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HYDROLOGICAL - LAND USE MAPPING OF MALAPRABHA AND GHATAPRABHA CATCHMENTS OF KRISHNA BASIN

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PREFACE

Knowledge of hydrologic land use pattern of any basin is very important because a record of surface cover characteristics can be used to define estimates of the quantity and quality of the water yield in response to a particular precipitation event or watershed treatment. The land use pattern in any basin is of dynamic nature and it influence to a greater extent the hydrologic system of the basin. In general, the land use pattern mainly depends upon physical attributes such as topography, soils and vegetation.

In our country, like other developing countries, efforts are being made for a rational and scientific regional and urban planning. But reliable and integrated information which is the pre-requisite for land use planning is not available. Such information could only be obtained by employing modern techn· ques and method for research and mapping.

In recent years, the advent of remote se sing has opened up new vistas in geological, geomorphological and land use mapping. Therefore, in the present study remote sensing technique has been used, as the conventional methods are laborious, time consuming and expensive The study has been conducted in the catchment area of Ghataprabha and Malaprabha sub-basins, because it is found that, though the catchment receives enough rainfall, adequate measures have not been taken in the upstream region of the river to conserve water and to enhance the crop production. The study constitute remotely sensed data coupled with field data to bring out suitable land use pattern in the catchment area for obtaining more crop production with available water resources

Visual interpretation technique have been used for obtaining land use pattern. The study has been carried out by Dr V K Choubey, Scientist C and Dr B K Purendra, SRA, of the Hard Rock Regional Centre, Belgaum.

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ABSTRACT

The land use pattern in any basin is of dynamic nature and it influence to a greater extent the hydrologic system of the basin. Hence for any management and development activity in the basin, information on the land use is a prerequisite. The mapping of the land utilisation pattern in the Malaprabha and Ghataprabha catchment of Krishna basin is proposed to be carried out.

The Malaprabha river, a tributary of river Krishna, has two principal tributaries the Bennihalla and the Hirehalla. It originates from the Chorla ghats. Its catchment area lies in the Belgaum, Bijapur, Dharwar and Raichur districts of Karnataka. The triangular shaped Malaprabha catchment with a total area of 11,549 Sq. Km., is having a flat to gently undulating physiography except for a new hillocks and valleys. The ridges sorrounding the basin seperates it from the Ghataprabha in the North, Krishna & Tungabhadra in the East and the East flowing rivers in the South and West.

In the basin S.W. monsoon breaks in May and continues till October. The mean annual rainfall is 933 mm (Monsoon 887 mm and Non-Monsoon 46 mm). The main soil type of the basin is the mixed red and black soil (35.0% of the area), followed by medium black soil (29%), deep black soil (12%), red sandy soil (20%) and red loamy soil (4%). In the basin 74.9% of the land is used for agricultural activities. Fallow land and cultivable wastes constitutes 6.5%, forests 11.3%, barren and 2.8% and others 4.5%.

The Ghataprabha river, a tributary of river Krishna, has three principal tributaries the Tamaraparani, the Hiranyakeshi, and the Markandeya. It originates from the western ghats and flows through the Kolhapur & Sindhudurg districts of Maharashtra and Belgaum and Bijapur districts of Karnataka. The triangular shaped Ghataprabha basin with a total area of 43,807 Sq.Km., has a gently undulating physiography with isolated hillocks and valleys and marked in the north and south by ridges separating it from the Krishna and Malaprabha basins respectively.

In the basin S.W. monsoon breaks in June and continues till October. The mean annual rainfall is 962 mm (Monsoon 799 mm and Non-Monsoon 163 mm). The main soil type of the basin is the deep black soil (43.8% of the area), followed by medium black soil (38%), laterite soil (12.6%), mixed red and black soil (3.4%) and coarse shallow black soil (2.2%). In the basin 64% of the land is used for agricultural activities. Fallow land and cultivable wastes constitutes 13.2%, forests 12.6% barren land 3.9%, and others 6.3%.

Based on present study, the recommended land use for both catchments for each of these systems take into account the suitability of soils,its erosion status, the availability of groundwater potential and the existing land use practices in the

area. However, in some areas need high priority for immediate attention. These are hilly areas with degraded forest cover which need to be attended for afforestation measures. Second category involves areas which are predominantly wastelands and marginally fallow lands, which can be utilised for fuel, fodder and plantation crops. These recommended land uses are essential for long term planning for improving and mitigating the drought conditions.

1.0 INTRODUCTION

Land use mapping is an essential part for many planning and management activities concerned with the hydrological aspects of the hemisphere. In the recent decades land resources shows a highly declining trend due to the ever increasing pressure of population. So it is necessary to plan the available land resources in a practical manner. For long term planning of any system we should have the land use pattern followed in an area. This involves the execution and interpretation of data of land resources, survey of soils, vegetation and other related aspects of land in order to identify and make a comparison of the promising kinds of land use. Land evaluation for its suitability for various uses, is a pre-requisite for preparation of land use plan of a region.

At the outset it is necessary to distinguish between land classification and land use planning. These are different processes. In the process of classification, it is necessary to evaluate the physico-chemical and meteorological characteristics of the land areas. The main objective of land classification is to distinguish what exists, and to enable the planner to appreciate the difference in quality of the land at its disposal. The land use pattern is further usefulfor the economists, politicians and decision makers to know the potentiality of the land.

In general, the term land use refers to the human activity associated with a specific piece of land, and, land cover relates to the type of feature present on the surface of the earth. For a hydrologic study of rainfall-runoff characteristics, it would be important to know the amount and distribution of roofs, pavement, grass, and trees in this tract. Furthermore, land use pattern will indicate hydrological conditions and geomorphic characteristics of the region.

1.1 OBJECTIVES

1. To prepare a hydrological land use map of the two catchments namely, Ghataprabha and Malaprabha of the Krishna basin using IRS-1A-LISS-II images.

2. It will serve as a basis for monitoring land use change, e.g. the growth of the irrigated area and possible changes in forest boundaries.

2.0 REVIEW

Land use and land cover are dynamic features over space and time, it is difficult to get real time information through conventional means. Also, these methods are time consuming, laborious and with high costs often when the study has time limitation, the planners and specialists in various disciplines are forced to use existing data on the land use which is usually out dated because of the constantly changing pattern of available resources and demand. For economical development of a region, planners need upto date knowledge which can only be obtained quickly, economically and accurately through remote sensing technique.

In the recent decades, state government agencies had started collecting data pertaining to the land use patterns followed in various parts of the state. Recently, the annual land use pattern followed in the Malaprabha and Ghataprabha sub-basin as per the information provided by the statistical department of Karnataka state for the year 1984-1985 and 1980-1981 respectively are published by National Water Development Authority (NWDA, 1990, TS No. 39 & 40).

A detailed geomorphological study was carried out by the institute during 1990-1991,(Vijayakumar, 1991). So the regional centre of National Institute of Hydrology, with the limited literature, brought out a land use pattern for both Malaprabha and Ghataprabha catchments. The general information related to soil classification and description of the sub-basin etc has been extracted from the literature provided by soil survey department and National Water Development Authority.

The optimal use of land and water resources have been studied by a number of researchers, including Morel-Seytoux (1975), Kashyap et al (1982), Beredehoeft and Young (1983), Chandra (1986), Chachadi et al (1988) and El-akadi (1989).

The growing pressure of population and the need of food of the human race, it is essential to have more crops to obtain more production from the area. This necessitates the increase of crop areas, multiple cropping associated with the necessary water resources development. This requires proper crop planning, which depends on a number of factors, viz. crop, crop intensity, water resources, climate, crop water requirements, method of irrigation, drainage efficiency of the system, soil characteristics, topography, socio economic conditions, etc. Hence there is an urgent necessity for systematic inventorying, mapping and monitoring of land resources for sustained agricultural production, (Bali, 1977; Murthy et al 1977) which could be achieved by the conjunctive use of both surface and ground water systems.

Surface and ground water are two components of the hydrological cycle with different but interrelated hydrologic, economic and environmental characteristics. Several studies on

conjunctive surface and ground water have been under taken and some of the earlier ones have been reviewed by Chachadi et al (1988) and Kamal (1989). Saunders (1967), stated that in order to assess the value of planned conjunctive use in relation to a particular area or a basin , it is necessary to look at th economic, hydrologic and legal system as a whole. Milligan (1969), studied conjunctive surface and ground water development considering both economic and water balance issues. In recent years, the optimal use of land and water resources for agricultural purposes, conjunctive use approach has been used by number of researchers including, Morel-Seytoux, (1975), Beredehoeft and Young (1983), Chandra (1986), Kashyap & Chandra (1982), El-kodi (1989) and Choubey et al (1992). The approach, in general, is to minimize or maximize certain functions (e.g. stream depletion, total pumping and water storage) that are subject to a number of constraints. The constraints may include specified demands, limited pumping, and specified flow to the stream.

In addition to the conventional methods, in the recent years remotely sensed data are being extensively used for water resources monitoring and management. However systematic study has not been done in terms of water resources planning.

In the present study remote sensing technique has been used as the conventional methods are laborious, time consuming and expensive when compared to the modern methods of resource surveying (Dwivedi, 1985 ; Singh and Dwivedi, 1986). Space imagery obtained through satellites are very useful for land use mapping and specific benefits can be summarised as follows.

(i) The space image is a permanent and authentic at any one time, showing the land use interrelationship and broad resource cndition.

(ii) The repetitive coverage predicted by the space crafts give a better idea of the changes that have taken place in land use practices.

(iii) It provides a good base and reduces the need for extensive field work and the cost involved for such field work.

(iv) It gives an improved definition of broad vegetational eco-tones because of reduced resolution and scale. Land use mapping of Malaprabha and Ghataprabha catchment has not been carried out in a systematic manner. However, Karnataka state Remote sensing agency had attempted for district wise mapping in the state. The earlier researchers had adopted various means for land use classification. Young (1978), discussed six basic principles of land suitability and evaluation. They are (i) land suitability assessed for specified kinds of land suitability and evaluation, (ii) comparative evaluation for benefits obtained with inputs needed,(iii) a multi disciplinary approach, (iv) evaluation in terms relevant to local or national conditions, (v)

suitability for use on a sustained basis , i.e. the use that is not bringing about severe or progressive degradation,

(vi) evaluation involving a comparison of two or more kinds of use , which are not exclusively agricultural. The USGS land use and land cover classification system was designed according to the following criteria:

(1) the minimum level of interpretation accuracy using remotely sensed data should be atleast 85 %.

(2) the accuracy of interpretation for the several categories should be equal,

(3) results should be repetitive,

(4) Classification must be applicable over extensive areas,

(5) The categorization should permit land use to be inferred from the land cover types,

(6) the classification should permit land use to be inferred from the land cover types, classification system should be suitable for use with remote sensor data obtained from large scale imagery or ground surveys,

(7) Categories should be divisible into more detailed subcategories that can be obtained from the large scale imagery or ground surveys,

(8) aggregation of categories must be possible,

(9) comparison with future land use and land cover data should be possible,

(10) Multiple uses of land should be recognised when possible,

The above facts were brought to light by Lillesand and Kiefer, (1987).

The present study has been taken up for the catchment area, because, it is found that, though the catchment receives enough rainfall, adequate measures have not been taken in the upstream region of the river to conserve water and to enhance the crop production. The study constitute remotely sensed data coupled with field data to bring out suitable hydrological land use pattern in the catchment area for obtaining more crop production with available water resources.

In the present study, IRS-1A-LISS-II images have been used to classify land use pattern and soils of the catchment. In addition, surface and ground water potential of the catchment has been computed considering five years data (1985- 1989). Water requirement for different crops also been computed.

3.0 DESCRIPTION OF STUDY AREA

3.1 MALAPRABHA CATCHMENT

The Malaprabha river is a right bank tributary of river Krishna. The Malaprabha catchment lies between north latitudes 15-00 and 16 - 12' and east longitudes 74 - 14' and 76 -05' comprising the catchment area of the river from its source to its confluence with the Krishna including the catchments of all its tributaries. The index map of the sub-basin is at fig.1.

The Malaprabha originates from the Chorla ghats, a section of the western ghats, at an elevation of about 792 m about 35 m south-west of Belgaum district in Karnataka. The river flows east and the north-west and joins the Krishna at Kapila sangam in the Bijapur district at an elevation of about 488 m. It traverses a length of 306 km before meeting the river Krishna. The Bennihala and the Hirehalla are the principal tributaries of the river Malaprabha.The catchment area of the sub-basin lies wholly in the State of Karnataka. District-wise break-up of the area of the catchment is given in table 3.1 below.

Table 3.1

District-wise break-up of the catchment area of Malaprabha catchment.

State	District	Area of the district falling in the catchment	Percentage of the area of district within the catchment.
Karnataka	Belgaum	3880	33.6
	Bijapur	1950	16.9
	Dharwad	5499	47.6
	Raichur	220	1.9
	Total	11549	100.0

To harness the waters of the Malaprabha river a dam is constructed at Navi-luteerth, Belgaum district to impound 1377 MCM water. The reservoir catchment covers an area of 3300 sq.km.

