WATERSHED MANAGEMENT OF THE KAKODONGA RIVER BASIN OF NAGALAND-ASSAM

Thesis submitted to the

NAGALAND UNIVERSITY

for the award of the Degree of

DOCTOR OF PHILOSOPHY
IN
GEOGRAPHY

By

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Under the Guidance of

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MAY, 2015

Dedicated

To

My Parents and Wife

Mr. RANA BORA,
Research scholar,
Department of Geography,
Nagaland University,
Lumami – 798 627.

DECLARATION

I hereby state that the thesis entitled "Watershed Management of the Kakodonga River Basin of Nagaland-Assam" submitted to the Nagaland University in May, 2015 for the partial fulfillment of the degree of DOCTOR OF PHILOSOPHY is the original work carried out by me in the Department of Geography during 2011 – 2015 under the guidance of Dr. Y. V. Krishnaiah, Department of Geography, Nagaland University, Lumami and it has not formed the basis fully or partially for the award of any degree, diploma or other similar titles earlier.

Place: Lumami, **(Mr. Rana Bora)**
Date:

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NAGALAND UNIVERSITY
(A Central University estd. by an Act of Parliament No. 35 of 1989)
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CERTIFICATE

I hereby certify that the thesis entitled "Watershed Management of the Kakodonga river basin of Nagaland-Assam" submitted to the Nagaland University in May, 2015 for the partial fulfillment for the award of degree of Doctor of Philosophy by Mr. Rana Bora (Reg. No. 532/2013, Dated : 23.11.2012), is the original and independent work carried out under my supervision and that the thesis has not formed the basis fully or partially for the award of any degree, diploma or other similar titles earlier.

Place: Lumami, (Dr. Y. V. Krishnaiah)
Date : Supervisor

PREFACE

Watershed has got worldwide recognition as a unit for development planning and it is also considered as the blue print for dry land agriculture development. Watershed can be defined as "a natural geo-hydrological unit area draining to a single outlet, exhibiting near about homogeneity in climate, topography, people and soil". Watershed development implies rational and judicious utilization of land and water resource for optimum production with a minimum hazard to natural resources. This helps improving environment through proper land use planning, protecting the land from soil erosion, gully and ravine formations, maintaining soil fertility, rainwater harvesting and recycling rain water properly, making proper drainage system, flood protection, runoff reduction, sediment reduction etc. Being a hydrological unit, every watershed has its own hydrological conditions. Therefore it is very much essential to study the hydrological conditions individually. India especially North eastern region including Assam is a land of rivers. Future of agricultural development will be jeopardizing without the proper management of watersheds of this region. Proper watershed development programs helps in moisture conservation, land development increase vegetative cover etc. Proper watershed management techniques leads to sustained agriculture development besides developing dairy, sericulture, fishery, horticulture, agro-forestry, human skills, income-employment potentials among rural masses.

Geospatial techniques application in water resource management system is a burg coming issue now a days and has attracted attention of students, researchers, scientist, faculties etc. The Geoinformatic techniques help us in acquiring reliable and timely data and analyze the data properly. It also makes decision making process easy, accurate and cost-effective.

The Kakodonga River is one of the important southern sub-tributaries of mighty River Brahmaputra. The river originates from Naga Hills and flows through the Brahmaputra plain of Assam. The basin area spreads over the territories of Jorhat and Golaghat districts of Assam and Wokha district of Nagaland. The Kakodonga River basin covers an area of about 1,112.86 sq. km. measuring to a maximum length and width of 56 km and 45 km. respectively. The study area is geographically located between $26^0 15^/ 10^{//}$*N to* $26^0 44^/ 48^{//}$ *N latitude and* $93^0 59^/$ *10"E to* $94^0 21^/ 45^{//}$ *E longitude. Maximum portion of the basin are occupying by agricultural land, mainly tea gardens and paddy field. During the rainy season excess water of the river inundate the low lying areas and causes heavy loss to property, lives and crops of agricultural fields. Siltation, flood, channel shifting, channel migration, soil erosion, changing land use/ land cover etc. are most common features of the Kakodonga river basin due to heavy rainfall in monsoon and pre-monsoon seasons.*

The main objectives of study are

1. *To study the land resources of the Kakodonga river basin,*
2. *To analyze the morphometric characteristics of Kakodonga river basin,*
3. *To study the water resources on monthly, seasonal and annual basis of the Kakodonga river basin,*
4. *To study the water balance elements on monthly, seasonal and annual basis,*
5. *To evaluate the land use, irrigation and cropping pattern of the Kakodonga river basin and*
6. *To propose watershed management programmes through a selected macro watershed of the basin for sustainable watershed development.*

The thesis is organized into eight Chapters. The first chapter is introduction, where an introductory note to every chapter is placed. Statement of the problem, significance of the study, the study area, objectives of the study, research methodology and review of literature are the main components of this chapter. The second chapter concentrates on land resources of Kakodonga river basin. In this chapter mainly relief, slope, drainage, geology, soil, natural vegetation, land use, intensity of soil erosion, land capability classification etc. are discussed in detail. Third chapter deals with morphometric characteristics of Kakodonga river basin in linear, areal and relief aspects. Fourth chapter highlights on water resources of the basin including mean temperature analysis, mean rainfall, rainfall intensity, rainfall variability and rainfall ratio analysis on monthly, seasonal and annual basis. Here, groundwater recharge of the basin is also estimated. The fifth chapter focuses on water balance of the basin. The sixth chapter is the description of land use, irrigation and cropping pattern of the basin. This chapter highlights revenue circle wise crop concentration, crop diversification, irrigation and land use pattern. On seventh chapter watershed management planning is proposed through a selected macro watershed of Kakodonga River basin. Socio-economic aspect of watershed management is also highlighted through the selected macro watershed. The last chapter is summery and conclusions, where a brief summary of the whole research work has been incorporated and also included some recommendation for the policy makers for bringing possible improvement in watershed management programmes of the Kakodonga river basin.

ACKNOWLEDGEMENTS

This piece of work would not have come to its present shape without the sustained help, guidance and supervision of Dr. Y. V. Krishnaiah, Assistant Professor, Department of Geography, Nagaland University. I express my deep sense of gratitude to him for his help and assistance rendered to me to complete my research work.

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I express my deep sense gratitude to Prof. M. Sambasiva Rao, Department of Geography, Sri Krishnadevaraya University, Anantapur, Andhra Pradesh for his valuable suggestions and assistance to me to complete this piece of work.

I also owe a special debt of gratitude and thanks to my colleagues of Geography department, and other respected teachers, and office staff of Borholla College for their encouragement.

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Date: *(Rana Bora)*

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Introduction

1

A watershed is a geo-hydrological unit in a topographically delineated area draining to a common point by a system of streams. It captures rainfall and carries the overland flow and run-off to an outlet of the main flow channel. The depth of watershed may extend from the top of the vegetation to the confining geological strata beneath. Watershed is unique as a fingerprint. Though the term of watershed strictly refers to the divide that separate one drainage from the other, in recent years it is being identified with drainage basin streams. A watershed may be either flat or undulating sprinkled with hillocks, hills or mountains. Each and every water and land area consist a part of one watershed or the other. The peoples and animals are part of watershed community. The size becomes important depending upon the objective of watershed. Larger watershed could be selected in the plains or where afforestation and grassland development is a main objective. In the hill areas where agriculture development is the main objective smaller watershed are chosen.

