raigarh, Dhamtari, Rajnandgaon, Surguja, Bilaspur and Kawardha districts. They are characterized by a humus-rich surface horizon (the uppermost layer) and with high levels of clay below the top layer. In most cases, ultisols have Kaolinite as dominant mineral, which has good bearing capacity and no shrink-swell property.

The third order of soils which are found in Chhattisgarh are shallow black soils (Inceptisols) also called as young soils. They are characterized by having the weakest appearance of horizons, or layers, produced by soil forming factors. Generally they are found in topographic settings conducive to soil erosion or water logging. They generally occupy river delta or hill sides. These soils are available in linear patches in parts of Surguja, Koriya, Jashpur, Korba, Bilaspur and Kawardha districts.

The most common soils distributed in largest area of Chhattisgarh are Red gravel soils, Red loamy soils & Red sandy soils of Alfisol. These soils taken together cover more than 50% area of the state. These occur in almost all the districts of the state. These are characterized by a thick humus layer which decomposes to form characteristic loamy layer, which usually refers to a high age of the soil. These soils typically exhibit well developed, contrasting soil horizons.

4.13 Soil province of Chhattisgarh

Soil province region of Chhattisgarh has been classified on the basis of soil type and soil depth. On the basis of soil type, it is of three types namely; Vertisols, Ultisols, Inceptisols and Alfisols. On the basis of soil depth, it is of three types and they are shallow depth (0-50 cm), medium (50-100), and high depth (>100 cm). Soil province region of Chhattisgarh is categorized into seven classes:-

Class I - Vertisol with high depth,

Class II - Ultisol with medium depth,

Class III - Ultisol with high depth,

Class IV- Inceptisol with high depth,

Class V- Alfisol with low depth,

Class VI - Alfisol with medium depth and

Class VII - Alfisol with high depth.

Class I comprises of Surguja(Western chiraikund, North east Khohir, Pandari region), Bilaspur (Lormi, Chilpi, Kanteli, Tkhatpur, Mungeli and Western Bilha), Korba (South Pali), Kawardha (Mohgaon, Silhati, Eastern Kawardha), Rajnandgaon (Western Chhuikhadan, Eastern Bhandarpur, Rajnandgaon, Tilai), Durg (Balod, North Gurur, Santipur, Eastern Gundardehi and Sikesa, Saja, Bametara, Nawagarh) and Raipur (Western Bhatapara, Simga, Tilda, North Bangoli, North West Rajim, Deobhog and Goharapadar) . whereas, maximum part of Sarguja, Jashpur and few parts of Korba (North East Syang) Raigarh (South Dharmjaygarh and Tetla), Janjgir (South Sakti, and South Jaijepur), Raipur (North

Soil Province Map of Chhattisgarh

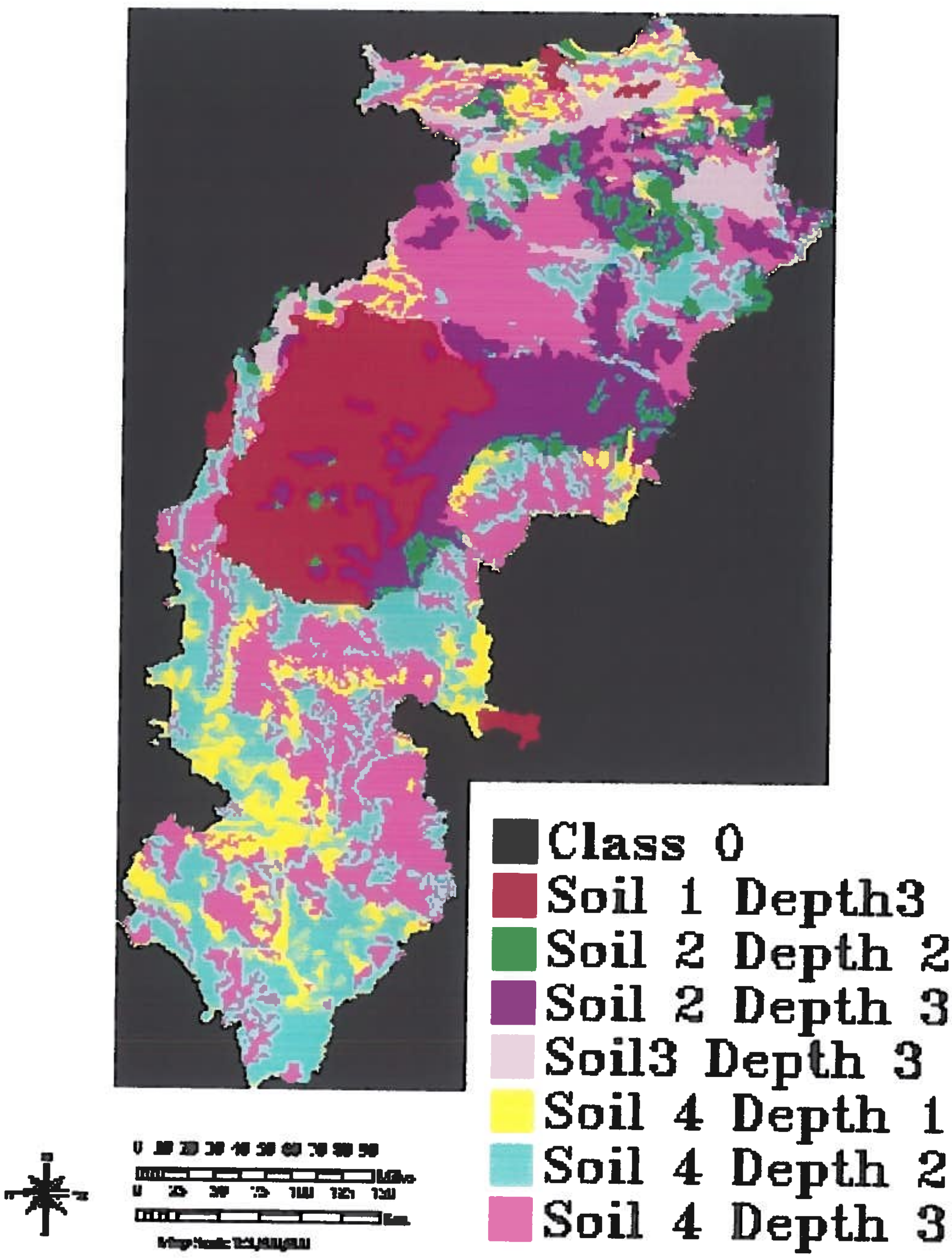

fig. 4.30

Balodabzar, Bilaigarh and North Western Rajim), Bilaspur, Kawardha, Durg fall under class II. Class III is confined with some blocks of Sarguja(Samri, Eastern Lundra, South Ramgarh, Eastern Bhakurma), Jashpur (Sakardih, Western Jashpurnagar), Korba (Fulsari, Madanpur, Kartala, Eastern Nonbira), parts of Raigarh (South Sithra, West Kudumkela), Bilaspur (Pendra and Tkhatpur), Janjgir (Malkhroda, Nawagarh, Akaltara, Jaijepur and Central Pamgarh), Raipur (Balodabazar, Bhatapara, North Palari, North Chhura), Durg (Central Doudilohara and Eastern Shantipur) and Dhamtari (Dhamtari and Chhati). The districts such as Koriya (Bharatpur, Taloli, Kelahari and Ghutru), few portions of Sarguja, Jashpur, Korba, Bilaspur and Kawardha come under class IV. The regions coming under the next class i.e. class V are Northern hills with Koriya and Sarguja, Chhattisgarh plains including its maximum parts like Bilaspur, Kawardha, Raigarh, Mahasamund, Raipur, Dhamtari, Kanker, Kawardha, Rajnandgaon and Bastar plateau comprising of Narayanpur, Bastar, Dantewada and Bijapur. However, several areas of Koriya, Sarguja and Jashpur of Northern hills, parts of Chhattisgarh plains and Bastar plateau are also coming under class VI. Class VII is consisting of Koriya (kotadore and Biharpur), Surguja (Ramanujganj, Tattapani, Tulsi, Ambikapur, Parsa and peria), Jaspur (Narayanpur, Bagicha, Ghatmunda), Korba (Piparia, Mahdaitikra, Kendai, Arsia, Katghora and Jilda), Raigarh (Lailunga, Gharghoda and Raigarh), Bilaspur (Parsi, Pendra, Gorela, Lamoni, Kota, Tedua, Tkhatpur, Bilha and Ratanpur), Janjgir (Baloda and Akaltara), Raipur (Tala, Chhura, Ghansir,), Mahasamund (Suarmar, Mahasamund, Patewa, Bagbahra, Jagdishpur and Basna), Dhamtari (Siphonpara and Birgudi), Kanker

(Narharpur, Dudhawa, Sarona, Charma, Bhanupratappur, Asulkhar), Durg (Santipur and Gurur), Rajnandgaon (Bhandha, Dongargarh, Chichola and Dogergaon), Narayanpur (Donger, Chapai and Bermur), Baster (Balega, Bhagdera, Amrawati, Piplawandi and Siwaniguda), Bijapur (Pasewara, Sundra, Koturu, Madded and Usur), Dantewada (Baghmundi, Gidam, Barsur, Kota, Golapali, Sukma and Kukaner).