3.1 Physioigraphy, geology , hydrogeology and meteorology:

The Malaprabha catchment is approximately triangular in shape. The terrain is flat to gently undulating except for a few hillocks and valleys. The northern boundary is the common ridge

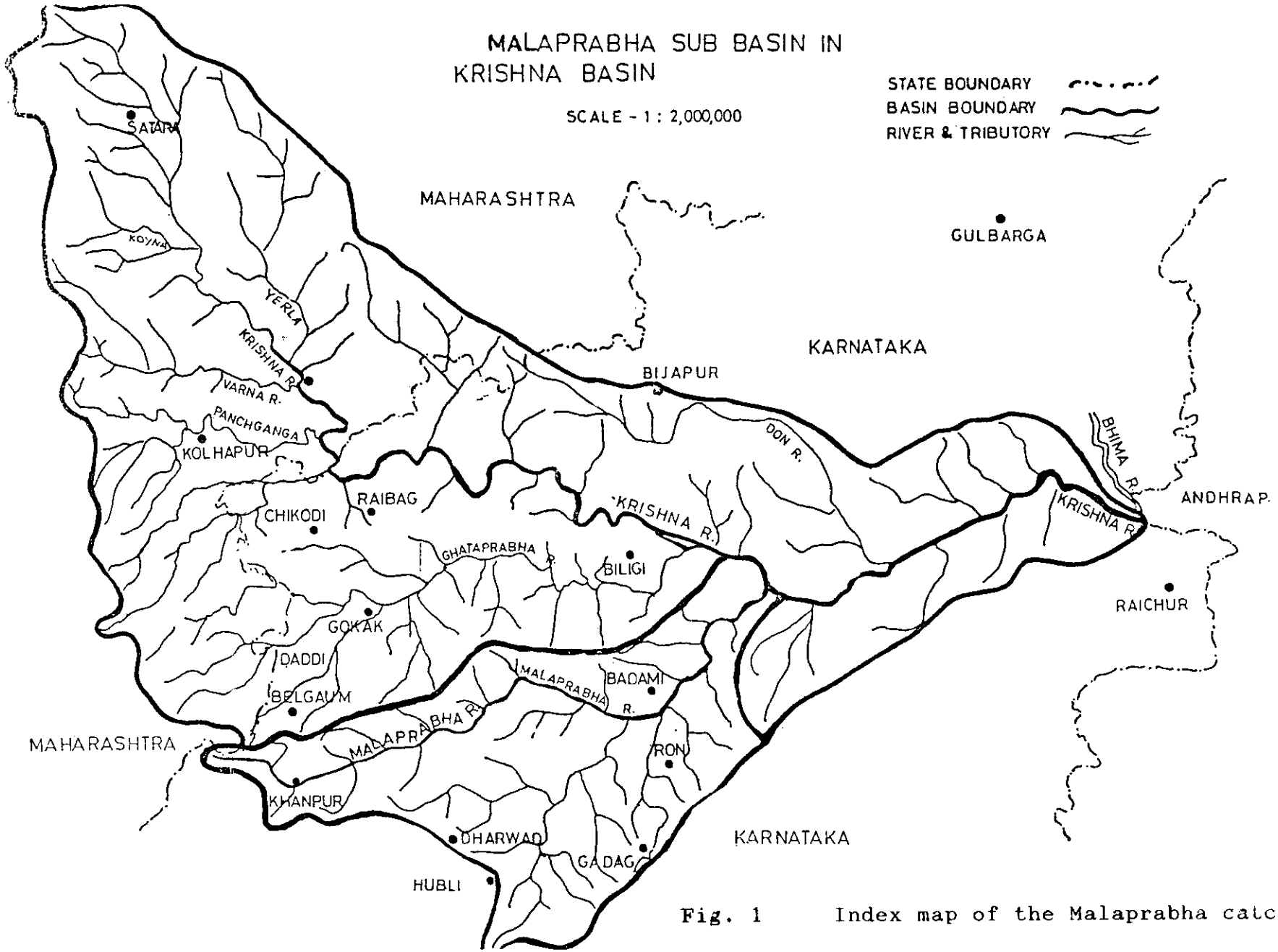


Fig. 1 Index map of the Malaprabha catchment

between the Malaprabha and the Ghataprabha rivers. The eastern boundary is the common bridge between the Malaprabha, the Krishna and the Tungabhadra rivers. The southern and western boundaries are the common ridge between the Malaprabha and the west flowing rivers. The important rock formations in the sub-basin are (i) sedimentary rock formations (Kaladgi group) comprising limestone, shale and quartzites (ii) Schistose rock formations (Dharwad super group) comprising granite, gneiss and crystalline rocks.

(a) Climate

There are three seasons prevailing in the catchment, the summer from March to April, the monsoon from May to November and the winter from December to February.

(b) Rainfall:

The Malaprabha catchment mainly experiences the south-west-monsoon. The rainfall in the nonmonsoon period is insignificant. The average annual rainfall of the catchment for the periods from 1901-02 to 1930-31, 1931-32 to 1948-49 and 1949-50 to 1984-85 were 718 mm, 775 mm and 815 mm respectively. Details are given in Annexure (a). From the data on monthly rainfall of different stations and the catchment, the monsoon period has been considered to be from May to November for the purpose of the hydrological study of the catchment.

(c) Temperature

The climate of the catchment is generally dry except in the monsoon months. Monthly normal and minimum temperatures in the catchment for Belgaum and Khanapur are given in Annexure (b).

Evaporation is governed by temperature, relative humidity, atmospheric pressure and wind velocity. It influences transpiration from plants and loss of water from reservoirs, water conveyance systems and loss of moisture in the upper layer of soil.

Humidity

The mean relative humidity is high during the south-west monsoon season and compartively low during the non-monsoon period. In summer, the weather is dry and the humidity is low. Data on monthly mean relative humidities in respect of the Belgaum and Khanapur are given in Annexure (c).

(e) Wind speed

The catchment is influenced by the south-west or west during the monsoon season. In the non-monsoon season winds from north-east and south-east are common. Data on monthly average wind speed for the two observatories are given in Annexure (d).

(f) Cloud Cover

The sky is heavily clouded during the south-west monsoon. During the remaining part of the year, clear or lightly clouded sky prevails. Data on cloud amount and percentage of sunshine are given in Annexures (e).

(g) Sunshine

The sunshine percentage in the catchment varies from 96-21. Details of sunshine percentage are given in Annexure (f).

(h) Evapotranspiration

Monthly average evapotranspiration (Etp) data computed by the IMD publication, potential evapotranspiration (PE) over India (Scientific report no.136) for the stations Khanapur and Belgaum are given in Annexure (g).

3.1.2 LAND USE PATTERN

The annual land use pattern followed in the Malaprabha and Ghataprabha catchment as per the information prvided by the statistical department of Karnataka state for the year 1984-1985 and 1980-1981 respectively are given below.

Category	Area (sq. km.)	
	Malaprabha	Ghataprabha
1. Forests	1304	1109
2. Barren land	306	348
3. Land put to non-agriculture use	412	350
4 Permanent pastures	1471	206
5. Miscellaneous crops	22	22
6. Culturable waste	60	243
7. Other fallows	74	157
8. Current fallows	594	773
9. Net area sown	863	5621
10. Area sown more than once	1107	174
11. Gross area sown	9737	5794
12. Geographical area	11549	8029

3.1.3 Soils

Types of soils :

Introduction of irrigation in an area must be preceeded by detailed field and laboratory investigations aimed at the classification of soils of the area for crop husbandry and to assess their suitability for irrigation. Detailed soil survey of the entire catchment has not been done so far. From the data contained in the various publications of the State Agriculture

Department, the soils in the catchment can be broadly divided into five groups.Table-3.1.3 below given percentage-wise break up of the five soil groups in the catchment.

Table - 3.1.3

Soil-wise break up of the catchment of the Malaprabha

Soil group	Percentage to the area of the catchment.
Medium black soils	12.0
Deep black soils	29.0
Mixed red and black soils	35.0
Red sandy soils	20.0
Red loany soils	4.0

(a) Medium black soils:

These soils usually occur in the Deccan trap, schist, lime-stone and shale regions of the catchment, occupying areas in parts of Belgaum, Bailhongal, Bagalkot, Gadag, Ron and Navalgund taluks. The medium black soils are also found to some extent on the peninsular gneiss areas. These soils are moderately deep to (23-90 cm), dark to very dark greyish brown, dark reddish brown or black in colour, usually calcareous, cracking and clayey. At places, on flat hill tops in the Deccan trap regions, under well drained conditions, the soils are non-calcareous. The texture of the surface horizon is usually clayey. These soils usually occur on very gently sloping mid lands. They are highly retentive, neutral to alkaline in reaction and are well supplied with bases. The contain high percentage of clay with clay fraction dominated by montomorillonitic type of clay mineral. These are moderately well drained with slow permeability. At places, lime concretions are found scattered on the surface as well as in the sub-surface horizons; powdery lime pockets are also seen in the sub-surface horizons, These soils are classified under the order : inceptisols and vertisols with sub-orders: ochrepts and usterts. These soils are fertile and produce good yields, when moisture is not limiting factor. These soils are moderately susceptible to erosion. The crops grown in these soils under rainfed conditions are: jowar,wheat, millets,cotton,sun flower, tobacco, groundnut, linseed, chillies, gram and other pulses.

(b) Deep black soils

These soils occur on gently sloping to nearly level lands of Deccan trap and lime stone regions in parts of Bagalkot, Hungunhd, Badami, Kundgol, Hubli and Shiggaon taluks. Deep black soils are also found occuring on a variety of (geological) parent materials like gneisses, schists, sedimentary rocks of mixed

origin including transported soils occuring in the basin of major river valleys and depressions. These soils are very deep (more than 100 cm). dark brown, dark greyish brown to very dary grey or black in colour. The texture is usually clayey throughout the profile. At places, on surface, clay loam to silty clay texture is also common. These are calcareous and weakly to strongly alkaline in reaction highly cracking montmorilonitic clayey soils. These are highly retentive and fertile and are moderately well drained to imperfectly drained with slow to very slow permeability. At places, lime concretions are found on surface and in the sub-surface horizons. Powdery lime pockets, gypsum crystals, yellowish to brown mottlings are also seen in the sub-surface horizons at places. These soils are fertile and generally produce good yields when moisture is not a limiting factor. These soils generally being in the low lying areas, retain run-off water from plands and are in a better position to support plant growth under rainfed and irrigated conditions are same as for the medium black soils given earlier.

(c) **Mixed soils:**

Mixed soils usually occur on gently undulating plain or comples geological materials gneisses, Dharwar schists and sedimentary rock formations and occupy areas in parts of Ramdurg, Bailhongal, Saundatti, Dharwad, Badami and Hungund taluks in the catchment. The red and black soils are found in association with each other in this area. Usually the red soils resemble the red sandy soils of midland region and the black soils resemble the medium and deep black soils such as saline, alkline and water logged areas are also seen at places. These soils are classified under orders: alfisols, vertisols and entisols with sub-orders: ustalfs, usterts and orbhents. Both the soils are productive when moisture is not a limiting factor. These soils are moderately susceptible to erosion and crops usually suffer due to lack of moisture during the growing period in the absence of irrigation facilities. The red soils are comparatively of crops grown under rainfed conditioolns are : jowar, cotton, groundnutt, chillies, wheat and pulses. The crops grown under irrigation are cotton, pulses, paddy, sugarcane, maize wheat and tobacco.

(d) **Red sandy soils :**

These soils occur on undulating lands on acidic rocks viz.,granites and granite gneisses occupying areas in parts of Dharwad, Hubli, Nargund, Navalgund, Ron, Kushtagi, Shighgaon and Yelburga taluks. Major areas fall under the dry agroclimatic region. These soils are deep to very deep, reddish brown to dark reddish brown, loamy sand to sandy loam or sandy clay loam on the surface with sandy clay to gravelly clay in the sub-surface horizon with well developed argillic (clay ridch) horizon. They are neutral to acidic in reaction and low to medium in cation exchange capacity and base saturation with medium to high water holding capacity. The clay complex is dominated by kaolinitic and hydrous oxides of iron and alumina minerals. The soils are welldrained with moderate permeability. They respond well to irrigation, manuring and other water & land management practices.

The yields obtained on these lands are generally good when moisture is not a limiting factor. The crops grown in these soils under rainfed cultivation are : jowar, castor, groundnut, pulses and oilseeds. Under irrigation, crops like paddy, sugarcane, potatoes, vegetables, chillies & plantains are grown.

(e) Red loamy soils:

These soils occur on hilly to undulating land on granites, granitic gneisses and Dharwar schists, occupying areas as long strip along the western ghats in the transitional tract comprising the western ghats of Belgaum, Khanapur taluks in the dry agro climatic region. These soils are very deep, dark brown to dark red, sandy loam to clay loam on the surface and loam to clay loam and at places gravelly sandy clay in the sub-surface horizon, with distinct argilic (clay rich) horizon. They are neutral to weakly acidic in reaction, low in cation exchange capacity and medium to high in water holding capacity. The clay complex is dominated by kaolinitic and hydrous oxides of iron and alumina minerals., The soils are wel drained with moderate permeabiulity. They respond well to irrigation manuring and other water & land management practices. These soils are classified under the order Alfisole and Ultisols with sub-orders of Ustalfs, Udalfts, Ustults and Udults. Crops like wheat, jowar, millets, groundnut and pulses are grown under rainfed cultivation. Under irrigation, crops like paddy, sugarcazne, chillies, sweet potatoes, vegetables & plantains are grown.

3.1.4 Drainage characteristics:

Catchment or drainage area is the most important property. It determines the potential run-off volume, provided the storm covers the whole area. The catchment divide is the loci of points delimiting two adjacent catchments, i.e. the collection of high points separating catchments draining into different outlets. Due to the effect of sub-surface flow, the hydrlogic catchment divide may not strictly coincide with the topographic catchment divide.The hydrlogic divide is less tractable than the topographic divide, (Ponce 1989). This parameter is very useful as it directly affects the flood hydrograph and the magnitude of flod peaks in mountainous areas. The larger the area,the greater the amount of syrface run-offand, consequently , the greater the surface flows. The drainage area of the Malaprabha catchment upto Khanapur is 540 sq.km.