Watershed is a biological, physical, economic and social system. It is a land mass bounded vertically by the area influenced by human activities and horizontally by water that drains into a point in the channel. Soil, water and vegetation are the most vital natural resources of the watershed. Judicious and effective management of soil water and vegetation in the watershed can ensure sustain productivity of food, fuel, fodder, forage, fiber, fruits, and small timber. In our present study an attempt has been made to describe the land and water resources, water balance, land use, irrigation, cropping pattern and sustainable watershed management of Kakodonga river basin.

Land is the gift of nature. Physical and socio-economic development of a region is mainly related with this component of nature. About 16.2% geographical area of our country is under wastelands, which are degraded lands. They include 4.3 million hectares of gullied or ravines, 3.9 million hectares of saline and alkali lands and 0.88 million hectares of water logged land. Every year about 16.55 thousands million cubic meters of soil, six millions tones of fertile soil along with 10 million tones of fertilizers and other plant nutrients are being lost. The progress of the country is linked with agricultural and biomass products which depends on soil, water-plant-nutrient relationship of watershed. They are the basis for micro level planning for optimum utilization of land, water and forest resources. Land evaluation includes both qualitative and quantitative classification.

Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watershed (Strahler, 1964). It is one of the basic parameters for watershed management plan. Therefore morphometric parameters have been used in various studies of geomorphology and surface water hydrology, such as flood characteristics, sediment yield and evolution of basin morphology. At present GIS techniques are used for assessing different terrain and morphometric parameters of drainage basin, as they offer a good environment and powerful tool for analysis of spatial information. In our present study areal, linear and relief parameters of Kakodonga river basin are analyzed.

Waters is an important liquid gold and also water is the life of living beings. But unfortunately water is increasingly becoming scare in many parts of the world. Rapid population growth, industrialization, urbanization and increasing use in agricultural sector especially for irrigation purpose have led to water shortages. An increasing gap between water supply and demand poses a threat to poverty reduction, ecological sustainability and future economic growth (Kumar and Seethapathi, 2002). At present India have only 4% water resources with 16% & 2.45% of world's population and land respectively. Tata Energy Recharge Institute reported that the steady fall of per capita availability of water and the per capita water availability in India fell from 6008 cubic meters in 1947 to 2266 cubic meters at present. The surface water resources of a basin have to be carefully evaluated by a systematic study of the distribution of rainfall and rainfall data collected from the available rain gauge stations over a period of time.

Water balance refers to the balance between the income of water from precipitation and outflow of water by way of evapotranspiration, surface run-off and infiltration to the soil. Water balance study was advanced significantly by the works of Thornthwaite (1943) in the United States, Penman (1948) in England. The essential parameters taken into consideration to study water balance are Precipitation (P), Actual Evapotranspiration (AE), Potential evapotranspiration (PE), Soil Moisture Storage (ST), Change in Soil Moisture Storage (ST) etc. Water balance in a basin indicates the total budget of the basin during a particular time by measuring all inputs and outputs. It is a useful method to find out water deficiency or surplus of a region and helps in basin management.

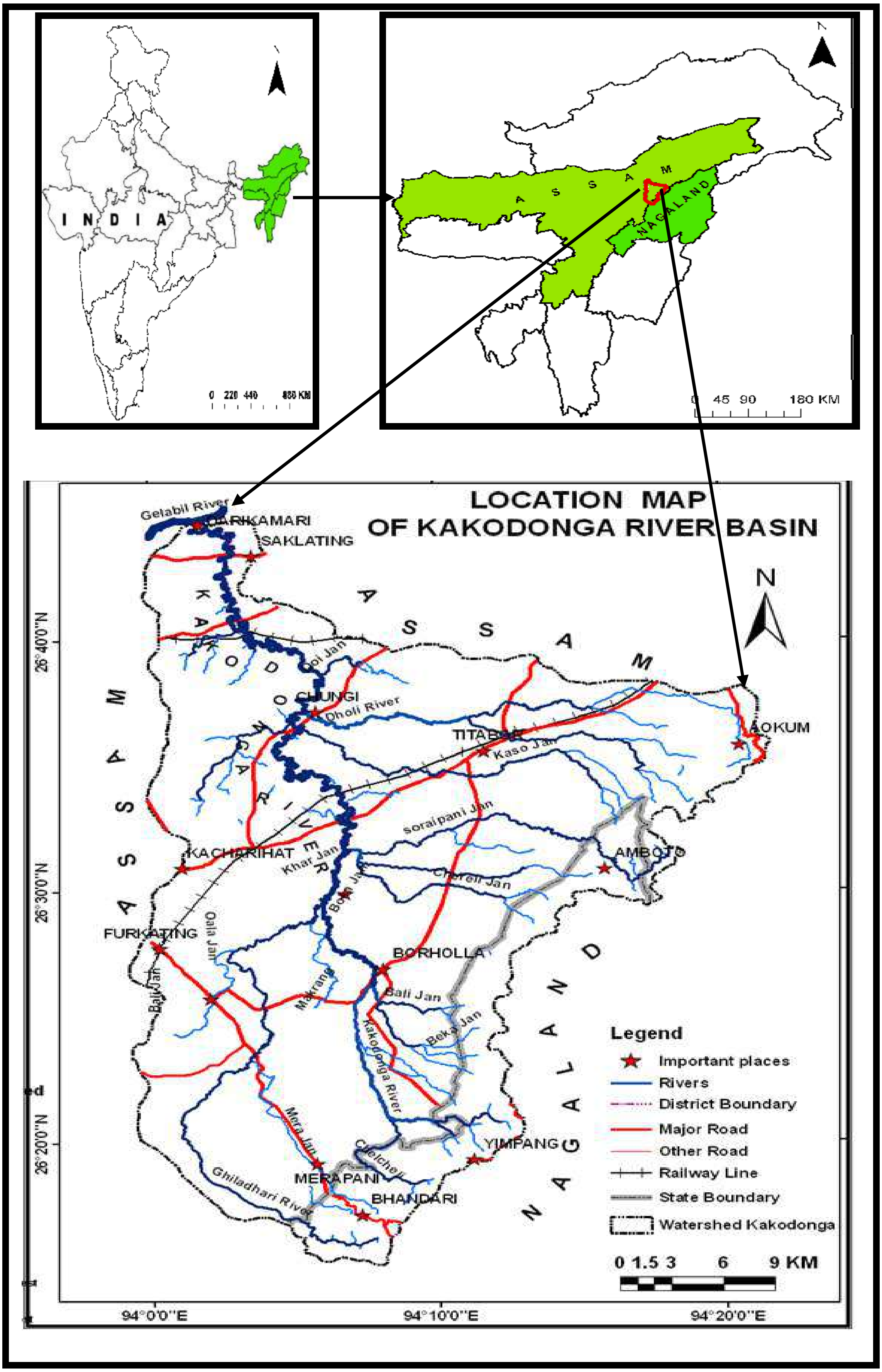
Land use describes how a parcel of land is used such as for agriculture, settlements or industry, where as land cover refers to the material such as vegetation, rocks or water bodies that are present on the earth's surface. Hence, land use refers to man's activities and various uses, which are carried on land and land cover refers to natural vegetation, water bodies, rock or soil, artificial cover and other resulting due to land transformations. The nature of land use / land cover in an area reflects not only the environmental conditions and land resource base of the area, but also it projects the level of development of the people under different physical, cultural and economic conditions. The per capita availability of agricultural land in India is less than one hectare. But around 60% of the total population of the country are directly dependent on agriculture and allied activities. Agriculture sector contributes about 14% of the total GDP of the country. Roughly 55% of the geographical area of the country is under net sown area. There is immense pressure of rapidly expanding population of India on these limited resources. In North Easter region the problem is more severe because most of the plain area of this part of the country is concentrated in Brahmaputra valley, Barak valley and in few small pockets of Manipur and Tripura states. Apart from these plains other parts are covered by mainly hilly and mountainous topography. Therefore maximum population concentration is found in the plain region and the plain area also produces most of the agricultural products of the region. Therefore every inch of land should be used judiciously, so that maximum benefit could be utilized without harming the sustainability of the region. Proper watershed management policy is very much effective in this perspective.