4.14 Slope aspect of Chhattisgarh

The topography of Chhattisgarh state is such that the most of the sloppy lands are occupied by the Northern hills followed by the Bastar plateaus. The level and slightly sloping topography is the basic characteristics of the Chhattisgarh plains, however overall such type of topography is dominant over the state.

Within the slope range of 0-5%, almost all the Chhattisgarh plains as well as a major portion of the Bastar plateau and the Northern hills lie.

The slope range of 5-10% is very much common in the Bastar plateau agro-climatic zone in general and the western part of Jagdalpur district in particular. Apart from Bastar plateau, this type of slope range is also frequently found in the Northern hills. Also some small patches of Bilaspur, Kawardha, Korba, Janjgir-Champa, Raigarh, Rajnandgaon & Mahasamund districts also exhibit such type of slope range.

The steepest slopes are found commonly on the Northern hill agro-climatic zones of the state. Such slopes are much densely located in the hills of Surguja and Korba districts. Although such steep slopes of even more than 10% are the

Land slope Map of Chhattisgarh

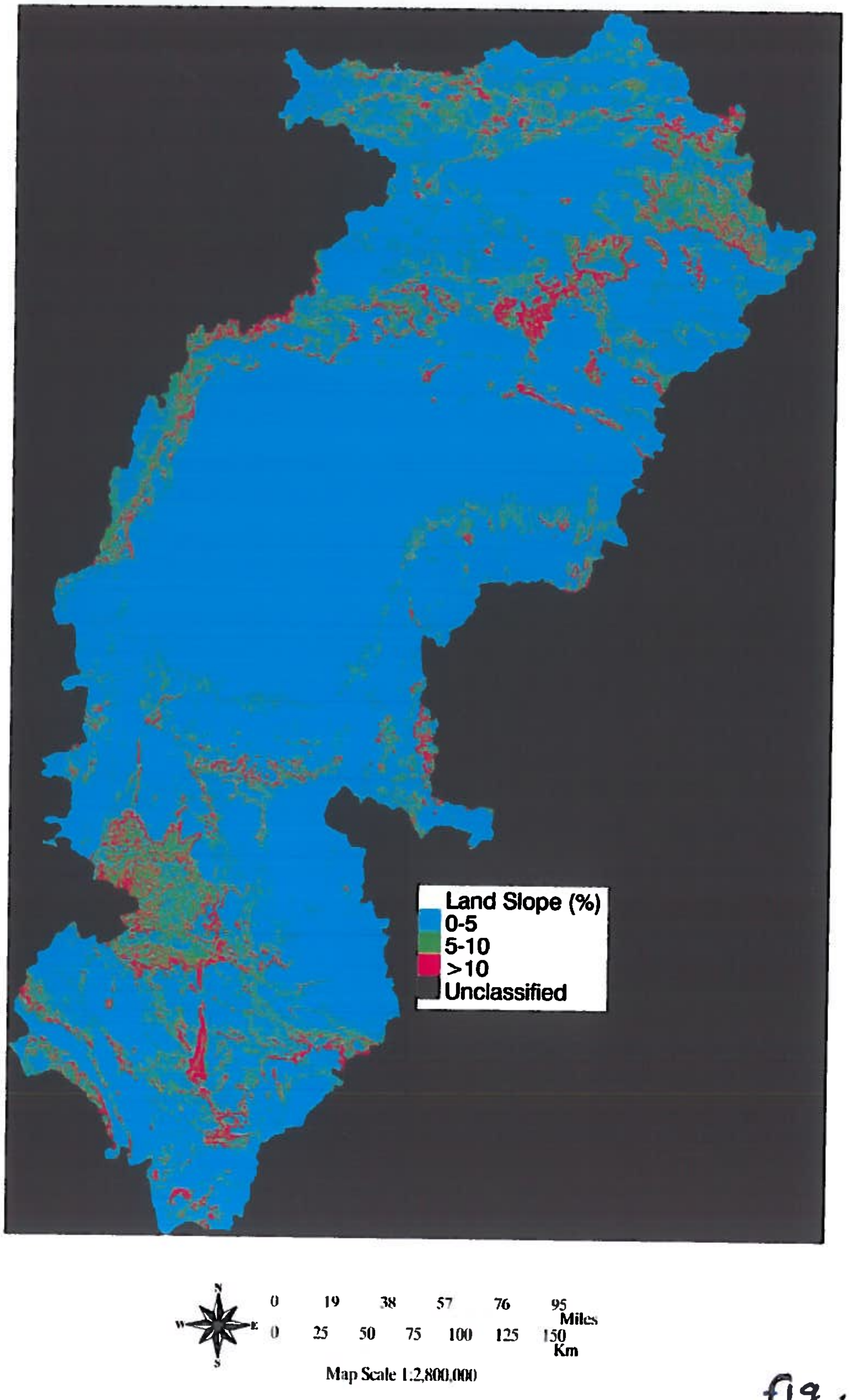

fig. 4·31

common characteristics of the Northern hills, it is also very much common in the districts of Bastar & Dantewada of the Bastar plateau agro-climatic zone. However, such steep topography is rarely found in the Chhattisgarh plains, but exceptionally is found in some hilly parts of the Bilaspur districts and some high reaches of Raigarh, Raipur, Mahasamund, Kanker, Kawardha and Rajnandgaon districts.

4.15 Agro-edaphic Zone

Agro-edaphic Zone is classified on the basis of percentage of slope and stone availability. On the basis of slope percentage it is of three types, viz. 0-5% (low slop), 5-10% (medium slop) and more than 10% (high slop). On the basis of stone availability in soil it is divided into two parts, viz. stony soil and nonstony soil. Further Agro-edaphic Zone of Chhattisgarh has been categorized into six classes.

Class I demonstrates the nonstony soil with low percentage of slope, class II indicates stony soil with low percentage of slope, class III describes nonstony soil with medium slope, class IV stands for stony soil with medium slope, class V for nonstony soil with high slope and class VI demonstrates the stony soil with high percentage of slopes.