(b) Drainage density is defined as the ratio of the total length of channels of all orders in a basin to the area of the basin. Drainage density is a textural measure of a basin which is generally independent of basin size. It is considered to be a function of climate, lithology, and stage of development. Numerically this ratio expresses the number of kilometers of channel maintained by a square kilometer of drainage area. The drainage density for the catchment is 0.0896 sq.km.

(c) Constant of channel maintenance :

Constant of channel maintenance is defined as the ratio between the area of a drainage basin and the total length of all the channelsexpressed in square feet/foot or square meter/meter. It is virtually the reciprocal of drainage density. The importance of this constant is that it provides a quantitative expression of the limiting area required for the developmental of a length of the channel. The constant of channel maintenance is 11.16 sq.km/km.

(d) Channel segment frequency

Channel segment frequency or stream frequency is defined as the number of streams/unit area in a drinage basin provided a more adequate characterization of a stream, than did drainage pattern. Its composition was completely described using the two textural measures of drainage density and stream frequency. The channel segment frequency of the catchment is 1.93/ sq.km.

(e) Circularity Ratio:

This is defined as the ratio of the basin area to the area of a circle having a circumference equal to the perimeter of the basin. The value of this ratio becomes unity as the shape of the drainage basin near to a circle. The above ratio for the Malaprabha catchment is 0.2914.

(f) Elongation ratio:

Elongation ratio of a basin is defined as the ratio between the diameter of a circle with the same area as the basin andbasin length. The value of the elongation ratio tends to unity as the shape of the drainage basin becomes a circle, (the value is 0.77).

(g) Watershed Shape Factor

Watershed shape factor is defined as the ratio of the main stream length to the diameter of a circle having the same area as the watershed. This is 1.85.

(h) Unity shape factor :

This is defined as the ratio of the basin length to the square root of the basin area. This is calculated as 1.46.

The above mentioned drainage characteristics are important for the analysis of the basin shapes. In addition to this relief aspects also plays a major role in drainage analysis. Relief aspect includes the following parameters.

(a) Basin relief
(b) Relief ratio
(c) Relative relief

(d) Ruggedness number
(e) Nash's measure of slope

Relief is the elevation difference between the reference points. Maximum catchment relief is the elevation difference between the highest point in the catchment divide and the catchment outlet. The principal water course is the central and largest water course of the catchment and the one conveying the run-off to the outlet. Relief ratio is the ratio of maximum catchment relief to the catchments longest horizontal straight distance measured in a direction parallel to that of the principal water course. The relief ratio is a measure of the intensity of the erosional processes active in the catchment. Relative relief, is the ratio of the basin relief expressed in units of miles to the basin perimeter. In general, it indicates the general steepness of a basin from summit to outlet. Ruggedness of a basin is a multiple of drainage density and relief. Nash (1960) defined measure of slope where the profile of the main channel having been plotted from the gauging site to the catchment boundary, a straight line was drawn through the gauging station and the vertical through the highest point of the main channel. further the slope of the line being so chosen that the area of the triangle was equal to the area contained below the channel profile. Slope and contour map of Malaprabha catchment areshown in fig. 2 & 3 respectively. Details regarding drainage characteristics of both the catchments are given by Vijayakumar, (1990).

3.2 DESCRIPTION OF GHATAPRABHA CATCHMENT

The Ghataprabha river is one of the southern tributaries of the river Krishna. The catchment area of the sub-basin lies between latitude 15 45' and 16 25' and longitude 74 and 75 55. The Ghataprabha river rises from the western ghats at an altitude of 884m, flows eastwards for a length of 283 km before joining the Krishna at Kudalisangam about 35 km north-east of Kaladgi at an elevation of 500m. The river flows for about 60 km in the Ratnagiri and Kolhapur districts of Maharashtra before entering the Belgaum district of Karnataka. It enters Karnataka and flows for about 283 km covering parts of Belgaum and Bijapur districts and joins the Krishna at Kudalisangam at an elevation of 500m, about 16 km from Almatti. Its principal tributaries are the Tampraparni, the Hiranyakeshi and the Markandeya,

The Tamraparni rising in Maharashtra flows in Maharashtra for 26 km and after a run of another 26 km in village in sindhudurg district of Maharashtra flows in Maharashtra for 63 km, forms the boundary between Maharashtra and Karnataazka for 6 km and after a run of 19 km in Karnataka, joins the Ghataprabha on the left bank. The Markandeya rising in Mahrashtra flows in Maharashtra 8 km and after a run of 66 km in Karnataka, joins the Ghataprabha on the right bank.

A dam is constructed at Hidkal in Hukkeri taluk to impound 2202 MCM water running two canals on either bank and coupled with weirs and lift irrigation schemes on the foreshores.

Fig. 2 Slope map of the Malaprabha catchment

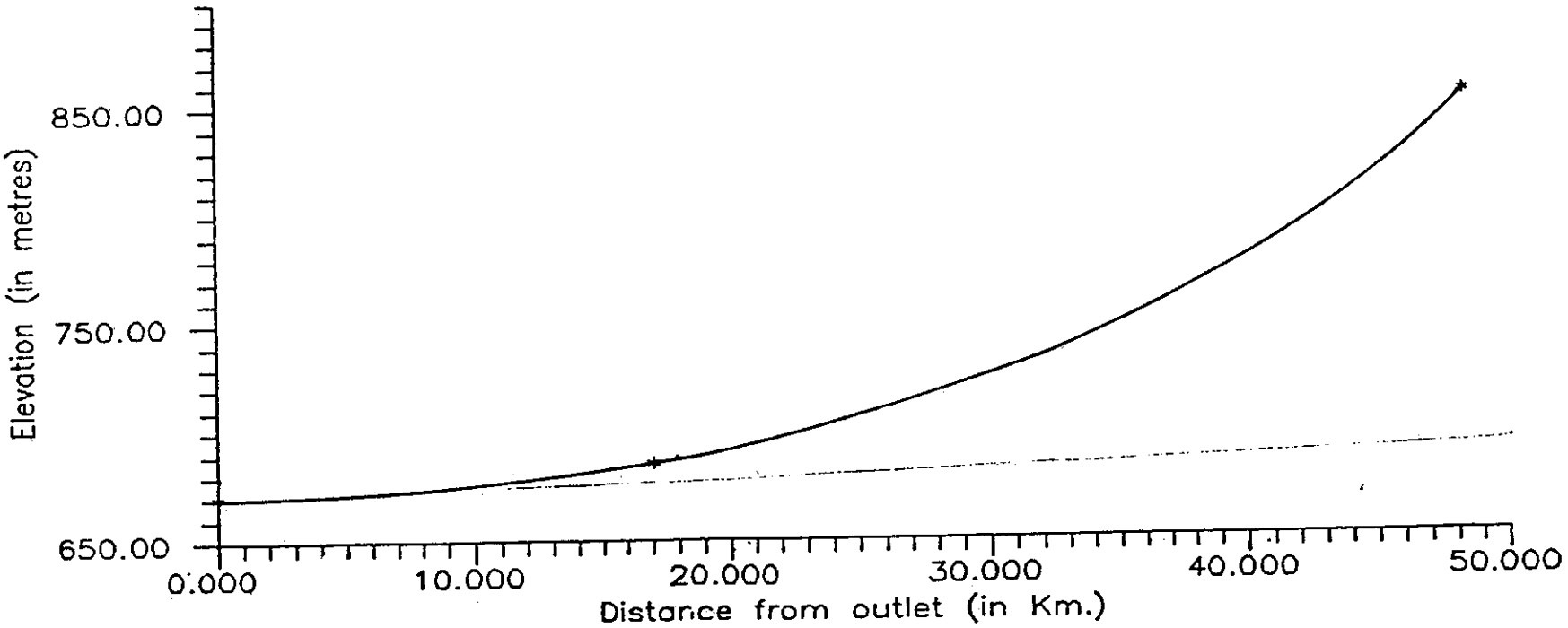
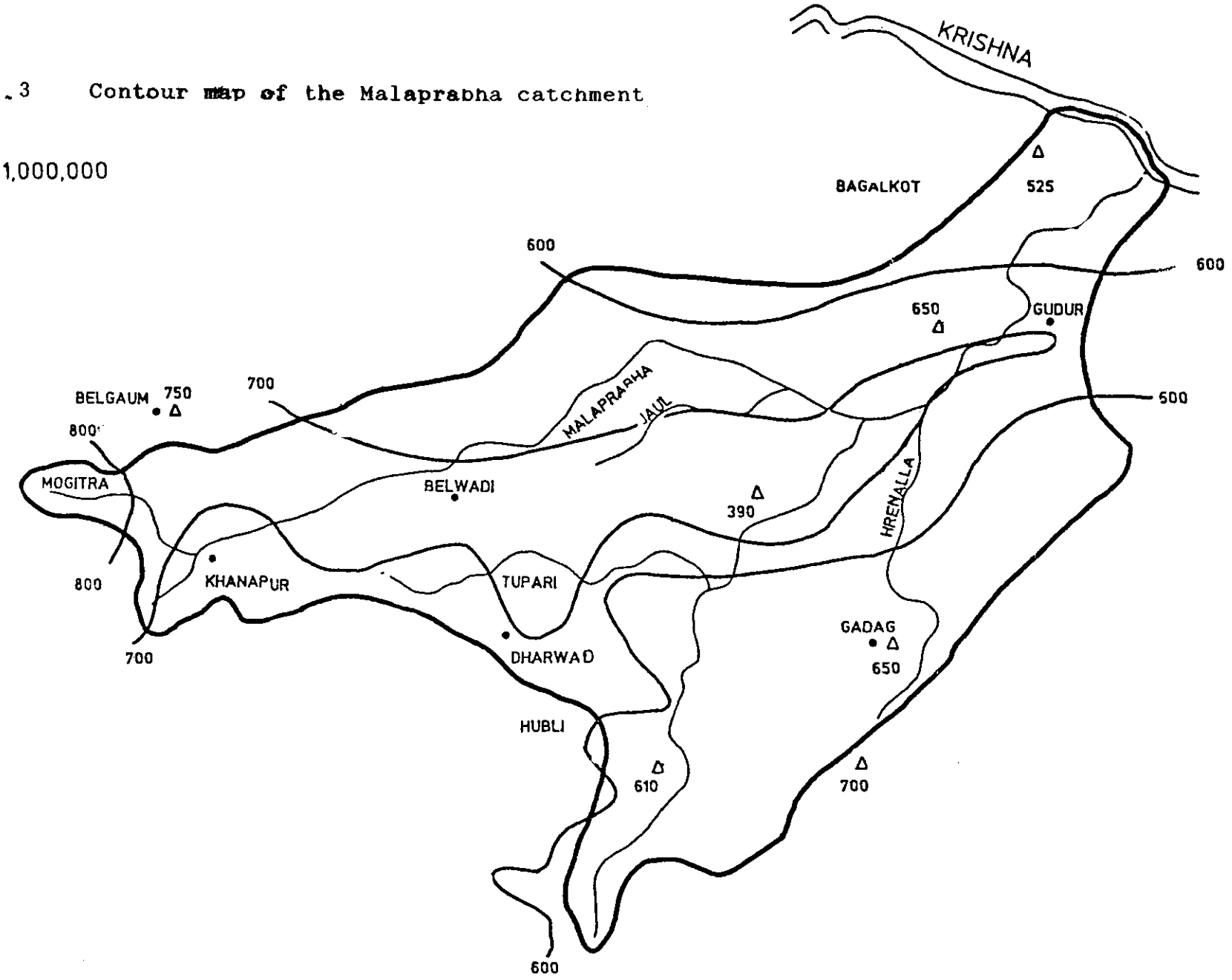


Fig. 3 Contour map of the Malaprabha catchment

SCALE = 1 : 1,000,000



The state-wise and district-wise break up of the catchment area is given in Table-3.2 . The Ghataprabha sub-basin is shown in figure 4.

Table 3.2

State/District	Total geographical area of the district Km^2	Area lying within the sub-basin Km^2	Percentage to the total area of the sub-basin
Karnataka			
Belgaum	13464	4630	52.4
Bijapur	17124	2189	24.8
Sub-total		6819	77.2
Maharashtra			
Kolhapur	8175	1894	21.5
Sindhudurg	5040	116	1.3
Sub-total		2010	22.8
Grand total		8829	100.0

3.2.1 Physiography, geology,hydrogeology and meteorology

Most of the catchment area is flat to gently undulating except for isolated hillocks and valleys. The sub-basin is approximately triangular in shape. The northern boundary of the catchment is the common ridge between the Krishna and the Ghataprabha rivers. The southern boundary is the common bridge between the Ghataprabha and the Malaprabha rivers and runs through Belgaum, Bailhongal, Saundatti, Ramdurg, Badami and Bagalkot taluks upto the confluence of Ghataprabha with the Krishna.

The geological formations met within the sub-basin are i) Deccan trap of tertiary age, ii) Sedimentary formations known as "Kaladagi group" comprising lime stone, shale and quartzities, iii) Schists, gneiss and other crystallising rocks and (iv) Laterite rocks. The types of soils generated from the formations are mostly permeable. The surface is covered with moorum and as such, run-off is moderate in the catchment.