Irrigation is generally defined as the artificial application of water to the plant needs. Irrigation plays a crucial role in the process of agriculture and provides an important technological input for stable and sustainable agriculture development.

Timely supply of water is very essential for the crops. It may double the crop productivity. Therefore an efficient irrigation system is required for the development of watershed. North eastern region of India is still lagging behind in this field in compare to other states of India though almost semi arid climate prevails in winter season. Cropping pattern represents a spatial crop sequence in a given area at a particular point of time. It indicates the relative proportion of area under different crops at a given time.

Statement of the problem

Watershed has got worldwide recognition as a unit for development planning and it is also considered as the blue print for dry land agriculture development. Watershed can be defined as "a natural geo-hydrological unit area draining to a single outlet, exhibiting near about homogeneity in climate, topography, people and soil." Watershed development implies rational and judicious utilization of land and water resource for optimum production with a minimum hazard to natural resources. It helps in improving environment through proper land use planning, protecting the land from soil erosion, gully and ravine formations, maintaining soil fertility and harvesting and recycling rain water properly, making proper drainage system, flood protection, runoff reduction, sediment reduction etc. Being a hydrological unit, every watershed has its own hydrological conditions. Therefore it is very much essential to study the hydrological conditions individually. India especially North eastern region including Assam is a land of rivers. Future of agricultural development will be jeopardizing without the proper management of watersheds of this region. Proper watershed development programs helps in moisture conservation, land development and increase vegetative cover. Watershed Management techniques leads to sustained agriculture development besides developing dairy, sericulture, fishery, horticulture, agro-forestry, human skills, income-employment potentials among rural masses.



I N D I A
0 220 440 880 KM
A S S A M
NAGALAND
0 45 90 180 KM
LOCATION MAP
OF KAKODONGA RIVER BASIN
N
Legend
Important places
Rivers
District Boundary
Major Road
Other Road
Railway Line
State Boundary
Watershed Kakodonga
0 1.5 3 6 9 KM
94°0'0"E
94°10'0"E
94°20'0"E
26°40'0"N
26°30'0"N
26°20'0"N

Fig 1.1

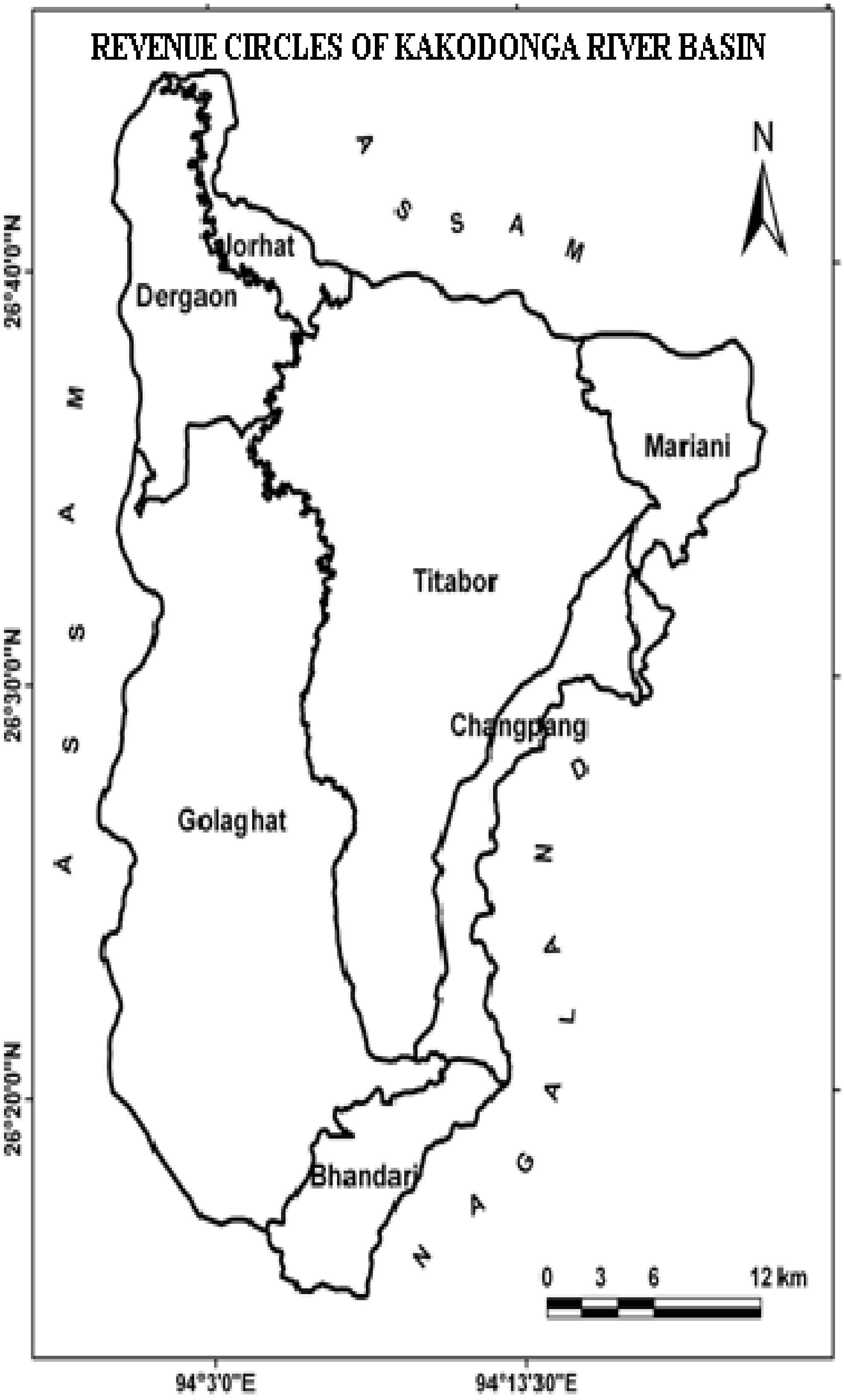

REVENUE CIRCLES OF KAKODONGA RIVER BASIN
N
ASSAM
Jorhat
Dergaon
Mariani
Titabor
Changpang
Golaghat
Bhandari
NAGALAND
ASSAM
26°40'0"N
26°30'0"N
26°20'0"N
0 3 6 12 km
94°3'0"E
94°13'30"E

Fig. 1.2

Remote sensing and Geographical Information System (GIS) and its application in water resource management system is a burg coming issue now a days and has attracted attention of students, researchers, scientist, teaches etc. The geoinformatic techniques help us in acquiring reliable, timely data and analyze the data properly. It also makes decision making process easy, accurate and cost-effective.

Significance of the study

The Kakodonga River causes heavy flood during the rainy season but the whole watershed area remain dry in other seasons, which create problematic conditions especially to the poor farmers of the area. The study will reveal the nature of such burning problem. Watershed management bears immense significance as it includes natural resources that exist in a particular ecological setting with intimate linkages among the components. Plans and strategies will be prepared for the sustainable growth of the watershed, which is very much significant from geographical point of view.