Class I is comprising of maximum portions of Koria, Surguja and Jashpur and some parts of Raigarh (Kudumkela, Kharsia, Tetla and Sarangarh), Korba (Pepariya, Nagai, Katghora, Pali, Korba and Kartala), Bilaspur (Marwahi, Kota, Lormi, Mungeli, Bilha and Tkhatpur), Janjgir (Baloda, Janjgir, Champa, Pamgarh, Nawagarh and Jaijepur), Kawardha (Chilpi, Western Borla, Renghakar and

Agro-edaphic Map of Chhattisgarh

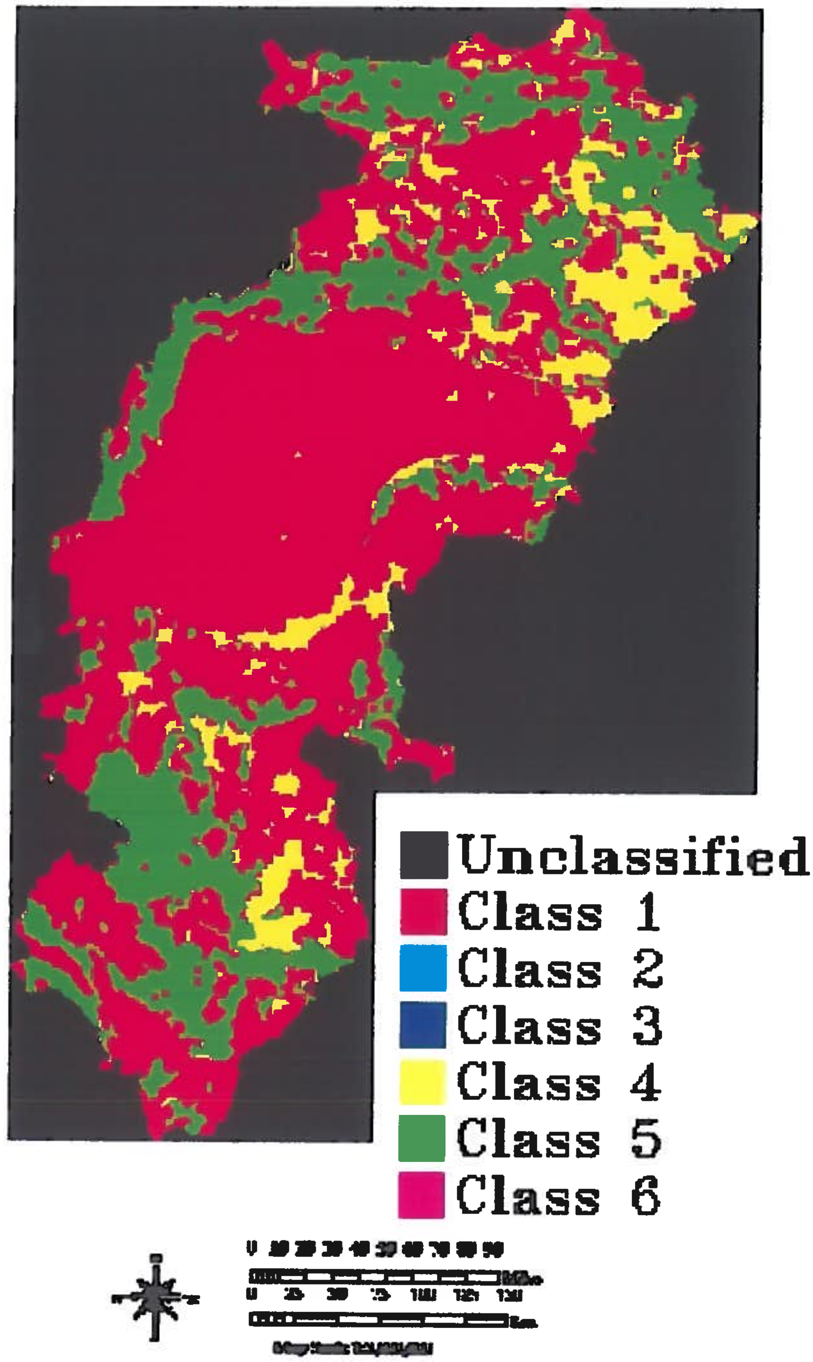

fig. 4.32

western Kawardha), Durg (Nawagarh, Bametara, Saja, Berla, Dhamadha, Bhilai, Durg, Gunderdehi, Gurur, Dondilohara, Balod and North Dondi), Raipur (Bhatapara, Simga, Tilda, Palari, Abhanpur, Rajim, Mainpur and Deovbhog), Mahasamund (Pithora, Jagdishpur, Mahasamund, Basna and Saraipali), Rajnandgaon (Pamgarh, Chichola, Rajnandgaon, Chhuikhadan, Dongargaon, Ambagarhchouki, Mohala and Manpur), Dhamtari (Achhora, Siphonpara, Birgudi and Central Nagri), Kanker (Sarona, Pasewada, Narharpur and Charama), Bastar (Vishrampuri, Keshkal, Parasgaon, Makri, Amrawati, Kondagaon, Jagdalpur and Darba), Narayanpur (Koilybera, Narayanpur and Donger), Bijapur (Pasewada, Sundra, Kuturu and Pujarikanker), Dantewara (Penta, Beri, Konta, Rokela and Sukkma). Different places of Koriya, Sarguja, Jashpur, Bilaspur, Raigarh, Janjgir, Kanker, Mahasamund, Raipur, Durg, Bastar and Dantewada fall under class IV. The remaining parts of Koriya, Surguja, Jashpur, Raigarh, Korba, Bilaspur, Kawardha, Rajnanadgaon, Raipur, Mahasamund, Dhamtari, Kanker, Narayanpur, Bastar, Bijapur and Dantewara have been placed under class V.

4.16 Agro-Climatic Zone

Agro-climatic zone of Chhattisgarh state has been classified on the basis of rainfall, temperature and length of growing period. On the basis of rainfall it is of three types, viz low rainfall (<1100 mm), medium rainfall (1100-1400) and high rainfall (>1400). On the basis of temperature it is of three types, viz low temperature (22-24^{0}C), medium temperature (24-26) and high temperature (26-28). On the basis of LGP it has been classified into three types, namely low range (110-120 days), medium range (120-130) and high range (130-140). The Agro-