Hydrogeological studies have been carried out by the Central Ground Water Board and the State Ground Water Department in the sub-basin. The studies reveal that in all the geological formations viz., the Dharwar schists, peninsular gneisses, quartzites and alluvial deposits, ground water occurs in the sub-basin. The occurence and movement of groundwater in these rocks is controlled by the nature and extent of weathering and the presence of joints and fractures in them. The sub-soil water

Fig. 4 Index map of the Ghataprabha catchment

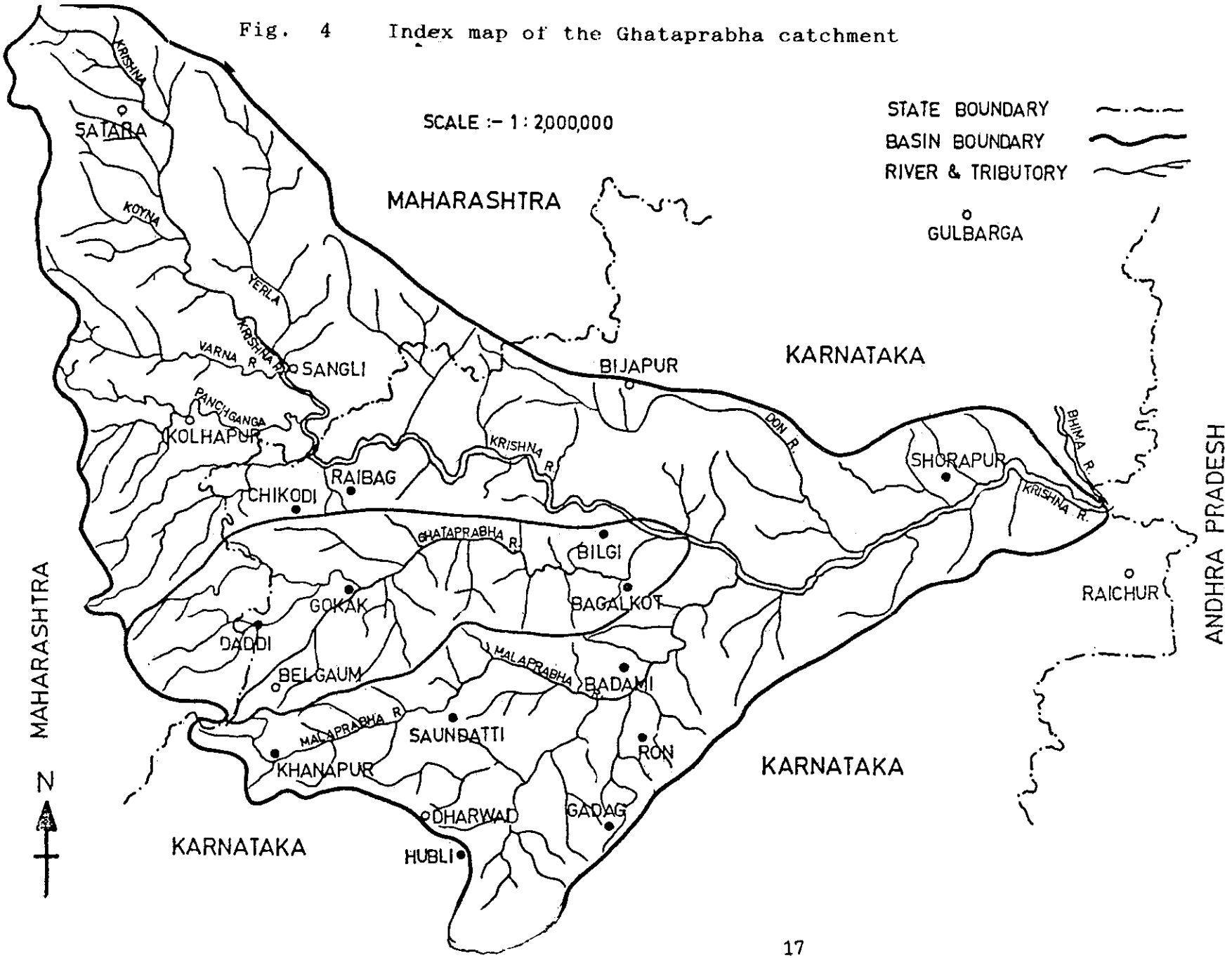


table generally does not exceed 9 m below ground water level under normal conditions. The ground water development in the sub-basin is from open wells and dug-cum-borewells.

(a) Climate

The climate of the catchment is marked by a hot summer and a mild winter. The monsoon sets early in June and continues to the end of October. The winter is from November to mid-February and the summer is from mid-February to end of May. December and April are the coldest and the hottest months respectively.

(b) Rainfall

There are 8 raingauge stations in the catchment and 3 raingauge stations outside and in close vicinity of the catchment. Data of all these stations are available for the period from 1901-02 to 1983-84.

(c) Temperature

The summer season on the whole is milder in the western parts of Belgaum, Chandgarh, Gadhinglaj and Ajra and more severe in the other parts of the catchment. On certain days during the summer season, the day temperature ocasionally rises upto 41 C. April is generally the hottest month with mean daily maximum and minimum temperatures of 35.7 C and 19.5 C. With the onset of monsoons in early June, there is an appreciable drop in the day temperature, but the nights continue to be warm. December is generally the coldest month with the mean daily maximum and minimum temperature being 29.3 C and 13.9 C respectively.

There is one IMD and one NIH observatory located in the catchment at Belgaum and Halkalrni. The normal temperature data at Belgaum for the period from 1931 to 1960 and Halkarni 198 to 1991 are given in Annexure-(c).

(d) Relative Humidity

The relative humidity is high during the south west monsoon and low during the non-monsoon period. In summer the weather is dry and humidity is low. The average monthly relative humidity values at Belgaum observatory are given in Annexure (d).

(e) Wind Velocity

Wind velocities are generally low with some increase during the late summer and in the monsoons. From April to September, wind blows mainly from the south-west and west. In October, it is from the directions between north and east but on some days from south-west or west. During November and December wind is mostly north-easterly or easterly. South-westerly and westerly appear in January and from February onwards the easterlies decrease in frequency and by April the afternoon wind blows predominantly from the west and south-west. The average

monthly wind speed data at Belgaum and Halkarni observatory are given in Annexure (e).

(f) Cloud Cover

During the south-west monsoon, the sky is heavily clouded. Cloud cover decreases in the post monsoon period and from December to February, the sky is generally clear or lightly clouded. Cloud cover increases from April onwards. Average monthly meas cloud cover values at Belgaum and Halkarni observatory are furnished in Annexure (f).

(g) Sunshine

The sunshine percentage in the catchment varies from 21 to 96. Details of subshine percentage at Belgaum and Halkarni observatory are given in Annexure (g).

(h) Evapotranspiration

Monthly normal Evapotranspiration (ETO) data was taken from the IMD publication "Potential Evapotranspiration (PE) over India (scientific report No.136-Feb.1971)" for Belgaum and Halkarni observatorty are given in Annexure (h).

3.2.2 SOILS AND LAND USE

Types of soils

Detailed soil survey of the catchment has not been done so far. From the publications of the State Agricultural Department and the soil maps, the soils in the catchment can be broadly divided into five groups. Table 3.2.2 below. given the percentage-wise break up of the soil groups in the catchment.

Table - 3.2.2

Type of Soil	Percentage of the area of each soil group to the catchment area.
Coarse shallow black soils	2.2
Medium black soils	38.0
Deep black soils	43.8
Mixed red and black soils	3.4
Lateritic soils	12.6
Total	100.0

The general characteristics of each of the above soils are described in the following paragraphs.

(a) Coarse shallow black soils

These soils are generally encountered on undulating ridges in the Deccan trap region and to some extent on the schist and lime-stone upland regions of Karnataka, occupying areas in north and north-west parts of the districts of Belgaum and Kolhapur in the catchment. These soils are shallow at depths less than 23 cm, dark greyiah brown, dark brown to dark reddish brown in colour and usually calcareous, with gravelly clay loam to clay in texture. Small patches of non-calcareous soils are encountered on flat hill top regions in the trap areas. These soils are neutral to weakly alkaline and have moderate to high water holding capacity with high cation exchange capacity. These soils are well drained and have moderate permeability. The dominant clay mineral is montmorillonitic. These soils are classified under the order entisols and inceptisols with sub-orders: Orthents and Ochrepts. These soils are severe to very severely susceptible to erosion. Several eroded soils, usually on the steeper slopes (exceeding 5 percent) are very shallow and are highly gravelly. At such places, boulders and rockout crops are common. Severely eroded very shallow skeletal (gravelly) soils are not suitable for cultivation. The crops grown under rainfed conditions are Jower, Bajra, Millet Pulses. However, the yields of drops are poor owing to shallow rooting depths and scanty rainfall.

(b) Medium black soils

These soils usually occout in the Deccan trap, schist, lime-stone and shale regions of the Karnataka State, occupying areas in parts of Belgaum, Hukkeri, Bailhongal, Mudhol and Bilgi taluks. The medium black soils are also found to some extent on the peninsular gneiss areas. These soils are moderately deep to deep (23-90 cm), dark to very dark, greyish brown, dark reddish brown or black in colour, usually calareous cracking and clayey. At places on flat hill tops in the Deccan trap regions under well drained conditions the soils are non-calcareous. The texture on the surface horizon is usually clayey. These soils usually occur on very gently sloping midlands. They are highly retentive, neutral to alkaline and are well supplied with bases. They contain high percentage of clay with clay fractiojn dominated by montmorillonitic type of mineral. These are moderately well drained with slow permeability. At places, lime concretions are found scattered on the surface as well as in the sub-surface horizons, powderly lime pockets are also seen in the sub-surface horizons. These soils are classified under the order inceptisols and vertisols with sub orders ochrepts and usterts. These soils are fertile and produce good yields, when moisture is not a limiting factor. These soils are moderately susceptible to erosion. Adequate soil and water conservation measures along with adoption of a package of practices is essential to obtain sustained high yields. Care should be taken when providing irrigation facilities to these soils. Since these soils contain high clay content with expanding type of clay mineral, with slow to very slow permeability indiscriminate use of water may lead to development of salinity and water logging problems. The crops

grown in these soils under rainfed conditons are jowar, wheat, millets, cotton, safflower, tobacco, singar, linseed, chillies, tur, gram and other pulses.

(c) Deep black soils

These soils occur on very gently sloping to nearly level or flat topography in the low lands of Deccan trap and lime stone regions, in parts of Hukkeri, Gokak, Ramdurg, Mudhol and Bagalkot taluks. Deep black soils are also found ocuring on a variety of (geological) parent materials like gneisses, schists, sedimentary rocks of mixed origin including transported soils occuring in the basins of major river valleys and depressions. These soils are very deep (more than 90 cm), dark brown, dark greyish brown to very dark grey or black in colour. The texture is usually clayey throughout the profile. At places on surface, clay loam to silty clay texture is also common. These are calcareous and are weakly to strongly alkaline, highly cracking montmorillonitic clayey soils. These are highly retentive and fertile and are moderately well drained to imperfectly drained with slow to very slow permeability. At places lime concretions are found on surface and in the sub-surface horizons. Powderly lime pockets, gypsum crystals, yellowish to brown mottlings are also seen in the sub-surface horizons to places. These soils are classified under the order vertisols with sub-order usterts. These soils are fertile and generally produce good yields, when moisture is not a limiting factor. These soils generally being in the low lying areas, retain run--off water from upland and are in a better position to support plant growth under rainfed conditions. These soils are slightly to moderately susceptible to errosion. Adequate soil and water conservation measures, appropriate provision of drainage facilities specially in the low lands and adoption of recommended package of practices are essential to obtain sustained high yields under rainfed cultivation. Utmost care is essential for providing irrigation to these soils as most of these soils occur on nearly level to flat topography with high content of swelling type of clay, with slow to very slow permeability. Indiscriminate use of water on these soils will damage the soil structure and may lead to salinity and water logging problems. The crops grown under rainfed and irrigated conditions are same as for the medium black soils given earlier.

(d) Mixed red and black soils

These soils usually occur on gently undulating plain or complex geological material comprising gneisses dharwar schists and sedimentary rock formations and occupy areas in parts of Ramdurg and Bailhongal taluks in the sub-basin. The red and black soils are found in association with each other in this area. Usually the red soils resemble the red sandy soils of midland region and the black soils resemble the medium and deep black soils in physico-chemical characteristics. Patches of problematic soils such saline, alkaline and water logged areas are also seen at places. These soils are classified under the orders: alfisols, vertisols and entisols with sub-orders:

ustalfs, usterts and orthents. Both the soils are productive, when moisture is not a limiting factor. These soils are moderately susceptible to errosion and crops usually suffer due to lack of moisture during the growing period. The red soils are comparatively of coarser texture and have moderate drainage and slow permeability. The crops grown under rainfed conditions are jowar, cotton, groundnut, chillies, wheat and pulses. The crops grown under irrigation are cotton, pulses, paddy sugarcane, maize, wheat and tobacco.

(e) Lateritic soils

These soils are found on undulating, rolling plain to gently sloping topography of the peninsular gneisses regions occupying areas in parts of Kolhapur district coming under the dry agro-climatic region. The laterites are usually formed under heavy rainfall and high temperature conditions, resulting in intensive weathering, leaching of bases and silica and accumulation of sesquioxides (iron and alumina). These soils are deep to very deep, yellowish red to dark red, reddish brown or brown, clay loam to gravelly sandy loam on the surface and clay laom to gravelly sandy or clay in the sub-surface horizon. They are acidic in reaction, low in cation exchange capacity, base saturation and water holding capacity. The clay fraction is dominated by Kaolinite type of clay mineral. These soils are well drained to excessively drained with moderate to moderately rapid permeability. They respond well to irrigation, manuring and other management practices. These soils are classified under the orders: orthents, ustults, udults, ustalfs, udalfs and ustox. The depth of these soils in the catchment varies from 15 cm to 100 cm. The crops grown in these soils under rainfed conditions are jowar, groundnut, pulses, safflower, linseed and other millets. Under irrigation the crops grown are paddy, sugarcane, chillies, wheat, turmeric and vegetables.