The study area

The Kakodonga River is one of the important southern sub-tributaries of mighty River Brahmaputra. The river originates from Naga Hills and flows through the Brahmaputra plain of Assam. The basin area spreads over the territories of Jorhat and Golaghat districts of Assam and Wokha district of Nagaland. The Kakodonga River basin covers an area of about 1,112.86 sq. km. measuring to a maximum length and width of 56 km and 45 km.

respectively. The study area is geographically located between $26^{0}15^{/}10^{//}$N to $26^{0}44^{/}48^{//}$ N latitude and $93^{0}59^{/}$ $10^{//}$ E to $94^{0}21^{/}45^{//}$ E longitude (Fig. 1.1). It occupies some parts of the revenue circles of Golaghat, Dergaon, Jorhat west, Titabor, Mariani of Assam and Changpang and Bhandari circles of Nagaland state (Fig. 1.2). The maximum portion of the basin are occupying by agricultural land, mainly tea gardens and paddy field. During the rainy season excess water of the river inundate the low lying areas and causes heavy loss to property, lives and crops of agricultural fields. Siltation, flood, channel shifting, channel migration, soil erosion, degradation of forest, changing land use/ land cover etc. are most common features of the basin.

The main objectives of study are

1. To study the land resources of the Kakodonga river basin.
2. To analyze the morphometric characteristics of Kakodonga river basin.
3. To study the water resources on monthly, seasonal and annual basis of the Kakodonga river basin.
4. To study the water balance elements of the study area on monthly, seasonal and annual basis.
5. To evaluate the land use, irrigation and cropping pattern of the Kakodonga river basin.
6. To propose watershed management programmes through a selected macro watershed of the basin for sustainable watershed development.

Hypothesis:

1. If land resources are not utilized properly, there is the possibility of land degradation in the form of ravine erosion, gully erosion, soil alkanity, soil salinity etc.,
2. Morphometric studies will help to delineate the lithological units and explain the nature of drainage and erosion.
3. Proper assessments of water resources are essential for optimum utilization and conservation of land and water resources of the Kakodonga river basin.
4. Water balance study is necessary to delineate water surplus and deficit zones.
5. Land use, irrigation and cropping pattern are fundamental parameters to analyze the land use efficiency, irrigation intensity, crop concentration, crop ranking, crop diversification and crop combination of the study area.
6. Micro watershed development is essential for management of land, water and vegetation.

Research Questions:

1. To what extent land resources are responsible for the development of Kakodonga River basin?
2. In what way morphometric characteristics are useful for drainage analysis of the Kakodonga basin?

3. What is the status of water balance in the present study area?
4. What types of land use, irrigation and cropping pattern exist in the study area?
5. Is there any impact of water resources on land use, irrigation and cropping pattern of the study area?
6. In what way micro level planning helps in watershed management of the Kakodonga River basin?

Research Methodology

1. Land resources of the basin are studied using the Survey of India (SOI) topographic sheets No. 83F/14, 83F/15, 83J/2, 83J/3, 83J/6 and 83J/7 on 1:50,000 scale and IRS P6 LISS III Imagery (23.5 meter resolution), 2011. All the topographic sheets were geo-referenced with the help of Arc GIS 9.3 software and ERDAS 8.7 software using Universal Transverse Mercator (UTM) Projection and WGS 1984 datum. Relief, slope, landforms, soil, land use and land cover, intensity of soil erosion maps were prepared. Based on these physical parameters land capability of the basin is evaluated.
2. In morphometric analysis, Strahler's (1957) method is used to assign orders to each stream. All the streams of the basin are digitized from the Survey of India topographic sheets and overlaid on concerned remote sensing imagery to detect the changes taking place in recent time. After that streams are modified in reference to

the imagery of the basin. The morphometric parameters are analyzed under three broad categories i.e. linear, areal and relief using various standard formulas.

3. The water resources of the basin are studied by analyzing rainfall data on monthly, seasonal and annual basis. The rainfall data was collected from ten rain-gauge stations located in and around of the basin. The surface water resources of the basin are also studied using Barghava (1977) method based on mean annual rainfall, rainfall intensity, rainfall variability and rainfall ratio of the basin. Radhakrishna *et al* method (1974), U. S. Geological Method (1962), Seghals' (1973) and Krishna Rao (1970) method are also used to calculate the annual ground water recharge of Kakodonga river basin.
4. The water balance of the basin is studied using Thornthwaite and Mather (1955) method on monthly, seasonal, and annual basis taking mean monthly temperature and mean monthly rainfall over a period of 31 years (1983-2013) for about ten selected rain-gauge stations. The water balance of the Kakodonga basin delineated using mean rainfall, water stored in ponds, tanks and reservoirs, evaporation and evapotranspiration, run-off and water recharge to sub surface. The information is generated on certain parameters such as water deficit, water surplus, moisture adequacy, aridity

index and climatic classification. Climatic classification of the basin is also done on the basis of Thermal Efficiency (TE).

5. The land use categories of the Kakodonga river basin is studied from SOI topographic sheets and IRS P6 LISS-III imagery (2011) data for both rabi and kharif seasons. The landuse, irrigation and cropping pattern data were obtained from Economic and Statistical Department, and Irrigation Department at revenue circle level to study the crop concentration, efficiency and intensity of land-use, irrigation, cropping pattern and diversification and combination of crop adopting different statistical methods like Bhatia (1965), Rafiullah's (1956) and Doi's (1957).

6. One macro watersheds of the basin is delineated for detail study. Socio-economic survey was also conducted to study present socio-economic atmosphere like population, literacy and agriculture and socio-economic status etc with the help of a questionnaire. Soil erosion intensity map is also prepared for the macro watershed as well as for whole basin following Bhattacharyya *et al* (2002) method. Physical parameters like land systems, landforms, soils, land capability, morphometric analysis, temperature, ground water availability, water balance etc. of the selected macro watershed are also analyzed to suggested appropriate watershed management programme.

Review of Literature

The concept of watershed development in India has been proposed by Shri Late V. P. Bali in 1974. The Ministry of Agriculture and Government of India has proposed the programme of soil and water conservation adopting watershed as a planning unit. Various studies carried out on concept and methodology of watershed management. FAO (1990) has given guidelines for watershed survey, planning and conservation. The author observed that remote sensing with its unique characteristics of synoptic view, repetitive coverage and reliability has opened immense possibility for watershed mapping, making resource inventory for optimum use of resources discussed by Kumar (2010). The surface condition including stream and other water bodies for water resource planning and reliable mapping of river is essential and remote sensing is very useful in this regard. Natarajan (2006) also commented that development of remote sensing technique and its proven application have created new hopes for quick assessment of natural resources in the context of watershed planning. Palanisami (2006) used GIS in his study of watershed planning and expressed that it is very useful tool for decision support. Kanan and Devi (2006) remarked that main purpose of Watershed project is overall Socio-Economic development of the villages through People participatory programme.Watershed management incorporate conservation management and steady flow of surface water and the rate of recharge of underground water expressed by Reddy *et al.,* (2008) and Bhattacharya (2008). They also made an attempt to cover all aspects of watershed as to observe, judge the effectiveness and efficiency of the watershed based on the development of natural resources, agriculture and socio economic condition. Rao (2013) mentioned that sand content of stream's banks and beds in different order streams decreasing from its higher order to lower order streams. Batchelor (2003) suggested some recommendation from a water audit in southern Andhra Pradesh. Shee and Maiti (2012) suggested that Environmental Management Plan is necessary for a basin. Sikka (2014) emphasized on active participation of local community for Integrated Watershed Management Programme. Anil (1994) also suggests a few measures for development of watershed in drought prone areas. Patil *et al,* (2011) highlights the watershed development through Remote Sensing and Geographical Information System in Sangli district of Western Maharashtra.