Agro-climatic Map of Chhattisgarh

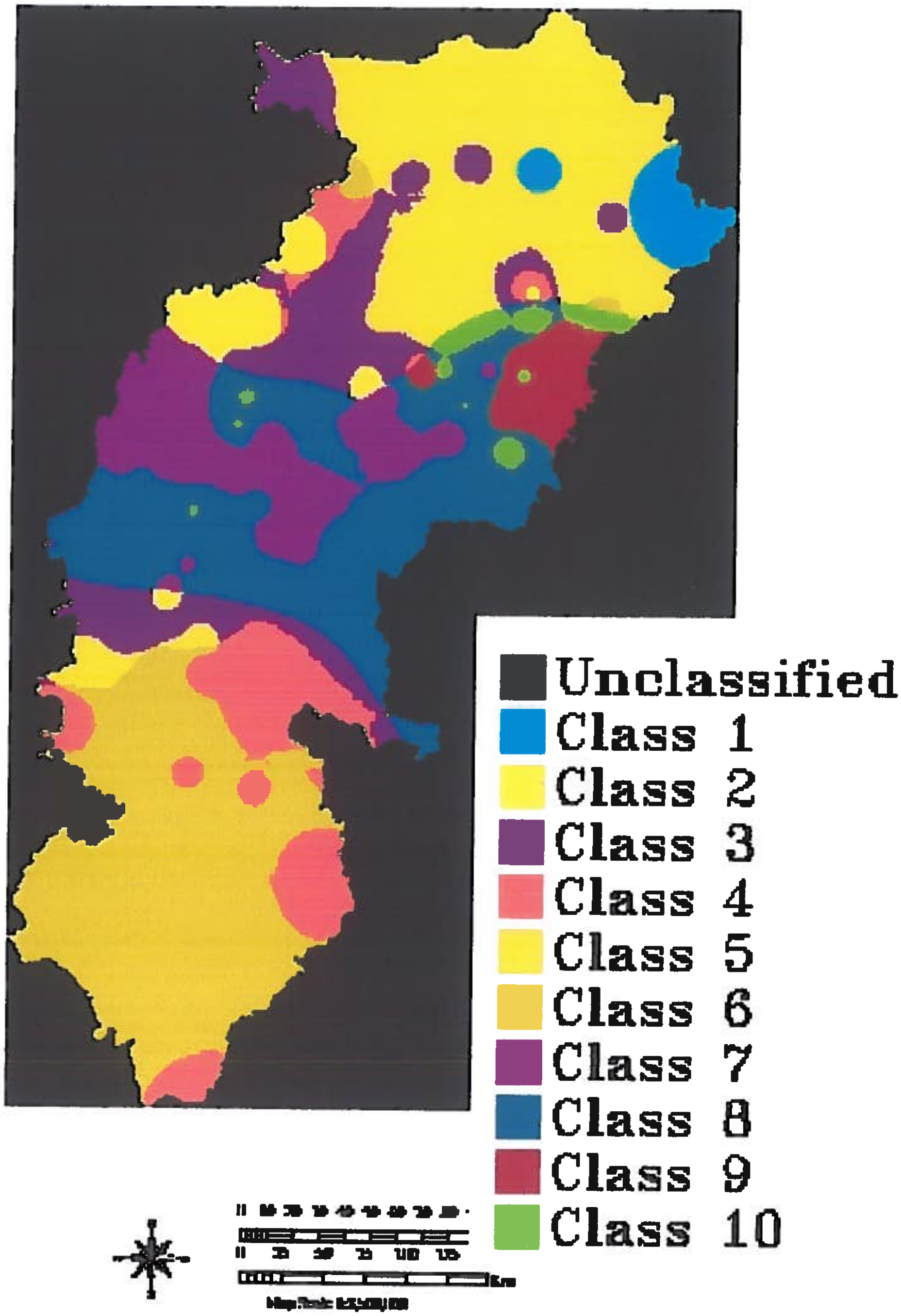

fig. 4.33

climatic zone of Chhattisgarh has been categorized into ten classes. Class I demonstrates low temperature, high rainfall, and medium LGP. Class II is of medium temperature, low rainfall and medium LGP. Class III is consisting of medium temperature, medium rainfall and medium LGP. Class IV is characterized with medium temperature, medium rainfall and high LGP. Class V describes medium temperature, high rainfall and medium LGP, whereas, Class VI comes under medium temperature, high rainfall and high LGP. Class VII demonstrates high temperature, low rainfall and medium LGP. Class VIII is characterized with high temperature, medium rainfall and medium LGP. Class IX comprises of high temperature, medium rainfall and high LGP and lastly Class X indicate high temperature, high rainfall and medium LGP.

Class I comprises of jashpur (Sakardih, Jashpurnagar, Rupsera and Raikera,), Sarguja (Rajpuri, Tulsi and Rajpur). The places like Koriya (Barder, Biharpur, Sonhat, Ramgarh, Devsil and Bhargao), Sarguja (Chiraikund, Sonwal, Ramanujganj, Wadrafnagar, Bhaski, Samari, Ambikapur, Ramgarh and Surajpur), Jashpur (Champa, Mahanai, Bagicha, Pathalgao, Tapkara and Kotaba), Korba (Pipriya, Nagai, Katghora, Arsia and Kartala) Bilaspur (Pendra, Maniari and South Bilaspur), Kawardha (Kui and Pandaria) and Durg (Balod) come under class II. Few portions of Koriya, Surguja, Jaspur, Korba, Bilaspur, Durg, Rajnandgaon, Dhamtari and Raipur fall under class III. Class IV comprises of several parts of Bilaspur, Korba, Raipur, Dhamtari, Kanker, Bastar, Narayanpur and Dantewada. The two districts namely, Rajnandgaon (Manpur and North Bhanupratappur) and Durg (South Gurur) come under class V with their few places. Class VI consists of different places of Koria, Jaspur, Kanker, Narayanpur, Bastar, Bijapur and Dantewada. Kawardha (Chilpi, Rengakhar, Kawardha, Lohara, Mohgaon and Gandai), Rajnandgaon (Chhuikhadan), Durg (Bemetara, Saja, Berla, Dhamdha and Nonkatti.), Raipur (Bhantapara and Balodabajar), Bilaspur (South Bilha region) districts fall under class VII . Class VIII comprises of few parts of Rajnandgaon, Durg, Raipur, Mahasamund, Raigarh and Janjgir. Class IX covers two districts namely, Raigarh and Janjgir. Lastly class X consists of Jashpur (South Jashpur), Raigarh (Bakaruma, Bhipur, Sithra and Sarangarh), Bilaspur (Sought Mungeli), Durg (Bhilai region).

4.17 Agro-ecological zone

Agro-ecological Zone is a land resource mapping unit, having a unique combination of land form, soil and climatic characteristics and/or land cover having a specific range of potentials and constraints for land use. Agro-ecological zone consist of agro-climatic zone, agro-edaphic zone, and soil province zone. Agro-ecological zone has been categorized in 63 classes using different parameters, agro-climatic zone has three parameters viz rainfall, temperature and legth of growing period, Rainfall has three ranges that are high (> 1400 mm), medium (1100-1400) and low (< 1100 mm), temperature has three ranges that are high (26-28^{0}C), medium (24-26) and low (22-24), length of growing period has three ranges that are high (130-140 days), medium (120-130) and low (110-120). Agro-edaphic zone has two parameters viz slope and availability of stone, Slope has three ranges that are high (> 10%), medium (5-10%) and low (0-5%). Soil

Agroecological Zones of Chhattisgarh

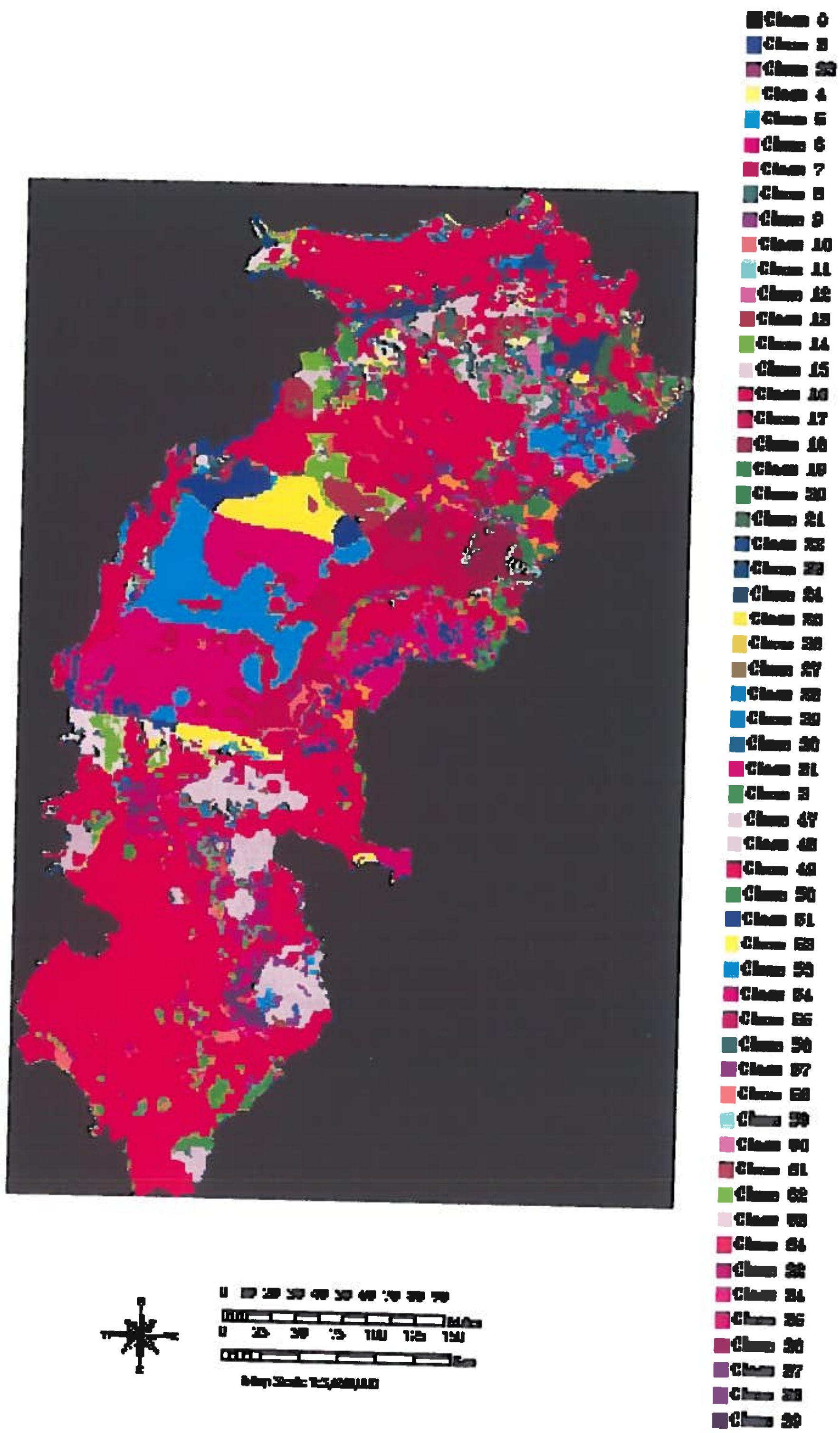

fig. 4.34

province zone has two parameter viz soil type and depth of soil, soil depth has three ranges high (>100 cm), medium (50-100) and low (0-50 cm).