3.2.3 Drainage characteristics

(a) Drainage area : Drainage area of the Ghataprabha catchment upto Daddi is 1055.0 sq.km. Slope and contour of the catchment shown in figure 5 & 6 respectively.

(b) Drainage density (L/A) : 0.0602 Km./sq.km.

(c) Constant of channel maintenance (A / L) : 16.62 sq.km/km.

(d) Circularity Ratio : 0.5511

(e) Elongation Ratio : 0.7713

(f) Watershed shape factor : 1.7321

(g) Unit shape factor : 1.463

(h) Channel segment frequency : 1.69 / sq.km.

Fig. 5 Slope map of the Ghataprabha catchment

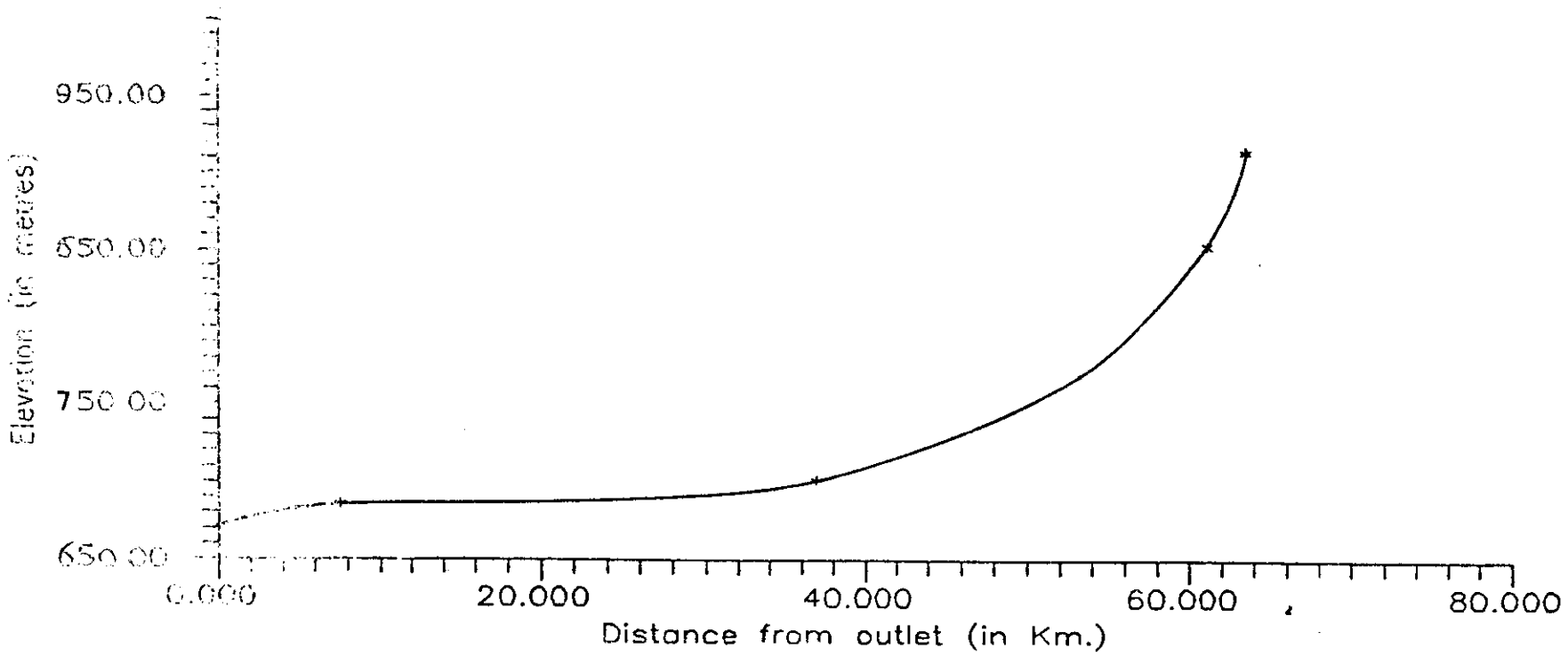
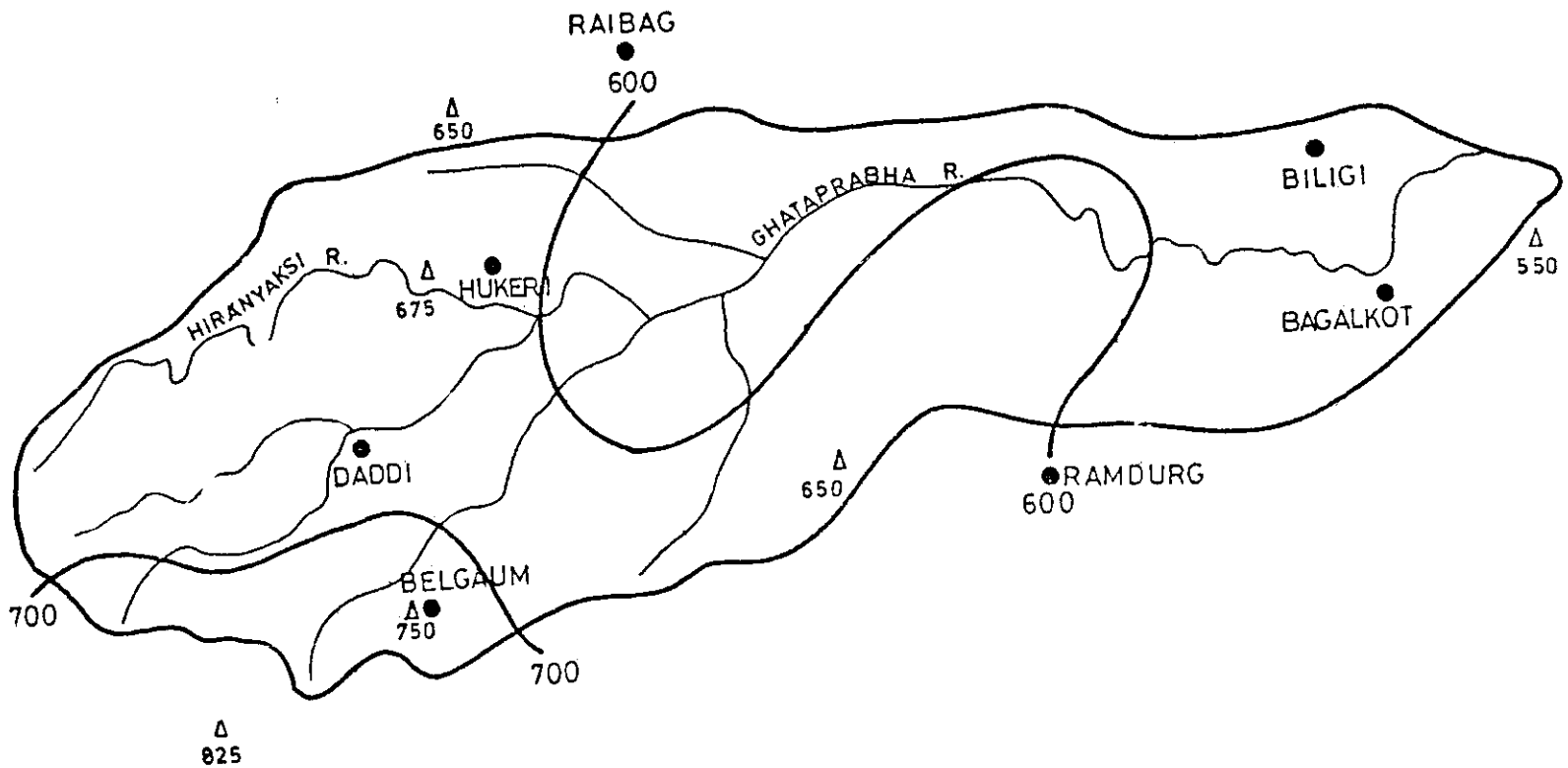


Fig 6 Contour map of the Ghataprabha catchment

SCALE – 1 : 1,000,000



4.0 METHODOLOGY

For the present study, IRS-1A-LISS-II images of 15 Oct 1989 were used.The imageries covering both the catchment falls in two scenes (P 28 R 56 & 57).False colour composite (FCC) at the scale of 1:250,000 has been visually interpreted to prepare land use and soil maps.The various categories of land use/cover and soils were delineated considering hydrological land use classification based on USGS classification (table 4.1). An interpretation key has been prepared based on tone, texture, pattern, shape and size (table 4.0). The information from toposheets and other available maps were used for obtaining ground truth informations. The classified image transferred on the base map in 1:250,000 scale. The area of various categories of land use and soil were determined by grid method.Thematic maps for the following themes have been prepared.

1. Soil maps indicating the soil type in the catchment area.
2. Land use maps showing existing land use pattern.

The surface and groundwater availability and water requirement for various crops have been computed considering five years data (1985-1989) collected from various state and central government agencies.Locations of ground water observation wells Malaprabha and Ghataprabha catchments are shown in the figure 7 & 8. Field data in respect of crop pattern,land use,groundwater and surface water draft etc were collected from the different places representing different parts of the catchment. The total available water resources for the year 1989 was calculated.

Table 4.0

Hydrologic Land use Classification Scheme

Level I		Level II	
1.	Agricultural land	1.1	Standing crop
		1.2	Fallow land
2.	Barren land	2.1	Sand dune like
		2.2	Riverine grass
3.	Riverine features	3.1	Dry river bed/ Ephemeral Stream
		3.2	Wet sand deposite
		3.3	Swamp/Marshy vegetation
4.	Water	4.1	Shallow water river/ canal
		4.2	Deep water in river/ Headwork pondage
		4.3	Vegry deep water in reservoir
5.	Forest	5.1	Decidous forest
		5.2	Evergreen Forest
		5.3	Shrubs
6.	Built-up Area		

Table 4.1

Key for interpretation

Category	Tone	Texture	Pattern	Shape	Size
Cropped land	Dark pink light pink	coarse smooth	regular irregular	regular	uniform
Cropped land	dark pink to light pink	coarse/ smooth	regular to irregular	regular	uniform
Fallow land	pinkish brown	smooth to medium	irregular	regular	uniform
Forest land	light to bright red	coarse	irregular	regular	uniform
Waste land	bluish grey for grasses and barren and pink for shrub.	smooth (bluish) medium (pink)	irregular	regular	varying
Lakes/pond	dark bluish to light bluish	smooth	irregular	irregular	varying
Rivers/ streams	dark bluish to light bluish	smooth	irregular	irregular	varying
Habitation	light blue	coarse	regular	irregular	varying