Narayan (1985) has also workout on minimum erosion and maximum benefit of soil conservation, and he has recommended measures for soil and water conservation and watershed development. Gupta (1992) and Krishnaiah (2010,a) have outlined strategies for integrated watershed development. Davenport (2004) has suggested Watershed Project Management Guide. Rai (1992) has suggested Environmental Management Physio-Ecological Facts.

The studies on land resource are very important for watershed management analysis. Ravnborg and Helle (2002) explored the relationship between poverty, soil quality and soil management strategy based on field research carried in Rio Saco, Cuscateca & Tascalapa Watersheds in Honduras, central America. Martin and Saha (2009) expressed that multiple integration options in GIS are of immense use for data integration and overland analysis to obtain better and faster result in judicious utilization and allocation of natural resources. He also found that the present land-use options can be changed to profitable ones for better economic returns and sustainable resource management of the given land, which could not have been possible through conventional land evaluation method. Jabeen and Ahmed (2013) stated that the land use/ land cover studies are of fundamental significance, as the land resources play a strategic rule in the determination of man's economic, social and cultural progress. Mishra and Singh (2013) pointed out that with the help of appropriate accuracy assessment techniques, we can get a well corrected classification result of any land use/ land cover map. Singh and Singh (2013) remarked that land use/ land cover changes are closely linked with the issue of sustainability of socio economic development. Ram (2004) emphasized on a systematic characterization and mapping of bio-physical resources viz., climate, landforms, soil, vegetation surface and ground water, transport network & village settlement, land use etc., using conventional and remote sensing techniques, correlates with socio-economic data, integrate them and formulate sustainable land use planning zones for optimizing production potentials in watershed. Prasad and Ghosh (2013) and Krishnaiah (2011,b) used Land Capability and Sitability Classification to find out their land suitability in Papagani river basin. Selvaraj and Naidu (2013) analyzed land characterization and soil site suitability for the major crops in a district of

Andhra Pradesh. Padmaja and Sabita (2012) highlighted the geomorphic aspect of Manjira Basin for resource evaluation.

The classical paper of Horton (1945) is a milestone for fluvial geomorphology. Following the modification of Horton's morphometric analysis and Strahler (1964) also developed some parameters for morphometric analysis. Binud *et al,* (2012) assessed the Morphometric Characteristics of Chittar River Basin, Kerela. According to Bora (1990) the effort of any river to maintain the balance and competence with varying amount and caliber of load throughout its length generally brings modification its channel morphology and slope. Rao *et al,* (2010) described the morphometric analysis of Gostani river basin through using spatial information technology. Jenita and Hussain, (2011) highlighted Manas river drainage analysis through Geographical Information system.

Singh and Sharma (2010) discussed that periodic assessment of groundwater resources should be given top priority on the behalf of water resource managers. Ground water regulatory measures need to be imposed in severely over exploited area through pro active approach. Sharma and Dubey (2013) explained semi arid region's rainfall analysis for water harvesting and irrigation development in Uttar Pradesh. Das (2013) and Krishnaiah (2014,a) remarked that water resource development and management should be carried out on watershed. Watershed is a hydrological unit, therefore it integrates both surface and sub-surface water availability, closely in turn tied with land use practices. Nayak (2011) expressed opinion on rainfall distribution Dharwar district of Karnataka state.

In India, a few geographers who have carried out studies on water resources are Dakshina murthi (1964), and Barghava (1977). Thornthwaite and Mather (1955) have developed formula for estimation of potential evaporation. In India the water balance formula (Thornthwaite and Mather, 1955 method) widely used by late Prof. V.P. Subrahmanyam. He was pioneer worker in the field of water balance studies in India adopting Thornthwaite and Mather (1955) method. He has published on monograph in 1985, on application of water balance technique in India. Hoogeveen (2010) develop a regional water balance for the Aral Sea basin and he mentioned that the water balance under natural circumstances can be calculated with the use of precipitation, runoff coefficients and open water evaporation. He also stated that application of runoff coefficients can be replaced by applying a monthly soil water balance which can result in a more detailed water balance both in time and space. Krishnaiah (2014, b) remarked that the 'water balance of watershed' is very relevant for working on environmentally safe and sustainable biomass production systems. Devi (1992) opines the active factors of climate from vegetation viewpoint are water surplus or water deficit, actual evapotranspiration and soil storage. The magnitudes of these factors are helpful in determining the distribution of vegetation. Akhter and Dhanani (2013) remarked that community based irrigation systems and water managements have gained much attention and importance for sustainable use of water. Sharma and Thakur (2007) and Krishnaiah (2010,b) expressed their views that the quantitative estimation of water balance is essential in land and water resources development not only for economic appraisal of the project but also for assessing the reliability and sustained availability of water needs in the long run. Singh (2012) used Visual Help model to quantify various component of the watershed and also try to understand the influence of various component and behavior of a basin. Tripathi (2009) analyzed the rainfall for crop planning in Uttarakhand and pointed out that for crop planning it is very appropriate to analyzed rainfall data weekly. Sharma and Sharma (2010) remarked that land use and precipitation significantly affect the ground water recharge (GWR) and the sediment yields and heavy rainfall and the anthropogenic intervention are important factors affecting GWR in the NE region. Kumar (2011) evaluated a micro watershed of Andhra Pradesh. Rao (2009) focused on the effect of large scale ground water withdrawal and its consequences.