The classes as per agro-ecological zone along with different places covered are described here.

1st Class considering vertisol soil, high soil depth, low slope, nonstony soil, medium temperature, low rainfall and medium LGP comprises of north eastern part of Kawardha, western part of Bilaspur, little portion of north Janjgir and south Durg. 2nd Class however, according to the present research was found not to cover any part of Chhattisgarh. Maximum part of Bilaspur, central Durg, few portion of eastern Raipur were categorized under 3rd class with vertisol soil, high soil depth, low slope, non stony soil, medium temperature, medium rainfall and medium LGP. 4th Class is characterized with vertisol soil, high soil depth, low slope, non stony soil, high temperature, low rainfall, medium LGP and covers maximum portion of Durg and few areas are Rajnandgaon, Raipur, Janjgir, Sarguja. 5th class is comprising of several part of Durg, some portion of Raipur, Rajnandgao, Dhamtari with almost similar features of 4th class except medium rainfall and high LGP. Ultisols soil with medium depth, high slope, non stony nature was found under 6th class which is characterized with high temperature, medium rainfall, medium LGP and covers few portion of Kawardha. Having almost similar characteristics like 6th class except medium temperature, low slope and high rainfall 7th class consists of some portion of Sarguja, jashpur and Korba. Few portion of Raipur comes under 8th class with similar findings like 7th class except with high temperature and low rainfall. Some part of Raipur and Durg comes under 9th class similar finding like 7th class except with stony soil, medium rainfall and high temperature. ultisols soil with medium depth, low slope, non stony nature was found under 10th class which is characterized with high temperature, medium rainfall, high LGP and covers few portion of Raigarh and Janjgir. ultisols soil with medium depth, high slope, non stony nature was found under 11th class which is characterized with medium temperature, high rainfall, medium LGP and covers few portion of Sarguja, jashpur, Raigarh and Kawardha.12st Class considering ultisol soil, high soil depth, low slope, nonstony soil, medium temperature, medium rainfall and medium LGP comprises of Sarguja, jashpur, Bilaspur, Janjgir and Kawardha. Some part of Bilaspur comes under 13th class similar finding like 12th class except high LGP. ultisols soil with high depth, low slope, non stony nature was found under 14th class which is characterized with medium temperature, high rainfall, medium LGP and covers few portion of Sarguja and jashpur. Maximum part of Raipur and some part of Bilaspur, Durg, Kawardha and Janjgir were categorized under 15th class with ultisol soil, high soil depth, low slope, non stony soil, high temperature, low rainfall and medium LGP. Some part of Janjgir, Raipur, Mahasamund Durg were categorized under 16th class with ultisol soil, high soil depth, low slope, non stony soil, high temperature, medium rainfall and medium LGP. Having almost similar characteristics like 16th class except high LGP 17th class consists of some portion of Raipur and Mahasamund. Some part of Sarguja jashpur Bilaspur and Korba were categorized under 18th class with ultisol soil, high soil depth, medium slope, stony soil, medium temperature, high rainfall and medium LGP. Ultisols soil with high depth, medium slope, stony nature was found under 19th class which is characterized with high temperature, medium rainfall, high LGP and covers few portion of Raigarh and Janjgir. Inceptisol soil with high depth, high slope, non stony nature was found under 20th class which is characterized with low temperature, high rainfall, medium LGP and covers few portion of Jashpur. Inceptisol soil with high depth, high slope, non stony nature was found under 21th class which is characterized with medium temperature, low rainfall, medium LGP and covers few portion of Kawardha and Bilaspur. Having almost similar characteristics like 21th class except high rainfall 22nd class consists of some portion of jashpur, Sarguja, Koriya and Kawardha. Inceptisol soil with high depth, low slope, non stony nature was found under 23rd class which is characterized with medium temperature, medium rainfall, high LGP and covers few portion of Kawadha, Rajnandgao, Kanker and Jagdalpur. Having almost similar characteristics like 23rd class except high rainfall and medium LGP 24th class consists of some portion of Sarguja and Koriya. Inceptisol soil with high depth, low slope, non stony nature was found under 25th class which is characterized with medium temperature, high rainfall, high LGP and covers few portion of Kanker, Dantewara and Narayanpur. 26th Class however, according to the present research was found not to cover any part of Chhattisgarh. Alfisol soil with low depth, high slope, non stony nature was found under 27th class which is characterized with medium temperature, medium rainfall, medium LGP and covers few portion of Sarguja, Kawardha and Dhamtari. Alfisol soil with low depth, high slope, non stony nature was found under 28th class which is characterized with medium temperature, medium rainfall, high LGP and covers few portion of Dhamtari. Alfisol soil with low depth, high slope, non stony nature was found under 29th class which is characterized with medium temperature, high rainfall, medium LGP and covers few portion of Kanker, Sarguja, Koriya and Dhamtari. Alfisol soil with low depth, high slope, non stony nature was found under 30th class which is characterized with medium temperature, high rainfall, high LGP and covers few portion of Jagdalpur and Kanker. Alfisol soil with low depth, high slope, non stony nature was found under 31st class which is characterized with high temperature, medium rainfall, medium LGP and covers few portion of Raipur and Mahasamund. Alfisol soil with medium depth, low slope, non stony nature was found under 32nd class which is characterized with medium temperature, medium rainfall, medium LGP and covers few portion of Koriya, Rajnandgaon, Durg, Kawardha, Bilaspur and Koriya. Some part of Dantewara, Jagdalpur and Narayanpur were categorized under 33rd class with alfisol soil, medium soil depth, low slope, non stony soil, medium temperature, medium rainfall and high LGP. Alfisol soil with medium depth, low slope, non stony nature was found under 34th class which is characterized with medium temperature, high rainfall, medium LGP and covers few portion of jashpur, Raigarh, Sarguja, Korba, Koriya and Kanker. Some part of Bilaspur, Kanker, Jagdalpur Dantewara and Bijapur were categorized under 35th class with alfisol soil, medium soil depth, low slope, non stony soil, medium temperature, high rainfall and high LGP. Alfisol soil with medium depth, low slope, non stony nature was found under 36th class which is characterized with high temperature, medium rainfall, medium LGP and covers few portion of Rajnandgaon, Raigarh, Durg, Raipur, Mahasamund and Janjgir. Some part of jashpur, Sarguja, Koriya, Dhamtari and Durg were categorized under 37th class with alfisol soil, medium soil depth, medium slope, non stony soil, medium temperature, medium rainfall and medium LGP. Alfisol soil with medium depth, medium slope, stony nature was found under 38th class which is characterized with medium temperature, high rainfall, medium LGP and covers few portion of Raigarh, jashpur and Jagdalpur. Some part of Jagdalpur, Kanker and Raigarh were categorized under 39th class with alfisol soil, medium soil depth, medium slope, stony soil, medium temperature, high rainfall and medium LGP. Alfisol soil with medium depth, medium slope, stony nature was found under 40th class which is characterized with high temperature, medium rainfall, medium LGP and covers few portion of Raipur, Dhamtari and Raigarh. Some part of jashpur, Raigarh, Dantewara, Sarguja, Durg and Kawardha were categorized under 41st class with alfisol soil, medium soil depth, low slope, non stony soil, medium temperature, medium rainfall and high LGP. Alfisol soil with medium depth, high slope, non stony nature was found under 42th class which is characterized with medium temperature, high rainfall, medium LGP and covers few portion of Sarguja, jashpur, Koriya, Korba and Raigarh. Small part of Jagdalpur, Bijapur, Dantewara and Bilaspur were categorized under 43th class with alfisol soil, medium soil depth, high slope, non stony soil, medium temperature, high rainfall and high LGP. Alfisol soil with medium depth, high slope, non stony nature was found under 44th class which is characterized with high temperature, low rainfall, medium LGP and covers few portion of Rajnandgao and Raipur. Alfisol soil with medium depth, high slope, non stony nature was found under 45th class which is characterized with high temperature, medium rainfall, medium LGP and covers few portion of Rajnandgao and Raigarh. Small part of jashpur, Sarguja, Raigarh, Kawardha and Bilaspur were categorized under 46th class with alfisol soil, high soil depth, low slope, non stony soil, medium temperature, low rainfall and medium LGP. Alfisol soil with high depth, low slope, stony nature was found under 47th class which is characterized with medium temperature, medium rainfall, medium LGP and covers few portion of Koriya, Bilaspur, Sarguja, Durg and Rajnandgao. Maximum part of Kanker and some part of Jagdalpur, Narayanpur, Bilaspur were categorized under 48th class with alfisol soil, high soil depth, low slope, non stony soil, medium temperature, medium rainfall and high LGP. Alfisol soil with high depth, low slope, non stony nature was found under 49th class which is characterized with medium temperature, high rainfall, medium LGP and covers maximum portion of Korba and few portion Jashpur, Sarguja, Koriya, Rajnandgaon and Durg. Some part of Koriya, Rajnandgao, Kanker, Narayanpur, Dantewara, Bijapur and Jagdalpur were categorized under 50th class with alfisol soil, high soil depth, low slope, non stony soil, medium temperature, high rainfall and high LGP. Maximum part of Rajnandgaon, Mahasamund and some part of Raipur and Janjgir were categorized under 51th class with alfisol soil, high soil depth, low slope, non stony soil, high temperature, medium rainfall and medium LGP. Alfisol soil with high depth, low slope, non stony nature was found under 52nd class which is characterized with high temperature, high rainfall, medium LGP and covers some portion of Raigarh and Janjgir. Some part of jashpur, Koriya and Bilaspur, were categorized under 53rd class with alfisol soil, high soil depth, medium slope, stony soil, medium temperature, medium rainfall and medium LGP. Alfisol soil with high depth, medium slope, stony nature was found under 54th class which is characterized with medium temperature, medium rainfall, high LGP and covers some portion of Bilaspur, Jagdalpur and Kanker. some part of jashpur, Raigarh, Sarguja, Koriya, Korba and Rajnandgaon were categorized under 55th class with alfisol soil, high soil depth, medium slope, stony soil, medium temperature, high rainfall and medium LGP. Alfisol soil with high depth, medium slope, stony nature was found under 56th class which is characterized with medium temperature, high rainfall, high LGP and covers some portion of Jagdalpur and very small part of Bijapur, Dantewara and Narayanpur. Small part of Raigarh, Janjgir, Raipur, Mahasamund and Bijapur were categorized under 57th class with alfisol soil, high soil depth, medium slope, stony soil, high temperature, medium rainfall and medium LGP. Very small part of Jashpur and Sarguja were categorized under 58th class with alfisol soil, high soil depth, high slope, non stony soil, medium temperature, medium rainfall and medium LGP. Alfisol soil with high depth, high slope, non stony nature was found under 59th class which is characterized with medium temperature, medium rainfall, medium LGP and covers very small portion of Koriya, Bilaspur and Jashpur. Very small part of Jagdalpur, Kanker and Narayanpur were categorized under 60th class with alfisol soil, high soil depth, high slope, non stony soil, medium temperature, medium rainfall and high LGP. Very small part of Jashpur, Sarguja, Koriya and Korba were categorized under 61st class with alfisol soil, high soil depth, high slope, non stony soil, medium temperature, high rainfall and medium LGP. Some part of Jagdalpur and Kanker were categorized under 62nd class with alfisol soil, high soil depth, high slope, non stony soil, medium temperature, high rainfall and high LGP. Alfisol soil with high depth, high slope, non stony nature was found under 63rd class which is characterized with high temperature, medium rainfall, medium LGP and covers very small portion of Raigarh.