Fig. 7 Location of the observation wells in the Malaprabha catchment

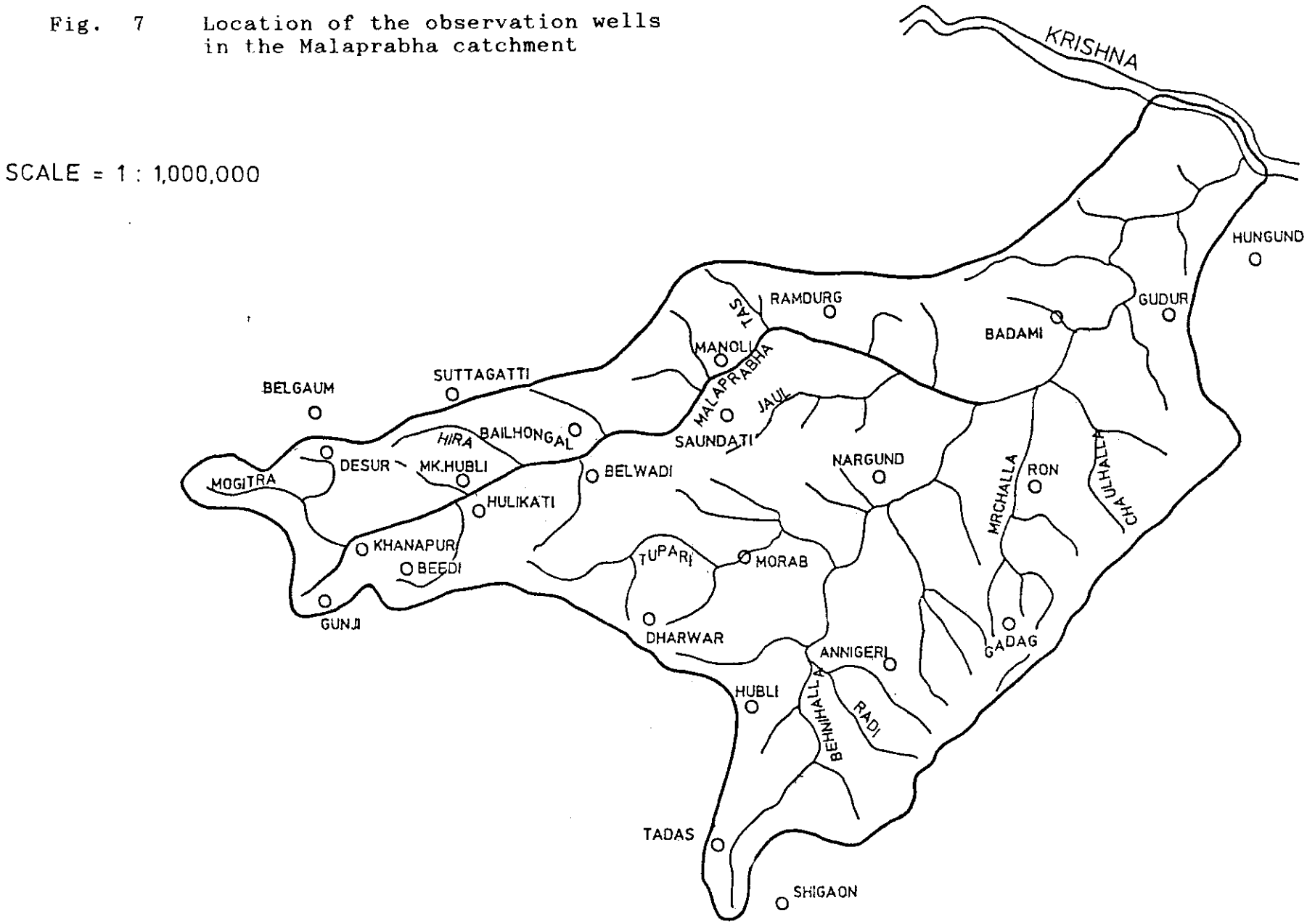
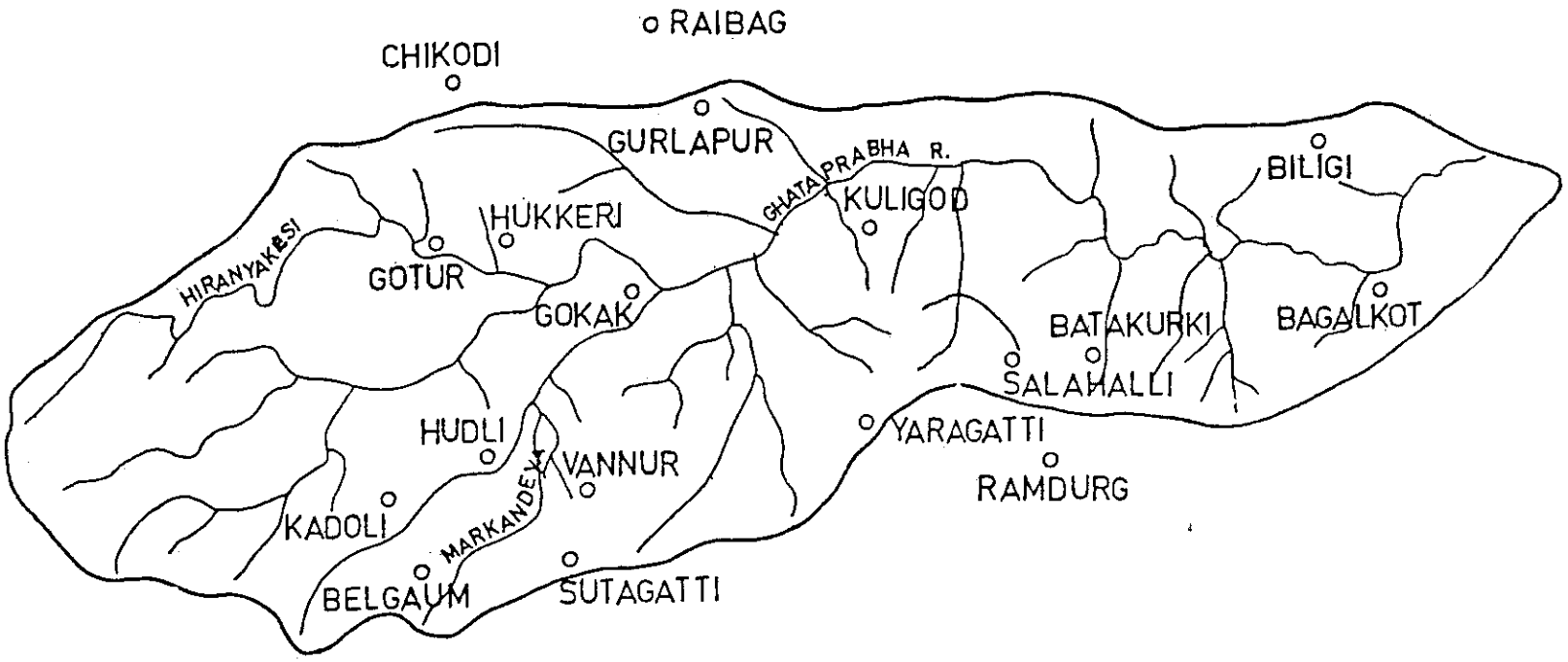


Fig. 8 Location of the observation wells in the Ghataprabha catchment

SCALE = 1:1,000,000



5.0 RESULTS AND DISCUSSIONS

5.1 MALAPRABHA CATCHMENT

Land use map has been prepared by using IRS-1A- LISS-II, FCC and shown in fig 9. This provides an efficient and timely data to map the current land use/ land cover, soil type distribution and pattern and also to monitor the changes over time. Unlike other areas, a good productive piece of land and availability of water are very precious and vital in a drought prone area, and as such, an optimal land use planning and environmental conservation of the best lands for the agriculture and marginal lands for fodder, plantations and horticultural development along with a sound water management policy is essential in all drought prone areas. The details are given in table 5.1.

5.1.1 Spatial distribution of land use

(a) Agriculture Land (Crop Land)

In general Agricultural land may be broadly defined as land used primarily for production of food and fiber. The category includes the following uses: crop land and pasture, orchards, groves and vineyards, nurseries and ornamental horticultural areas and confined feeding operations. Where farming activities are limited soil wetness, the exact boundary may be difficult to locate and agricultural land may grade into wetland.When wetland are drained for agricultural purposes, they are included in the agricultural land category. When such drainage enterprises fall into disuse and if wet land vegetation is re-established, the land reverts to wet land category.

In the IRS-1A-LISS-II data used for the Malaprabha catchment, the crop land includes all the standing crops during October, 1989, (represents, Kharif season). The crop lands are mostly confined to the valley fills of the rivers/streams, whereever the groundwater source is available. In the catchment most of the cultivated area is rainfed crops, such as paddy, ragi, Cotton and Sugarcane etc.

(b) Fallow

It has been noticed that considerable arable land under red soil remains fallow because red soil has little moisture retention capacity and as such the soil remains dry during most part of the year. More fallow lands can be brought under crop with increasing irrigation facilities. Large area (25.3 %) is under forests. Most of the notified forests have been degraded partly due to failure of rainfall for long time . Dograded and encroached forests can be used for horticulture crops and social forestry.

Fig. 9 Land use map of the Malaprabha catchment

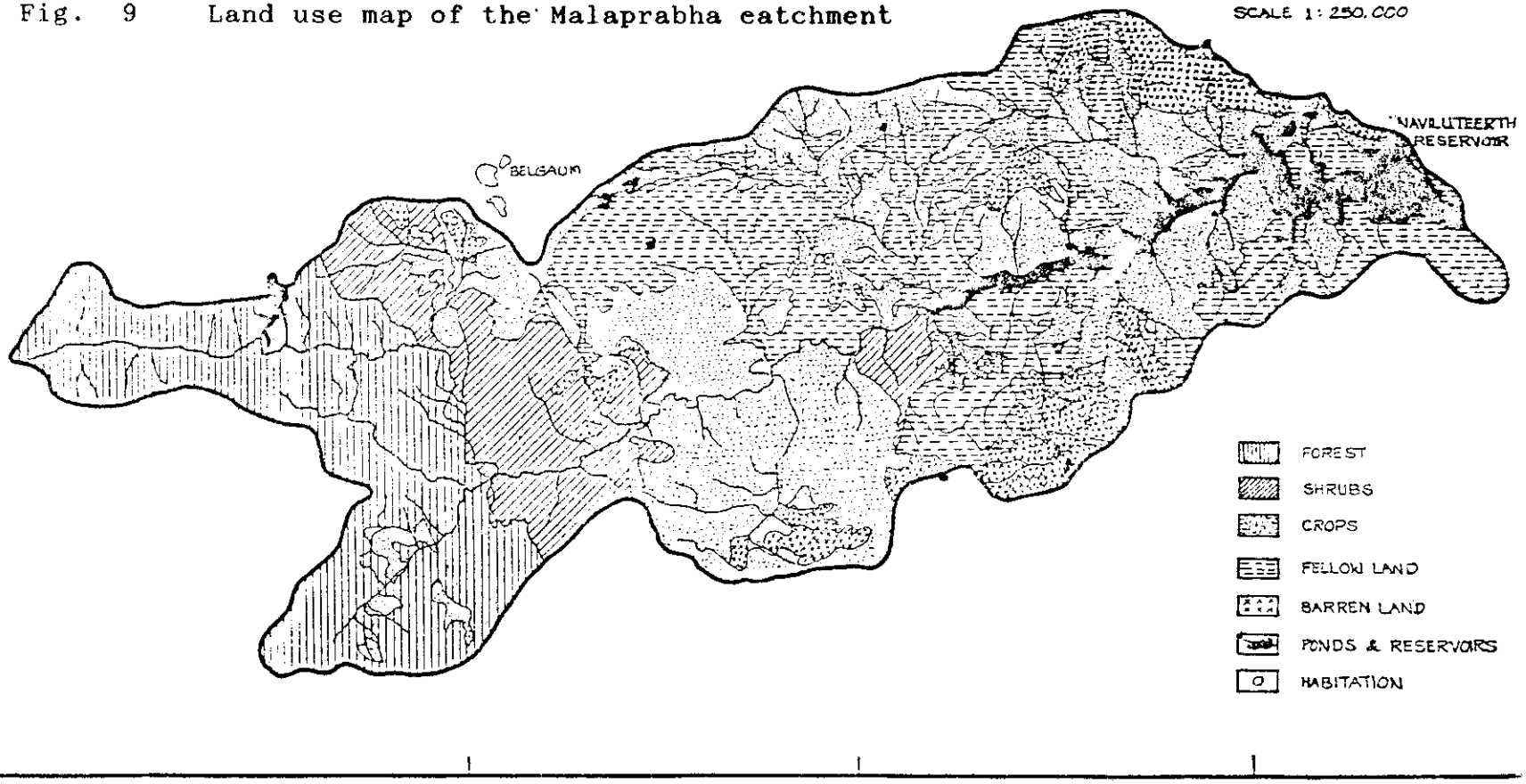


Table 5.1:LAND USE PATTERN FOR THE YEAR 1989, USING IRS-1A-LISS-II

TOTAL CATCHMENT AREA UPTO DAM SITE - 3300 Sq.Km

Category		Area (in sq.km.)	percentage with respect to total catchment area
1.	Forests	834.63	25.3
2.	Shrubs	346.43	10.5
3.	Waste land	258.13	7.8
4.	Cropped area	1091.75	33.08
5.	Fallow land	634.63	19.23
6.	Ponds and reservoir	130.85	3.97

(c) **Waste Land**

Thin soil cover at the surface with 2-8 percent slopes, often supports shrubs and grass. These areas may be brought under fodder and plantations after adopting soil conservation measures. Eucalyptus and subsabul, Cascarina and Sisam are the suitable species for these areas . Areas with 5 - 15 slope and shallow soil can be brought under pasture development.

5.1.2 Land capability classification

The important soil types found in the catchment,(fig10) are Red loamy soils (32.3 %) , medium black soils (37.02 %) , and mixed red and black soil (30.66 %).

(a) **Red Loamy Soils**

These soils are seen in the nearly level to gently sloping upper pediplains. They are moderately deep, dark brown to dark red , sandy loam to clay loam and at places gravel and sandy clay in the sub-surface horizon, with distinct argillitic horizon. Soils are medium textured and moderately well drained .These are found in the transitional tracts comprising the western parts of Belgaum and Khanapur taluks in the dry agro-climatic zones. These soils are classified under the order of Alfisols and Ultisols with sub-orders of ustalfs, ustalts and udults. Horticultural crops are recommended on these soils.

(b) **Medium Black Soils**

These soils occur in parts of Belgaum, Khanapur and Bailahongal taluks. Soils are moderately deep to deep, dark to very dark greyish brown, dark reddish brown or black in colour, usually calcreous cracking and clayey. These soils are classified under the order: inceptisols and Vertisols with sub-orders. Ochrepts and Usterts. These are moderately well drained with slow permeability.

(c) **Mixed Red and Black soils**

These soils generally found on gently undulating plain or complex geological materials and occupy areas in parts of Bailahongal and Soundatti taluks.These soils are classified under the order: alfisols, Vertisols and entisols with sub-order :ustalfs, usterts and orthents.

5.1.3 Cropping pattern

The cropping pattern in the catchmentis the basin and water required for each crop is shown in table 5.1.3. It is observed that Cotton and Jowar covers 23.63 % each , followed by paddy, pulses, groundnut, sugarcane and wheat. Field studies also revealed the same facts.