Hussain (1996) highlights on wide temperature limits, according to him moisture is more important than any other environmental factor in crop production. Todkari (2010) expressed that problems of agricultural land-use planning are envisaged by the extension of agriculture land, raising the productivity of land, soil conservation, improved seeds, pesticides, plant protection and better agriculture implements, change in the crop distribution and agro based industries in any area. Vijith and Satheesh (2007) described that land-cover refers to the physical characteristics of the earth’s surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities and land-use refers to the way in which land has been used, usually with accent on the functional role of land for economic activities. Vaidya (1997) has highlighted that land is the basic resource for human society and land use is the surface utilization of all developed and vacant lands on specific point at a given time and space. It is a systematic arrangement of various classes of land on the basis of certain similar characteristics, mainly to identify and understand their fundamental utility-intelligently and effectively in satisfying the needs of human society. Jaiswal and Verma (2013), Kumar and Biswas (2013) studied about Land Use/ Land Cover changes in Varanasi District and Kanpur City respectively using Remote Sensing and GIS techniques. Dadhwal *et al,* (2012) focused on impact of different land use systems on soil properties in a watershed of lower Himalaya region. Rainfall variability and its impact on change of cropping system are discussed by Subash *et al,* (2012) and Krishnaiah (2013). Singh (2012) highlighted the impact of IWM in sustaining Socio-Economics and Eco-development. Shakeel and Kanth (2012) also analyzed land use and landform of Liddar River Basin, Kashmir and concluded that the high hill slopes should be kept for forest and low lying areas adjacent to the basin are best suited for agriculture purpose. Chandramauli and Singh (2012) studied about Land Use and advised to create an informational, legal, institutional and economic environment that facilitates best use of land. Thakuriah (2010) mentioned that the micro-morpho units exhibit an assemblage of micro level morphological features. Sarkar and Kundu (2011) expressed their views that texture, chemical productivity, water retention capacity of the soil and the terrain characteristics together are the most important factors that influence the capacity. They have done Land Capability Classifications by USDA method in Jalpaiguri area. All India Soil and Land Use Survey (1990) have prepared the Atlas of Watershed in India on 1: 1 million scales. Narayan (1985) has also worked out a minimum erosion and maximum benefit of soil conservation. Ministry of Rural Development, Govt. of India (2001) has given guidelines for Watershed development. Basu and Guha (1996) have explain that agriculture in India is diverse with resources and their spatial distribution across the country, and dynamic in crops, livestock and other activities dominated by monsoon rains and their seasonal distribution**.** Mohammad (1992) has stated that climatic limitations affect capability, the capability of soil decreases with the decrease in effective rainfall. The importance of watershed planning for the development of agriculture is emphasized by Andotra and Sambyal (2009). They also remarked that future food security is dependent on proper watershed management. Phukan (1990) outlined an attempt to understand nature of agriculture and analyses the process of agricultural development in Assam from 1950-51 to 1984-85, a period of three and half decades on planned development efforts. It takes into account available micro as well as macro studies on the various aspect of the agricultural economy of Assam. Singh and Singh (2013) and Krishnaiah (2011,a) pointed out that crop combination analysis enables us to view the various crops collectively in a given point of time and crop diversification denotes the multiplication of agricultural activities in an area where various crops compete each other for occupying space. Saha (2013) studied about Crop Diversification in Indian Agriculture and stated that Crop diversification is found to be continuing over the time period and most of the states are associated with this process. Raju (2012) also did similar study in Vizianagaram district, Andhra Pradesh. Sarkar and Bhattacharya (2011) have done land assessment study with the help of laboratory analysis of soil sample for agricultural study. Senapati and Santra (2008) mentioned that in the hill slopes, the catchment area are worst affected due to siltation. Taludar and Singh (2011) reveals that there has been a record change in land use pattern especially during the late 1990s and early 2000s when the Green revolution was initiated in Brahmaputra valley. Nath and Bora (2012) remarked that the rise of the river Brahmaputra bed after the great earthquake of 1950 increased the intensity and frequency of flood in plains.

Organization of the thesis

The thesis is organized into eight Chapters. The first chapter is introduction, where an introductory note to every chapter discussed in the thesis is mentioned. Statement of the problem, significance of the study, about the study area, objectives of the study, research methodology followed and review of literature are the main component of this chapter. The second chapter concentrates on land resources of Kakodonga river basin. This chapter mainly focus on physiography, relief, slope, drainage, geology, soil, natural vegetation, land use, intensity of soil erosion, land capability classification etc. Third chapter deals with morphometric characteristics of Kakodonga river basin under linear, areal and relief aspects. Fourth chapter highlights on water resources of the basin including temperature analysis, mean rainfall, rainfall intensity, rainfall variability and rainfall ratio analysis on monthly, seasonal and annual basis. The annual groundwater recharge and ground water resources of the basin are also estimated in this chapter. The fifth chapter focuses on water balance of the basin. The sixth chapter depicts land use, irrigation and cropping pattern of the basin. The revenue circle wise crop concentration, crop diversification, irrigation and land use pattern etc. are the focal themes discussed in the chapter. On seventh chapter watershed management planning is proposed through a selected macro watershed of Kakodonga River basin and also highlighted socio-economic aspect of watershed management. The last chapter is ‘Summery and Conclusion’ where a brief summary of whole research work has been incorporated and also included some suggestion for the policy makers to bring possible improvement in the Kakodonga river basin.

******

Chapter-2

Land Resources of the Kakodonga River Basin

2

2. Introduction:

Land resources have paramount importance for watershed management planning. Physical and socio-economic development of a region is mainly related with this component of nature. Land use/ land cover studies are of fundamental significance, as the land resources play a strategic rule in the determination of man's economic, social and cultural progress (Jabeen and Ahmed, 2013). Therefore, in this chapter an attempt has been made to cram all the land resources of the study area. IRS P6 LISS-III imagery (23.5mt resolution) 2011 and Survey of India topographic sheets on scale 1: 50, 000 have been used to prepare the base map and other thematic maps. All the topographic sheets and imageries are geo-referenced and digitized in GIS environment using Arc GIS and ERDAS Software. The relief and slope of the Kakodonga basin is studied from Survey of India topographic sheets. Soil map was obtained from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Jorhat division. Soil map of Kakodonga basin is traced out from this map. Following same method Geology map is also prepared which was collected from Geology department. The landforms, land use, hydro-geomorphic units, intensity of soil erosion and land capability classification maps have been prepared for fruitful study of land resources.

2.1 Relief

The term relief indicates vertical variation of land surface of the earth. Relief is the result of various geomorphic processes. Differences in elevation lead to variations in relief and others features like slope, drainage frequency and drainage density etc. (Singh and Sinha, 1996). The relief of the basin has been signified by absolute relief differences with a maximum elevation of 767 meter and minimum of 79 meter above Mean Sea Level (MSL). However the lowest and highest contours are recorded as 80 m and 760 m above MSL respectively. The highest point of the basin is identified at Yimbarasa village near Bhandari of Wokha District, Nagaland and lowest point at Darikamari, near Jorhat town of Assam, which is also the mouth of the river Kakodonga. The relief of the basin varies from extreme south to extreme north (Table 2.1 & Fig. 2.1). Out of the total, 691.26 sq. km area of the basin has less than 100 meter elevation from MSL, which comprises maximum portion of the basin viz., 62.11%. The altitude varies from 100 m to 200 m above MSL is lying over an area of 333.23 sq. km of the basin and it is comprised of 29.94 %. This area is noticed in foothills zone of Nagahills and spreading over north-eastern to south-western parts of the basin. The altitude varies from 200 m to 300 m in northeaster to south-eastern border of the basin. This altitude zone has an area of 51.53 sq. Km (4.63%). The altitude ranging from 300 m to 400 m above MSL is observed in southern portion and a small patch is spreading from north-eastern to south-eastern parts of the basin and it comprises 23.43 sq. Km (2.11%) area of the basin. The altitude zone ranges from 400 m to 500 meter above MSL is situated in southern portion of the basin and occupies 8.64 sq. km. (00.78%) area. The maximum elevated portion i.e. above 500 m MSL is confined in extreme southern tip of the basin, which occupies an area of 4.77 sq. km (0.43 %).