Summary, Conclusions and Suggestions for Future Research work

CHAPTER-V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

Chhattisgarh state has been categorized into 3 sub Agro-climatic zones viz. Chhattisgarh Plains, Bastar Plateau, and Northern Hills region spreading over a total geographic area of 1,35,191 sq. km, Forest and the net cultivated area occupies 43.85 percent and 42.93 percent of the total geographical area, respectively. The climate of the state is dry sub-humid. The average rainfall of the state is around 1400 mm, of which about 90 percent is received during the southwest monsoon.

Agro-ecological zone is a major area of land that is relatively uniform with respect to crop production possibilities. Since climate and soils are two most important natural resources which determine the ability of agricultural land to produce crops, Agro-ecological zoning encompasses the delineation of land into regions or zones that are broadly homogenous with respect to climate and soil. AEZ models are applied on the database to analyse potentials of land for various kinds of use. The AEZ models include models for the calculation of length of growing period, irrigation requirements, land suitability, and land productivity. The data collection centers for the aforesaid parameters of Agro-climatic zone and AEZ include revenue department of Chhattisgarh, College of agriculture Raipur, Bilaspur, Ambikapur, and Jagdalpure and has been analyzed for framing as a standard for the entire Chhattisgarh state. Agro-ecological zones (AEZ) studies carried out in the past mainly dealt with rainfed agriculture; however research on irrigation resource of Chhattisgarh has so far remained largely ignored in these studies. The spatial surface of the rainfall data was generated in a GIS based model ARC-View 3.1 GIS software using the IDW (Inverse Distance Weightage) algorithm for agro-ecological zoning was developed using soil resources, temperature and moisture regimes as an input layers for geo-processing. Land systems and land capability maps were digitized. Soil resources inventory was compiled from dept. of soil science, IGKV, Raipur. A land resources database of the study area was created. Altogether 63 Agro-ecological cells were generated. Agro-edaphic and Agro-climatic zones were defined from the collected data. Agro-ecological zones database was generated; and Agro-ecological zones map was produced.

On the basis of total rainfall quantum, Chhattisgarh state has been classified as high rainfall zone, medium rainfall zone and low rainfall zone. Under annual rainfall zone the lowest rainfall (<1300 mm) was recorded in western Raipur and eastern Durg, while highest rainfall (>1600 mm) was recorded in eastern part of Jashpur. During *Kharif* season the lowest rainfall (<1300 mm) was recorded in the districts Kawardha, Rajnandgaon, Durg, Kanker, Dhamtari, western part of Koriya, Korba, Bilaspur, Mahasamund, north west part of Narayanpur and Jagdalpur and maximum part of Raipur and the highest rainfall (>1525 mm) was recorded in very small part of Jashpur. Further lowest rainfall (<85 mm) during the *Rabi* season was recorded in the Raigarh, maximum part of Sarguja, Janjgir, Mahasamund, Durg, Kawardha and approximately 50% part of

Korba, Raipur, Dhamtari, Kanker, Rajnandgao and in few parts of Jagdalpur, Jashpur and Koriya while as highest rainfall (>1600 mm) was recorded in the very small part of Jagdalpur and Dantewara.

In Chhattisgarh under annual temperature the lowest temperature (<23^{0}C) was recorded in the small part of Jashpur and the highest temperature (>26^{0}C) was recorded in the Mahasamund, maximum part of Raigarh, Raipur, Durg, Janjgir, Kawardha, Rajnandgao, and some part of Dhamtari, Korba and Bilaspur. Lowest mean temperature during *Kharif* season (<26^{0}C) was recorded under some part of Jashpur while highest temperature (>30^{0}C) was recorded under maximum part of Raigarh, Janjgir and some part of Raipur, Mahasamund, Durg, Kawardha and Rajnandgao .During *Rabi* season lowest temperature (<21^{0}C) was observed in the eastern parts of jashpur and central part of Sarguja. Highest values for this parameters (>24^{0}C) was found in Mahasamund, maximum parts of Raigarh, Raipur, Durg, Dhamtari, Janjgir and small parts of Kawardha.