Fig. 10 Soil map of the Malaprabha catchment

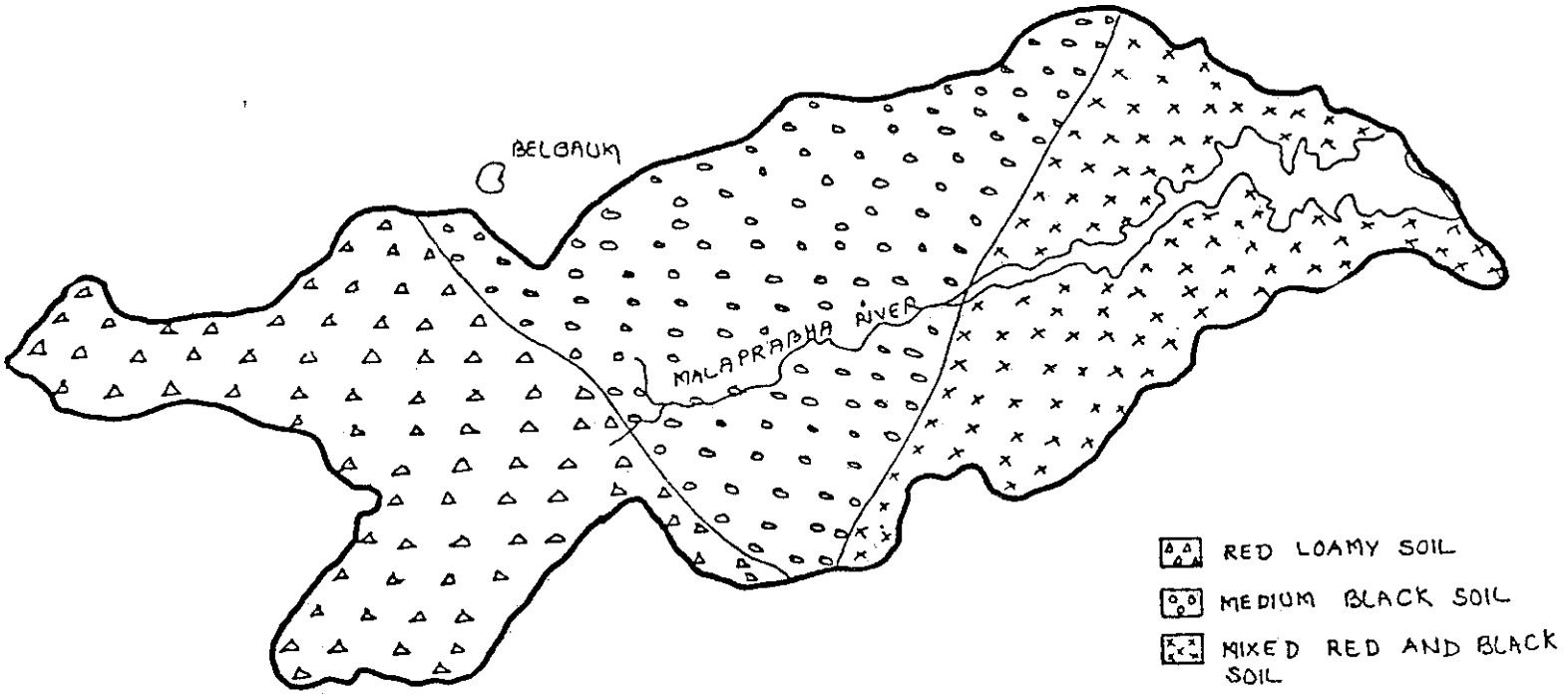


Table 5.1.3: Cropping pattern and water requirement for Malaprabha catchment

CROPS	Delta (metre)	% of Crops	Total water required
KHARIFF			
1. Paddy	1.36	13.7	205.0
2. Jowar	0.14	2.01	13.27
3. Cotton	0.39	23.63	101.30
4. Groundnut	0.10	1.9	8.78
RABI			
1. Wheat	0.4	6.28	27.63
2. Jowar	0.6	23.60	156.00
3. Pulses	0.28	11.0	33.89
4. Groundnut	0.42	9.10	42.04
PERENNIAL			
1. Sugar cane	1.49	8.78	144.87
		Total water required	732.78 MCM

5.1.4 Water Availability in the Catchment area.

The total surface and groundwater availability in the catchment area has been computed. The surface water potential of the region is 827.6 MCM and Groundwater available is 188.98 MCM. It is observed that major part of the water is used for the cultivation of paddy and sugarcane.

Based on present cropping pattern and the water requirement it can be suggested that the percentage of sugarcane can be reduced from 8.78 % to a minimum and can be grown in the upstream region where the tributaries hold water. The crops like groundnut and jowar which requires comparatively less water may be grown during the Rabi season. In the catchment area groundwater should be utilised properly and neceesary measures can be taken for the artificial recharge of groundwater in the upstream region.

5.2 GHATAPRABHA CATCHMENT

5.2.1 Spatial distribution of Land use

Land and water resources are intimately inter connected and exerts considerable influence in determining the various hydrologic phenomena like infiltration, overland flow, evaporation and interception etc. Furthermore land use and vegetal cover characteristics of a watershed (fig.11), has a significant influence on the quality and quantity of run-off available from it. Concised details of the land utilisatien pattern followed in the Ghataprabha catchment (upto dam site) which covers an area of 1434 sq.km is given in the table 5.2.1.

(a) Crop Land :

Agriculture land covers about 26.59 % of the total catchment. This includes cropping systems, horticulture, grazing and forestry. Generally, the type of land use is governed by social, socio-economic and characteristics of the soil. In the catchment most of the cultivated area is dependent wholely upon rainfall and restricted to the valley fills of the rivers and streams, where ever the ground water is available. In the catchment farmers grow mainly paddy, cotton, groundnut, maize and jowar.

(b) Fallow Land :

A total of 9.83 % of the catchment remains as fallow land. This is formed due to the lack of water supply either by rainfall or irrigation. It is also dependent upon the moisture retention capacity of the soil. Fallow lands can be brought under irrigation by providing small irrigation tanks or using ground water available in the region.

Fig. 11 Land use map of the Ghataprabha catchment

Table 5.2.1:

LAND USE PATTERN OF GHATAPRABHA CATCHMENT DURING THE YEAR 1989, USING IRS-1A-LISS-II DATA

TOTAL CATCHMENT AREA UPTO DAMSITE - 1434 Sq.km

Table 1

	Area sq.km	%
1. Forests	390.00	27.19
2. Barren Land	42.38	2.95
3. Shrubs	418.75	29.20
4. Cropped area	381.12	26.57
5. Fallow	141.00	9.83
6. Ponds & Reservoir	61.0	4.25

(c) Barren Land

Barren land is generally permanently unsuitable for productive use. These regions usually have a thin soil cover with 2-8 % slopes and supports shrubs and grasses. These areas may be brought under fodder and plantations after adopting soil conservation measures. Areas with 5-15 % slope and shallow soil can be brought under pasture development. The removal of sand, gravel, and stones covering good agricultural land is another case where land could be returned to production. Special attention should be paid to the healing process of barren land by revegetation through seeding, planting and sodding. Complete protection of the land is absolutely essential.

(d) Shrubs (Pasture and grazing land)

This class of land is generally used intensively through establishment of reseeded and high yielding pastures. Its most important features are relatively shallow soils with less than 30 % gravels and slopes not exceeding 25-30 % The important treatment for such sort of land is good land preparation (including the application of fertilisers and lime if needed) and reseeding with locally adapted mixtures of palatable and nutritious grasses, legumes and herbs.

(e) Forests :

The forest cover of the catchment is 27.19 %. The wet deciduous forests occur in the west zone of the Belgaum district and in the Kolhapur and Sindhudurg districts. The dry tropical thorn forests occur in parts of Belgaum district. The main species in the forests are teak, Rose wood, Jack wood, bamboo and fruit bearing trees. The famous sandal wood trees are found inparts of the Ajra taluk of the Kolhapur districts. Most of the notified forests have been degraded partly due to irregular rainfall and climatic aberrations. Degraded and encroached forests can be used for horticultural crops and social forestry.

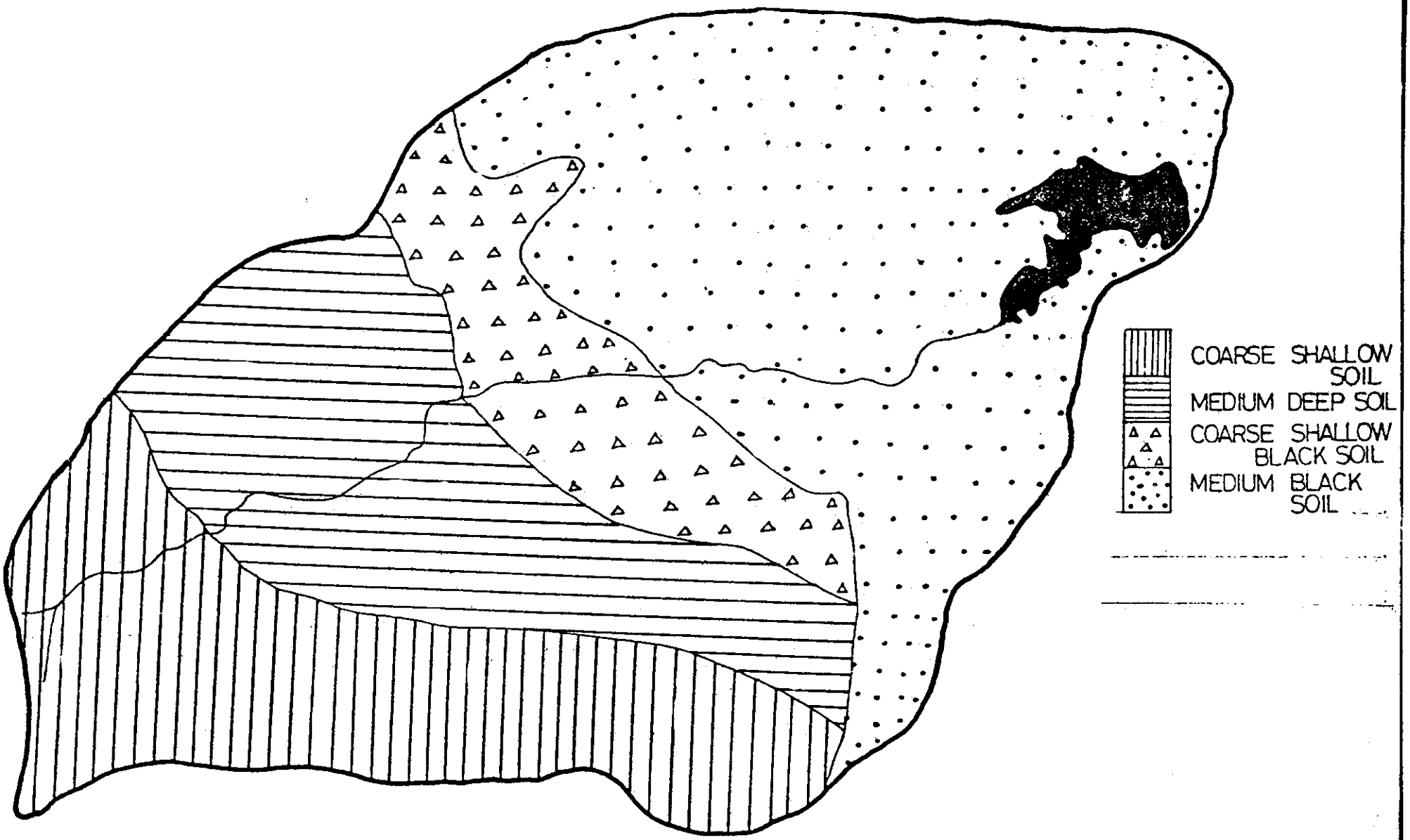
5.2.2 Land Capability Classification

The land capability classification is an interpretative grouping of soils mainly based on the (i) inherent soil characteristics, (ii) external land features and (iii) environmental factors that limit the use of land. The major soil groups (fig.12), found in the catchment are (i) lateritic soils (coarse shallow soil, 22.25 % and medium deep soil, 21.35 %), (ii) coarse shallow black soil, (10.67 %) and medium black soil (45.73 %).

(a) Lateritic Soils

Lateritic soils include both coarse shallow soil and medium deep soil. These soils are found on undulating, rolling plain to gently sloping topography occupying areas in parts of Kolhapur district coming under the dry agro-climatic region. In

Fig. 12 Soil map of the Ghataprabha catchment



this type of soils root penetration is limited by the presence of hard pan, which occurs at varying depths. They are poor in nutrients and respond well to phosphates and nitrogen. They are acidic in reaction, low in cation exchange capacity. The soils are mainly composed of kaolinitic clays which are well drained to excessively drained with medium permeability. These soils are classified under the orders: entisols, ultisols, alfisols and exisols with sub-orders: orthents, ustults, udults,ustalfs, udalfs and ustox. The crops grown in these soils are jowar, groundnut pulses, safflower, linseed and other millets. Under irrigation the crops grown are paddy, sugarcane, chillies, wheat, turmeric and vegetables.

(b) Coarse shallow black soils.

These type of soils are found on undulating ridges in the Deccan hard rock region occupying areas in north and north west parts of Belgaum and Kolhapur districts. These soils are shallow at depth less than 23 cm, dark greyish brown, dark brown to dark reddish brown in colour and calcareous, with gravelly clay loam to clay in texture. These soils are neutral to weakly alkaline and have moderate to high water holding capacity with high cation exchange capacity. These soils are classified under the order entisols and enceptisols with sub-orders: Orthents and Ochrepts. These soils are severe to very severly susceptible to erosion. The crops grown under rainfed conditions are jowar, bajra, millet, and pulses. However the yields of crops are poor owing to shallow rooting depths and scanty rainfall.

(c) Medium black soils:

These soils occur usually on very gently sloping mid-lands of the Deccan traps, schists, lime stone and shale regions of Belgaum district. These are moderately well drained with slow permeability. Soils of this region are classified under the order: inceptisols and vertisols with sub-orders: ochrepts and usterts. The composition of the clayey soils are mainly montmorillonitic. Because of the montmorillonitic composition , indiscriminate use of water may lead to development of salinity and water logging problems. The crops grown in these soils, under rainfed conditions are jowar, wheat, millets, cotton, safflower, tobacco, groundnut, ginger, linseed, chillies, tur, gram and other pulses.

5.2.4 Water availability in the catchment

The total surface and ground water availability in the catchment and the crop water requirement have been estimated. The surface water potential of the region is 1815 MCM and ground water is only 171 MCM. However, it is estimated that only 681 MCM of the available water resources utilised for the present crops and the remaining water goes unutilised. Further it is observed that ground water is depleting regularly from year to year (1985-1989) showing that ground water is extensively used without properly using surface water. The location of observation wells are shown in fig. 8. If the water is utilised in a planned

manner, the available water is sufficient for whole irrigation in the catchment.