Table 2.1: Relief of the Kakodonga river basin

Sl. No.	Height in Meter	Area of the basin (In sq. km)	Area in %
1.	< 100	691.26	62.11
2.	100-200	333.23	29.94
3.	200-300	51.53	04.63
4.	300-400	23.43	02.11
5.	400-500	08.64	00.78
6.	> 500	04.77	00.43

Source: Survey of India Toposheet (1971)

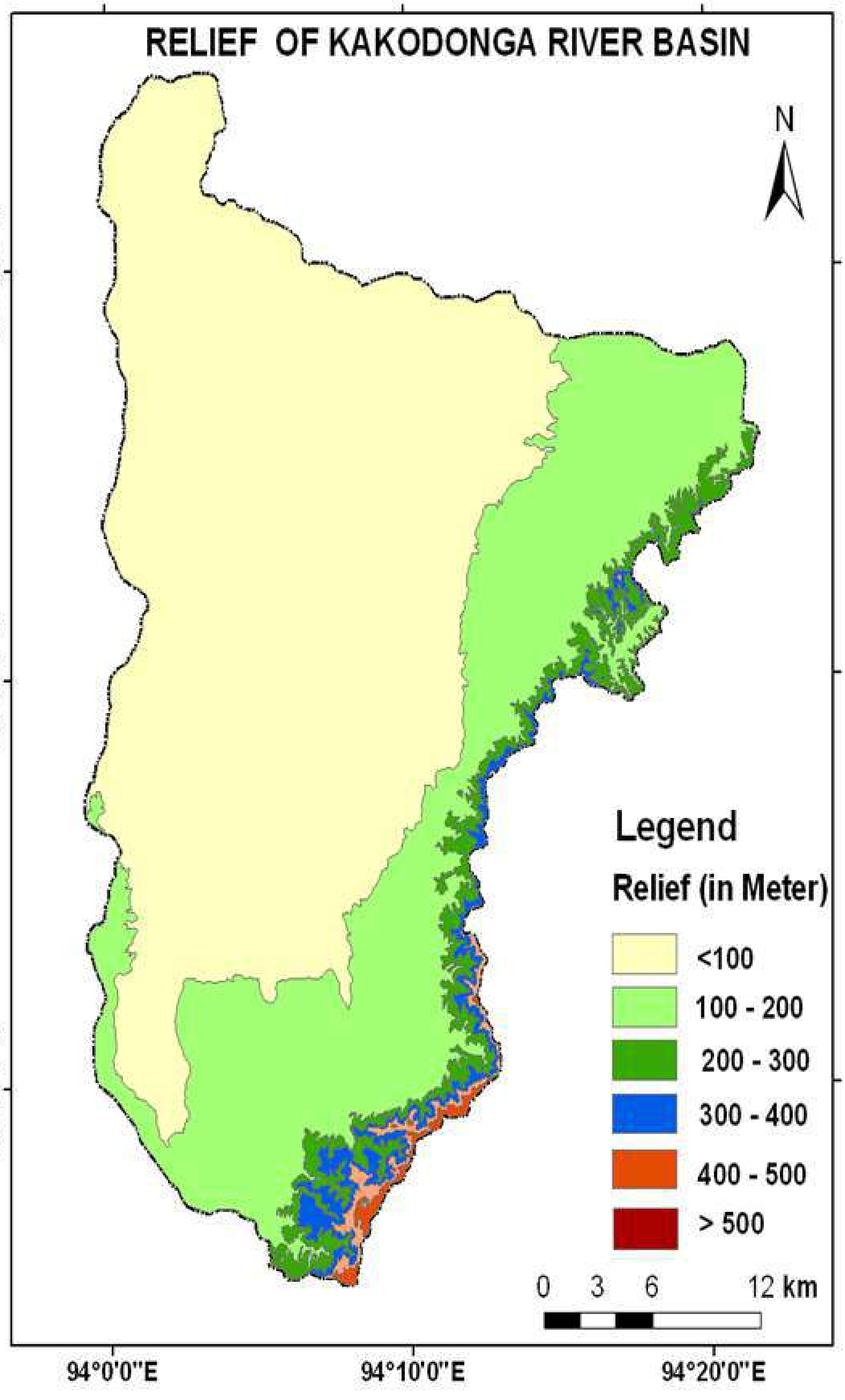

RELIEF OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
Relief (in Meter)
<100
100 - 200
200 - 300
300 - 400
400 - 500
> 500
0 3 6 12 km

Fig. 2.1

2.2. Slope

The slope influences the rate and amount of runoff and has a direct impact on soil erosion. The slope map of the Kakodonga river basin is prepared in GIS environment using spatial analysis technique. The slope units have been divided into six categories. The first category is less than 5^0 (very gently sloping). The second category is 5^0 to 10^0 (gently sloping). The third category of slope unit varies from 10^0 to 20^0 (moderately sloping). The fourth category of slope unit ranges from 20^0 to 30^0 (strongly sloping). The fifth category of slope unit ranges from 30^0 to 40^0 (very strongly sloping) and sixth category of slope unit indicates above 40^0 (steeply sloping) slope areas. (Table 2.2 & Fig. 2.2). The maximum area of the basin i.e. 956.55 sq. km (85.96 %)

Table 2.2: Slope of the Kakodonga river basin

Sl. No.	Slope (In degrees)	Area of the basin (In sq. km)	Area in %
1.	0-5^0 (Very gently sloping)	956.55	85.96
2.	5^0-10^0 (Gently sloping)	48.14	04.34
3.	10^0-20^0 (Moderately sloping)	68.16	06.12
4.	20^0-30^0 (Strongly sloping)	33.60	03.02
5.	30^0-40^0 (Very strongly sloping)	5.77	0.52
6.	Above 40^0 (Steeply sloping)	0.42	0.04

Source: Survey of India Toposheet (1971)

falls under the slope category of below 5^o, while the slope category of above 40^o accounts a very less area i.e. 0.42 Km^2 (0.04%) of the basin. The steeply