Least values for annual relative humidity i.e <56% were noticed with western part of Raipur, central part of Durg, Raigarh and in some specific parts of Janjgir, Mahasamund, Dhamtari and Rajnandgao. Likewise highest values for annual relative humidity (>62%) were observed in the south eastern parts of Jagdalpur apart with some eastern parts of Dantewara. Comparing the relative humidity of *Rabi* and *Kharif* seasons from minimum to maximum, study reaveled that lowest (<66.5%) was observed in the western parts of Raipur, central part of Durg, Raigarh, few parts of Janjgir, Mahasamund, Dhamtari, Rajnandgao during kharif season while as minimum relative humidity (<45%) was recorded in some parts of Durg, Raipur, Raigarh and few parts of Janjgir, Bilaspur as well as in Dhamtari during Rabi season, respectively. Similarly highest relative humidity percentage (>71%) during kharif season was found in south eastern parts of Jagdalpur, eastern parts of Dantewara, while as during Rabi season, maximum relative humidity of (>51%) was observed in maximum parts of Dantewara, Jagdalpur and few parts of Bijapur, simultaneously.

Study reaveled that annual cloud cover ranged from minimum (<3 octa) in eastern parts of jashpur and few parts of Sarguja to maximum (>4 octa) in some parts of Jagdalpur and Dantewara, respectively. However the lowest (<4.5 octa) was recorded from eastern parts of jashpur apart with few parts of Sarguja and highest (>6 octa) from some parts of Jagdalpur during *Kharif* season. This trend of cloud cover varied during Rabi season with lowest (<1.5 octa) in eastern parts of Jashpur and highest (>2.5 octa) in some parts of Jagdalpur.

As evident from the investigation annual rainy days was lowest (<65/ days) noticed from maximum parts of Durg, Dhamtari, Kanker and few parts of Rajnandgaon, were as highest rainy days (>80) were recorded from eastern parts of jashpur and Jagdalpur. During *Kharif* season lowest rainy days (<60) were observed in district of Durg, Dhamtari, Rajnandgao, maximum parts of Kanker, Raipur, Kawardha as well as in few parts of Mahasamund, Jagdalpur and Narayanpur while as highest rainy days (>70) in eastern parts of jashpur, Jagdalpur and few parts of Sarguja and Dantewara. As far as *Rabi* season is concerned minimum rainy days (<6) were recorded from Deobhog region of

Raipur and highest (>9 days) in eastern parts of Jashpur, north Bilaspur and in some parts of Sarguja.

From wind speed point of view of study area, lowest (<3 kmph) was found in Deobhog region of Raipur and highest (>6) from maximum parts of Sarguja, Koriya, Bilaspur, Durg, some parts of jashpur, Raigarh, Kawardha, Mahasamund and Dhamtari. Deobhog region of Raipur recorded lowest wind speed (<3) during *Kharif* season while as highest (>6) during the said period was recorded from maximum portion of plains, Northern hill of Chhattisgarh apart with few parts of Jagdalpur and Narayanpur districts. During *Rabi* season lowest wind speed was recorded (<2) from the same Deobhog region of Raipur were as highest (>5) observed from Kawardha, Koriya, Sarguja, Bilaspur, few parts of Korba, Durg, Rajnandgaon, Raipur, Jashpur and Raigarh.

The result of length of growing period tells that under 100 mm soil moisture depth lowest (<105 day) LGP was recorded in central part of Kawardha and highest (120 days) was recorded under whole Bastar plateau, Kanker, and some part of Dhamtari, Raipur, Raigarh, Janjgir, Koriya, Durg. Central part of Kawardha and whole Bastar plateau have the lowest (<116) and highest (>134) LGP under 150 mm soil moisture respectively.

North part of northern hill region and some part of Janjgir, Korba, Jagdalpur, Raigarh have the lowest (<18 mj/m^2) and highest (>19.5) annual average radiation intensity respectively. During kharif season western part of Koriya have the lowest (<17) radiation intensity. Highest radiation intensity (18.5) was recorded under some part of Raigarh, Korba, Janjgir, Jagdalpur and few parts of Dantewara and Raipur during kharif season. During Rabi season lowest (<18.5) radiation intensity was recorded in Koriya, eastern Sarguja, and some part of Korba, Bilaspur. Maximum part of Raigarh, Jagdalpur, Dantewara and few part of Korba, Raipur have the highest (>19.5) radiation intensity during *Rabi* season.

Lowest annual PET of less than 1500 mm was recorded under north part of northern hills and few east part of Jagdalpur. As for as highest annual PET is consider western part of Raipur, eastern part of Durg and few part of Dhamtari have more than 1650 mm of annual pet. During *Kharif* season western part of Koriya with eastern part of Jagdalpur and western part of Raipur with eastern part of Durg have the lowest (<830) and highest (>920) PET was recorded in north part of Sarguja and some part of Kanker, Durg, Dhamtari, during *Rabi* season respectively.

The present scenario of forest area in the Chhattisgarh state is decreased from 45% to 36% from 1900 to 2000 census. In district wise distribution of forest, the Koriya district ranks the first, fallowed by Bastar and Dantewara district. 28 % of the state comprises of fallow land which is widely distributed in the district of Koriya, Sarguja, and Raigarh.

The deep soils are the predominant in the state as a whole and in Chhattisgarh plain in particular. These soils are characterized by their depth which is more than 100 cm. The soils having depth of 75-100 cm are mostly found in the districts of Northern hills and Bastar plateau. The soil depth of 50-75 cm is predominant in the soils of Dantewada and Narayanpur districts. The medium depth of soil ranging between 25-50 cm is exposed in the portions of Bijapur, Narayanpur, Bastar, Dantewada, Kanker, Dhamtari, Durg, Raipur, Mahasamund, Korba and Raigarh. The predominant depth of soil in Narayanpur, Bijapur of Bastar plateau ranges from 10-25 cm. Very shallow soil, of less than 10 cm depth are found in a significant amount in the parts of Surguja, Bilaspur, Mahasamund, Raigarh, Kanker, Bastar, Bijapur and Dantewada districts.

The central part of Chhattisgarh is covered mainly by deep black and medium black soils (Vertisol). Areas coming under this order are parts of Durg, Rajnandgaon, Kawardha, Bilaspur, Raipur, Surguja and Dhamtari districts. The soils scattered in small portions of Chhattisgarh plains and Northern hills are the Ultisol. The Indian equivalent of Ultisols which are available in this state are lateritic soils and red & yellow soils. The third order of soils which are found in Chhattisgarh are shallow black soils (Inceptisols) also called as young soils. They generally occupy river delta or hill sides. These soils are available in linear patches in parts of Surguja, Koriya, Jashpur, Korba, Bilaspur and Kawardha districts. The most common soils distributed in largest area of Chhattisgarh are Red gravel soils, Red loamy soils & Red sandy soils of Alfisol. These soils taken together cover more than 50% area of the state.

Slope aspect of Chhattisgarh plain comprises mostly of slightly slopy topography of 0-5 %. 5-10% slope is common in Bastar plateau. Northern hill is dominant in steepest slope.

The six class of agro-edaphic zone give as idea about the different place with its edaphic property. By having the idea further study can be made for better crop growth according to edaphic character. Every crop has its different critical stages which can be made control by having the idea of climate at the time of critical stage. Critical stage is mainly affected by water requirement and climatic condition. The 10 classes of Agro-climatic zones can be further utilized by scientist to work out better crop growth according to Agro-climatic zone. Soil and climate together play a major role in crop growth with high yield. The Agro-ecological zone map give as idea of a soil type and climatic condition of a particular place. The classes of 64 Agro-ecological zone map help the scientist and farmer to grow a crop according to climatic condition and soil type of Chhattisgarh.