5.2.5 Cropping pattern

The essence of a new strategy in agriculture is the emphasis on increasing the yield per unit area. The success of this depends upon the suitable agronomic practices, use of fertilisers, soil and water management and plant protection measures. The present cropping pattern in the catchment shows that wheat, paddy, jowar, groundnut, cotton and sugarcane are grown more in the catchment. In addition to this, Bajra, pulses, Ragi and fodder are also grown sufficiently in the catchment area. The present cropping pattern and corresponding water requirement is shown in the table 5.2.5

Table 5.2.5: Cropping pattern and water requirement for Ghataprabha catchment

CROPS	Delta	% of crops	Total water required
Khariff			
Paddy	0.95	12	148.2
Jowar	0.07	8	7.3
Ragi	0.07	4.5	3.9
Cotton	0.50	9	57.33
G.nut	0.18	6.75	4.5
Fodder	0.05	4	4.36
Bajra	0.05	6.5	4.2
Rabi			
Wheat	0.42	13.5	73.5
Jowar	0.58	11.25	84.7
Pulses	0.26	6.5	22.0
G.nut	0.37	9.0	43.3
Perennial crop			
Sugar cane	1.90	9.0	222.3
		Total	680.63

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 MALAPRABHA CATCHMENT

Based on present study , the recommended land use for each of these systems take into account the suitability of soils,its erosion status, the availability of groundwater potential and the existing land use practices in the area. However, in some areas need high priority for immediate attention. These are hilly areas with degraded forest cover which need to be attended to for afforestation measures. Second category involves areas which are predominantly wastelands and marginally fallow lands, which can be utilised for fuel, fodder and plantation crops. These recommended land uses are essential for long term planning for improving and mitigating the drought conditions.

In addition to the above measures, most important works involved in efficient management of watersheds of the catchment are, (i) identification of suitable watersheds,(ii) Bunding of fields on contour lines and division of land into compartments to reduce runoff and promote soil retention and seepage,(iii) People should be educated to understand and follow, through extension services and audio- visual media. Addition farm yard manure produced locally and utility in agriculture. Strip cropping may be adopted for increasing the overall economy of farm production. Selection of crops and their rotation of suitable crops should be taken up for increasing the yield.

6.2 GHATAPRABHA CATCHMENT

Based on land use pattern, soil characteristics and the water requirement an ideal cropping pattern may be suggested . It is understood that if the heavily irrigated crops are proposed for the soils on the ridges and uplands, they require more water due to their lighter texture and shallow depths. This may lead to water logging in mid-up lands. Therefore it is suggested that paddy and sugarcane must be restricted to only low-lying areas. Wheat should be grown in cool and dry climatic regions, if the soils are mainly clay loams, loams and sandy loams. Jowar can be grown on variety of soils ranging from clay to sandy loams. When grown on clay to clay loams the irrigation requirement is low and for lighter soils, irrigation requirement is higher. It is observed that the crops like groundnut can be well developed in the regions of well drained soils and forest trees need very deep soils, while pasture needs shallow soils. In the lateritic soils plantations like coconut, cashewnut and mango can be grown . In the Ghataprabha catchment, it is estimated that only 35 % of the water is utilised for agricultural purposes and rest of the water is unutilised in the catchment area. So it is recommended to launch a massive artificial ground water recharge and adoption of non conventional ground water techniques, such as construction of percolation tanks, invert wells and sub-surface dykes to mitigate the effects of drought in coming years. High priority areas should be identified for taking immediate measures for afforestation, soil conservation, development of fuel, fodder

and plantation crops. In addition, bunding of fields on contour lines and division of land into compartments to reduce run-off and to promote soil retention and seepages also recommended.

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Annexure (a)

Malaprabha sub-basin

The monthly average and annual rainfall of different raingauge stations in and around the sub-basin

Period: From 1955-1956 to 1984-1985.

Months	Name of the stations	
	Belgaum	Khanapur
May	114	131
June	22Ø	376
July	445	812
Aug	264	428
Sep	128	143
Oct	1Ø7	113
Nov	36	54
Dec	8	3
Jan	Ø	1
Feb	3	1
Mar	1Ø	3
Apr	44	25
	1389	2Ø9Ø

Annexure (b)

Malaprabha sub-basin

Monthly average maximum and minimum temperature observed at different IMD observatories.

Period : From 1931 to 1960 Unit : C

Month		Belgaum	Gadag
Jan	Max	30.1	30.3
	Min	14.0	16.7
Feb	Max	32.2	33.0
	Min	15.1	18.6
Mar	Max	35.0	36.0
	Min	18.0	21.0
Apr	Max	35.7	37.3
	Min	19.5	22.5
May	Max	34.0	36.5
	Min	20.6	22.6
June	Max	27.5	31.1
	Min	20.6	21.9
July	Max	25.2	28.5
	Min	19.8	21.2
Aug	Max	25.6	28.9
	Min	19.4	20.9
Sept	Max	27.0	19.7
	Min	19.0	20.5
Oct.	Max	30.1	30.8
	Min	18.6	20.2
Nov.	Max	29.3	29.8
	Min	17.1	18.4
Dec	Max	29.3	29.1
	Min	13.9	16.5
Annual (Mean)	Max	30.1	31.7
	Min	18.0	20.1

Annexure (c)

Malaprabha Sub-basin

Monthly average relative humidity data of different IMD observatories

Period : From 1931 to 1960 Unit : %

Month	Hour	Belgaum	Gadag
Jan	08.30	66	61
	17.30	30	35
Feb	08.30	61	54
	17.30	30	31
Mar	08.30	62	58
	17.30	32	31
Apr	08.30	72	71
	17.30	46	41
Ma y	08.30	78	78
	17.30	58	49
June	08.30	85	88
	17.30	76	68
July	08.30	90	84
	17.30	92	73
Aug	08.30	92	84
	17.30	87	70
Sept	08.30	89	83
	17.30	81	66
Oct.	08.30	81	75
	17.30	64	57
Nov	08.30	70	64
	17.30	47	46
Dec	08.30	67	63
	17.30	35	41
Annual (Mean)	08.30	76	72
	17.30	57	51

Source: India Meteorological Department, Climatological tables of observatories in India.

Malaprabha sub-basin

Monthly average cloud cover observed at different IMD observatories

Period: From 1931 to 1960

Month	Hour	Belgaum	Gadag
Jan	08.30	0.9	2.3
	17.30	1.5	2.8
Feb	08.30	0.8	2.3
	17.30	1.4	2.8
Mar	08.30	0.8	2.0
	17.30	1.8	3.0
Apr	08.30	1.8	2.8
	17.30	3.0	4.5
May	08.30	3.2	4.2
	17.30	3.4	4.8
June	08.30	5.9	6.1
	17.30	6.0	6.2
July	08.30	7.0	6.9
	17.30	7.1	6.9
Aug	08.30	6.7	6.7
	17.30	6.8	6.6
Sept	08.30	5.6	6.1
	17.30	6.1	6.3
Oct.	08.30	3.9	4.7
	17.30	5.1	5.4
Nov	08.30	2.4	3.7
	17.30	3.4	4.3
Dec	08.30	1.3	2.7
	17.30	1.9	3.1
Annual (Mean)	08.30	3.4	4.2
	17.30	4.0	4.7

Source: India Meteorological Department, Climatological tables of observatories in India.

Ghataprabha sub-basin

Monthly average sunshine percentage
observed at Belgaum IMD observatory

Period : From 1931 to 1960 Unit : %

Month	Belgaum
Jan	95.5
Feb	96.0
Mar	95.0
Apr	88.0
May	79.0
June	40.0
July	21.0
Aug	26.0
Sept	42.0
Oct	64.0
Nov	83.0
Dec	93.5
Annual (Mean)	74.5

Source : Climatological tables of observatories in India (for cloud cover) sunshine percentage is taken from cloud cover-sunshine percentage graph.

Malaprabha sub-basin

Normal monthly and annual potential evapotranspiration for the different IMD observatories.

Period : From 1931 to 1960 Unit : mm

Month	Belgaum	Gadag
Jan	113.2	121.7
Feb	124.7	130.7
Mar	166.5	172.9
Apr	171.0	178.5
May	171.5	184.0
June	113.7	144.6
July	92.2	130.2
Aug	95.4	130.7
Sept	100.1	123.4
Oct	117.3	123.2
Nov.	109.6	112.5
Dec	105.5	111.9
Annual	1491.3	1664.1

Source: Potential Evapotranspiration (PE) over India computed by the India Meteorological Department

Annexure (a)

Ghataprabha sub-basin

The normal monthly and annual rainfall of different raingauge stations in and around the sub-basin

Period: 1954-55 to 1983-1984

Months	Name of the stations			
	Chandgad	Belgaum	Hukkeri	Halkani*
June	509	216	104	721
July	1226	464	164	674
Aug	749	282	99	245
Sept	216	129	124	200
Oct	117	107	115	31
Nov	45	36	45	6
Dec	6	8	6	0
Jan	0	0	0	0
Feb	2	3	1	0
Mar	8	9	11	0
Apr	40	46	37	0
May	93	114	107	7
Annual Total	3011	1414	813	269

*NIH data year book, period 1989-91

Ghataprabha sub-basin

Monthly average maximum and minimum temperature observed at Belgaum IMD Observatory

Period: From 1931 to 1960 Unit : C

Month		Belgaum	Halkarni*
Jan	Max	30.1	22.5
	Min	14.0	14.6
Feb	Max	32.2	23.0
	Min	15.1	15.4
Mar	Max	35.0	23.3
	Min	18.0	17.6
Apr	Max	35.7	25.0
	Min	19.5	20.6
May	Max	34.0	25.3
	Min	20.6	20.7
June	Max	27.5	21.0
	Min	20.6	20.7
July	Max	25.2	23.0
	Min	19.8	20.0
Aug	Max	25.6	22.5
	Min	19.4	19.9
Sept	Max	27.0	23.3
	Min	19.0	19.3
Oct	Max	30.1	23.5
	Min	18.6	19.5
Nov	Max	29.3	24.2
	Min	17.1	18.8
Dec	Max	29.3	22.8
	Min	13.9	16.7
Annual (Mean)	Max	30.1	23.3
	Min	18.0	18.7

Source: India Meteorological Department publication "Climatological tables of observatories in India"

*National Institute of Hydrology data year book period 1989-91

Ghataprabha sub-basin

Monthly average relative humidity
data at Belgaum IMD observatory

Period: From 1931 to 1960 Unit : %

Month	Hour	Belgaum	Halkarni*
Jan	0830	66	71.2
Feb	0830	61	55.7
Mar	0830	62	58.5
Apr	0830	72	81.6
May	0830	78	71.5
June	0830	85	76.9
July	0830	90	81.4
Aug	0830	92	81.8
Sept.	0830	89	77.9
Oct	1830	81	71.5
Nov	0830	70	72.4
Dec	0830	67	71.5
Annual	0830	76	72.7

Source: India Meteorological Department publication,
"Climatological tables of observatories in India".

*National Institute of Hydrology data year book period 1989-91

Ghataprabha sub-basin

Monthly average wind speed observed at
Belgaum IMD observatory

Period : From 1931 to 1960 Unit : km/hr

Month	Belgaum	Halkarni*
Jan	6.4	7.6
Feb	6.6	8.0
Mar	7.2	7.0
Apr	8.5	7.5
May	10.6	11.3
June	13.0	14.2
July	14.4	20.2
Aug	13.5	20.0
Sept	9.9	8.0
Oct	8.1	6.5
Nov	6.8	9.0
Dec	6.5	9.1
Annual (Mean)	9.3	10.7

Source: India Meteorological Department publication "Climatological tables of observatories in India".

*National Institute of Hydrology data year book period 1989-91

Ghataprabha sub-basin

Monthly average clour cover observed at Belgaum IMD observatory

Period : From 1931 to 1960

Unit: Okta

Month	Hour	Belgaum
Jan	0830	0.9
	1730	1.5
Feb	0830	0.8
	1730	1.4
Mar	0830	0.8
	1730	1.8
Apr	0830	1.8
	1730	3.0
May	0830	3.2
	1730	3.4
June	0830	5.9
	1730	6.0
July	0830	7.0
	1730	7.1
Aug	0830	6.7
	1730	6.8
Sept	0830	5.6
	1730	6.1
Oct	0830	3.9
	1730	5.1
Nov	0830	2.4
	1730	3.4
Dec	0830	1.3
	1730	1.9
Annual (Mean)	0830	3.4
	1730	4.0

Source: India Meteorological Department publication "Climatological tables of observatories in India".

Annexure (f)

Malaprabha sub-basin

Monthly observed sunshine percentage
at different IMD observatories

Period : From 1931 to 1960 Unit : %

Month	Belgaum	Gadag
Jan	95.5	86.5
Feb	96.0	86.5
Mar	95.0	87.0
Apr	88.0	74.5
May	79.0	64.0
June	40.0	36.5
July	21.0	23.5
Aug	26.0	28.0
Sept	42.0	36.0
Oct.	64.0	55.0
Nov	83.0	71.0
Dec	93.5	83.0
Annual (Mean)	74.5	64.0

Source: Climatological tables of observatories in India (for cloud cover) sunshine percentage is taken from Cloudcover-sunshine percentage graph.

Ghataprabha sub -basin

Normal monthly and annual potential evapotranspiration for Belgaum IMD observatory

Period: From 1931 to 1960 Unit: mm

Month	Belgaum
Jan	113.2
Feb	124.7
Mar	166.5
Apr	171.0
May	171.5
June	113.7
July	92.2
Aug	95.4
Sept	100.1
Oct	117.3
Nov	109.6
Dec	105.5
Annual	1480.7

Source: Potential evapotranspiration (PE) over India computed by India Meteorological Department.

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