Abstract

AGRO-CLIMATIC AND AGRO-ECOLOGICAL CHARACTERIZATION OF CHHATTISGARH

By

SANJAY BHELAWE

ABSTRACT

The study was carried out entitled, "Agro-climatic and Agro-ecological characterization of Chhattisgarh" to characterize the agro-climatic and agro-ecological parameters. The characterization was based on screening of distinct agro-climatic parameters apart with agro-ecological parameters and preparation of data base for the said zones of Chhattisgarh. The annual average data of 30 stations falling in Chhattisgarh and surrounding states of Madhya Pradesh, Maharastra, Orissa, Uttar Pradesh, Jharkhand and Andhra Pradesh have been collected from the literature published by India Meteorological Department (IMD) (Climatological tables 5th addition 1999). The average climatic data of whole India is routinely published by IMD considering the weather data of last 30 years. The spatial surface of the rainfall data was generated in ARC-View 3.1 GIS software using the IDW (Inverse Distance Weightage) algorithm

The study reaveled that agro-climatic factors viz temperature, rainfall, humidity, cloud cover, radiation intensity, rainy days, wind speed, and potential transpiration varied during annual duration including Rabi and kharif season from one region to another region of Chhattisgarh. Annual temperature varied from $<23^0$C to $>26^0$C,

another region of Chhattisgarh. Annual temperature varied from <23^{0}C to >26^{0}C, rainfall between <1300 mm to >1600 mm, relative humidity <56% to 62 %, cloud cover <3 octa to >4 octa, rainy days <65 to >80 days, wind speed <3 kmph to >6 kmph, potential evapotranspiration from <1500mm to 1650 mm, and radiation intensity from <18 mj/m^2 to >19.5 mj/m^2 for minimum to maximum respectively. Length of growing period was standardized on the basis of these said factors which range from <105 to 120 day suitable for crop growth. Further the classification of 10 Agro-climatic classes was done based on all these aforesaid climatic factors.

The present investigation indicates VI agro-edaphic zones on the basis of slope and stone availability with percentages of slope ranging from <0-5% to >10%. Similarly soil depth ranged from < 10 cm to >100 cm and soil type variation includes vertisol, ultisol, inceptisol and alfisol in this study area of Chhattisgarh. The overall view and results of the investigation based on the compilation of all these factors classified Chhattisgarh into 63 Agro-ecological classes.

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Appendices

APPENDIX- I

AVERAGE RAINFALL DATA OF 90 STATIONS USED IN THE STUDY

S. N.	District	Tahsil	Latitude	Longitude	Avg. Rain
1.	Bastar	Jagdalpur	19.08	82.03	1167.5
2.	Bastar	Kondagaon	19.60	81.65	1273.1
3.	Bastar	Keskal	20.08	81.60	1278.6
4.	Bastar	Narayanpur	19.72	81.25	1270.9
5.	Dantewada	Dantewada	18.88	81.35	1482.9
6.	Dantewada	Bhopalpattnam	18.87	80.38	1581.4
7.	Dantewada	Bijapur	18.78	80.82	1363.4
8.	Dantewada	Konta	17.82	81.38	1172.2
9.	Kanker	Kanker	20.27	81.33	1136.3
10.	Kanker	Naharpur	20.42	81.67	1159.3
11.	Kanker	Charama	20.50	81.33	1484.6
12.	Kanker	Antagarh	20.10	81.17	1688.7
13.	Kanker	Bhanupratappur	20.32	81.08	1969.6
14.	Bilaspur	Bilaspur	22.08	82.13	1103.4
15.	Bilaspur	Masturi	21.97	82.25	885.9
16.	Bilaspur	Pendrarod	22.77	81.90	837.8
17.	Bilaspur	Kota	22.27	81.97	1049.4
18.	Bilaspur	Bilha	21.92	82.05	1187.7
19.	Bilaspur	Mungeli	22.07	81.68	1192.9
20.	Bilaspur	Takhatpur	22.08	81.83	1093.0
21.	Dhamtari	Dhamtari	20.70	81.57	1103.5
22.	Dhamtari	Nagri	20.42	81.83	1223.6
23.	Dhamtari	Kurud	20.83	81.72	1192.2
24.	Durg	Durg	21.22	81.28	1348.2
25.	Durg	Dhamdha	21.45	81.25	957.2
26.	Durg	Patan	21.03	81.50	1192.3
27.	Durg	Gunderdehi	20.92	81.25	989.0
28.	Durg	Balod	20.73	81.13	823.3
29.	Durg	Doundi	20.50	81.00	1015.5
30.	Durg	Doundilohara	20.75	80.92	1207.5
31.	Durg	Navagarh	21.87	81.58	1382.4
32.	Durg	Bemetara	21.72	81.53	1346.0
33.	Durg	Berla	21.52	81.42	823.3
34.	Durg	Gurur	20.70	81.33	1071.1
35.	Janjgir-Champa	Champa	22.03	82.70	1391.2
36.	Janjgir-Champa	Janjgir	22.02	82.58	1049.5
37.	Janjgir-Champa	Pamgarh	21.87	82.42	973.5
38.	Janjgir-Champa	Shakti	22.03	82.97	895.6
39.	Janjgir-Champa	Malkhorada	21.88	83.00	1261.5

S. N.	District	Tahsil	Latitude	Longitude	Avg. Rain
40.	Janjgir-Champa	Dabhara	21.78	83.08	1104.5
41.	Janjgir-Champa	Navagarh	21.85	82.58	1303.1
42.	Kavardha	Kavarda	22.02	81.25	835.4
43.	Kavardha	Pandria	22.22	81.42	998.8
44.	Korba	Korba	22.33	82.70	1797.6
45.	Korba	Kartala	22.30	82.92	1392.7
46.	Korba	Katghora	22.50	82.55	1437.5
47.	Korba	Pali	22.33	82.33	1377.4
48.	Mahasamund	Mahasamund	21.10	82.10	1057.4
49.	Mahasamund	Saraipali	21.08	82.45	1301.0
50.	Mahasamund	Basana	21.30	82.83	1150.3
51.	Raigarh	Raigarh	21.88	83.40	1039.0
52.	Raigarh	Dharamjaigarh	22.47	83.22	906.1
53.	Raigarh	Ghorgora	22.13	83.37	1247.6
54.	Raigarh	Kharsia	22.00	83.17	1360.2
55.	Raigarh	Sarangarh	21.58	83.08	1447.5
56.	Raigarh	Lailunga	22.37	83.60	1323.1
57.	Raipur	Raipur	21.23	81.65	1080.9
58.	Raipur	Simga	21.63	81.70	772.0
59.	Raipur	Arang	21.20	81.98	939.7
60.	Raipur	Bhatapara	21.72	81.92	1082.4
61.	Raipur	Balodabazar	21.67	82.17	880.9
62.	Raipur	Bilaigarh	21.67	82.75	771.2
63.	Raipur	Kasdol	21.63	82.42	811.7
64.	Raipur	Tilda	21.53	81.75	1001.6
65.	Raipur	Rajim	20.97	81.88	1004.0
66.	Raipur	Gariaband	21.63	82.07	1138.7
67.	Raipur	Devbhog	19.90	82.67	1244.2
68.	Raipur	Abhanpur	21.08	81.75	769.7
69.	Rajnandgoan	Chuhikhadan	21.53	80.98	831.0
70.	Rajnandgoan	Khairagarh	21.42	80.98	1073.2
71.	Rajnandgoan	Dongargarh	21.20	80.75	1138.2
72.	Rajnandgoan	Rajnandgoan	21.08	81.03	1198.4
73.	Rajnandgoan	Dongargoan	21.00	80.75	1052.4
74.	Rajnandgoan	Choki	20.78	80.73	1146.7
75.	Rajnandgoan	Mohala	20.60	80.67	1229.3
76.	Rajnandgoan	Manpur	20.40	80.67	1403.3
77.	Jashpur	Jashpur	22.88	84.13	1532.0
78.	Jashpur	Patthalgoun	22.53	83.50	1642.0
79.	Jashpur	Bagicha	22.92	83.67	1251.1
80.	Jashpur	Kunkuri	22.72	84.00	1358.1
81.	Korea	Bharatpur	23.16	82.50	1283.5

S. N.	District	Tahsil	Latitude	Longitude	Avg. Rain
82.	Korea	Manendragarh	23.08	82.17	1317.3
83.	Korea	Baikunthpur	23.16	82.50	1250.0
84.	Korea	Sonhat	23.35	82.42	1393.9
85.	Sarguja	Rajpur	23.25	83.40	1409.5
86.	Sarguja	Ambikapur	23.12	83.20	1364.3
87.	Sarguja	Lundra	23.03	83.40	1438.1
88.	Sarguja	Sitapur	22.77	83.48	1345.5
89.	Sarguja	Pratappur	22.37	83.22	1502.7
90.	Sarguja	Surajpur	23.23	82.87	1285.5