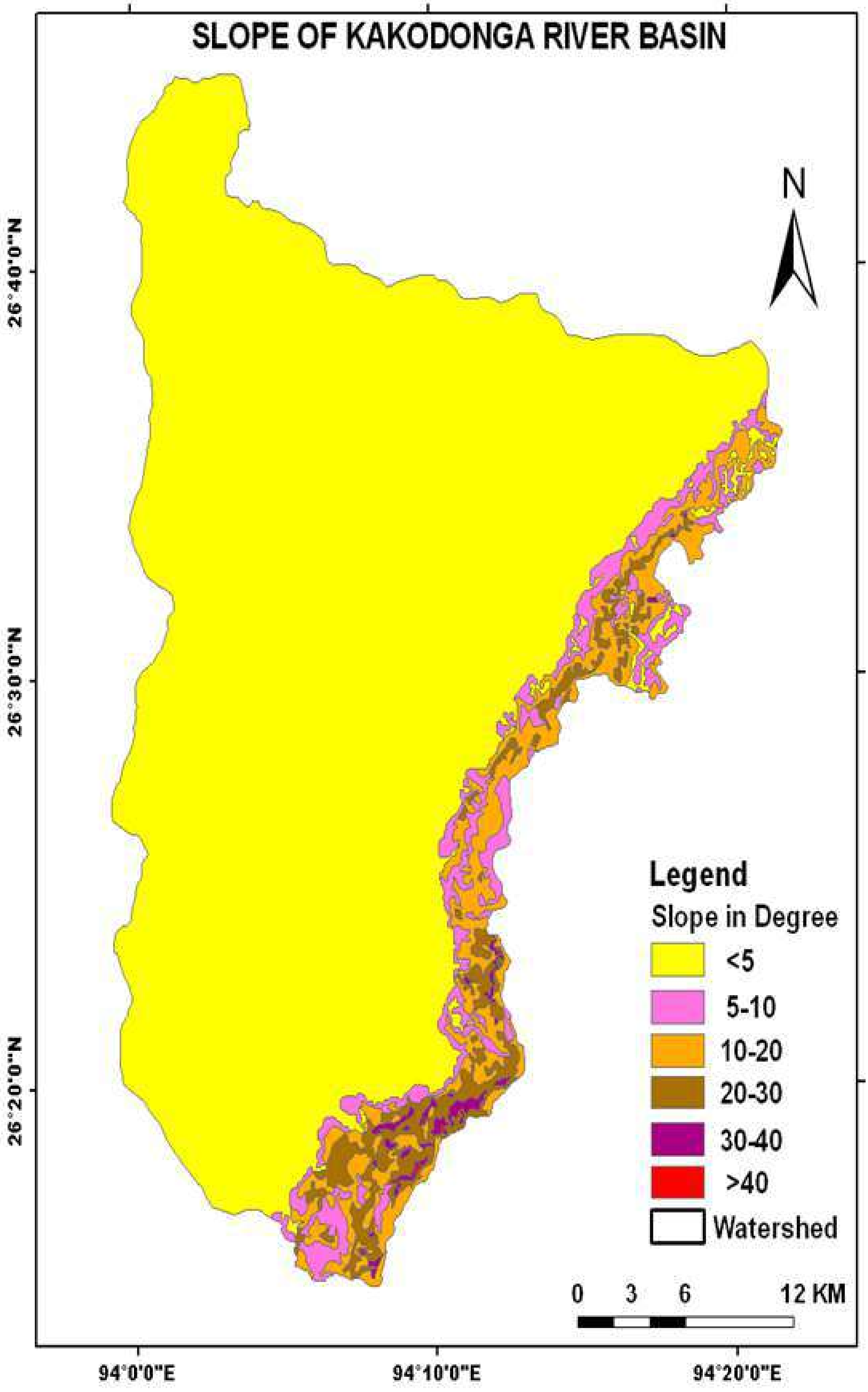

SLOPE OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
Slope in Degree
<5
5-10
10-20
20-30
30-40
>40
Watershed
0 3 6 12 KM

Fig. 2.2

sloping area is found in south-eastern part of the basin i.e. in hilly areas of Nagaland and majority of the basin is sloping area is found in south-eastern part of the basin in hilly areas of Nagaland and majority of the basin is being dominated by very gentle slope i.e. 956.55 (85.96 %), followed by moderately sloping (6.12%), gently sloping 48.14 sq. km (4.34%), strongly sloping (3.02%) and very strongly sloping (0.52%) areas respectively.

2.3. Drainage

The Kakodonga is one of the important southern tributaries of the mighty river Brahmaputra in North East India. It originates in Naga Hills near Lio Longidum village of Wokha district, Nagaland and traverses a distance of 105.90 km through hills and extensive plain area until reaching its confluence with the Gelabil River (Fig. 2.3). Its major right bank tributaries are Bojalkata, Chereli, Soraipani, Kasojan, Dholi, Doijan and left bank tributaries are Chelcheli, Ghiladhari and Khar Jan. Kakodonga River is also known as Delsiri River in ancient time. After originating in Naga Hills the river enters in plains of Assam near Kulajan and flows towards westerly direction until its joins with Chelcheli. After that the river flows almost straightway in northern direction for a distance of about 9 km. Then it takes north eastern direction and meets Bojalkata Jan from right bank of the river. Near Borholla Kakodonga River takes a bend and flows towards north westerly direction. After that the river flows toward northern direction and Ghiladhari River joins at Bosa village. After crossing North East Frontier railway line Kakodonga

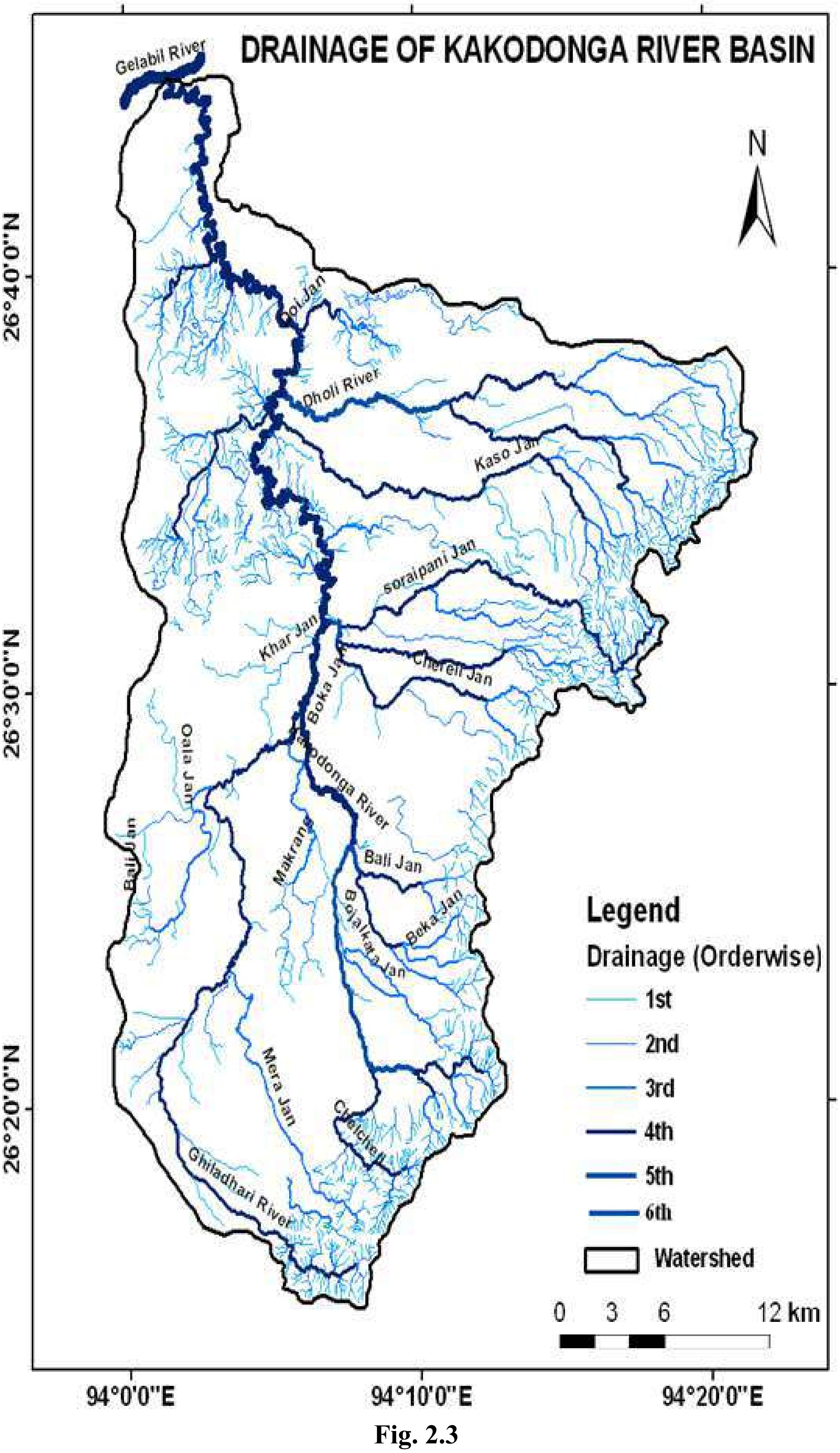

DRAINAGE OF KAKODONGA RIVER BASIN
Gelabil River
Doi Jan
Dholi River
Kaso Jan
soraipani Jan
Khar Jan
Chereli Jan
Boka Jan
Oala Jan
Kakodonga River
Bali Jan
Makrang
Bojalkata Jan
Beka Jan
Mera Jan
Chelchel
Ghiladhari River
N
Legend
Drainage (Orderwise)
1st
2nd
3rd
4th
5th
6th
Watershed
0 3 6 12 km
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E

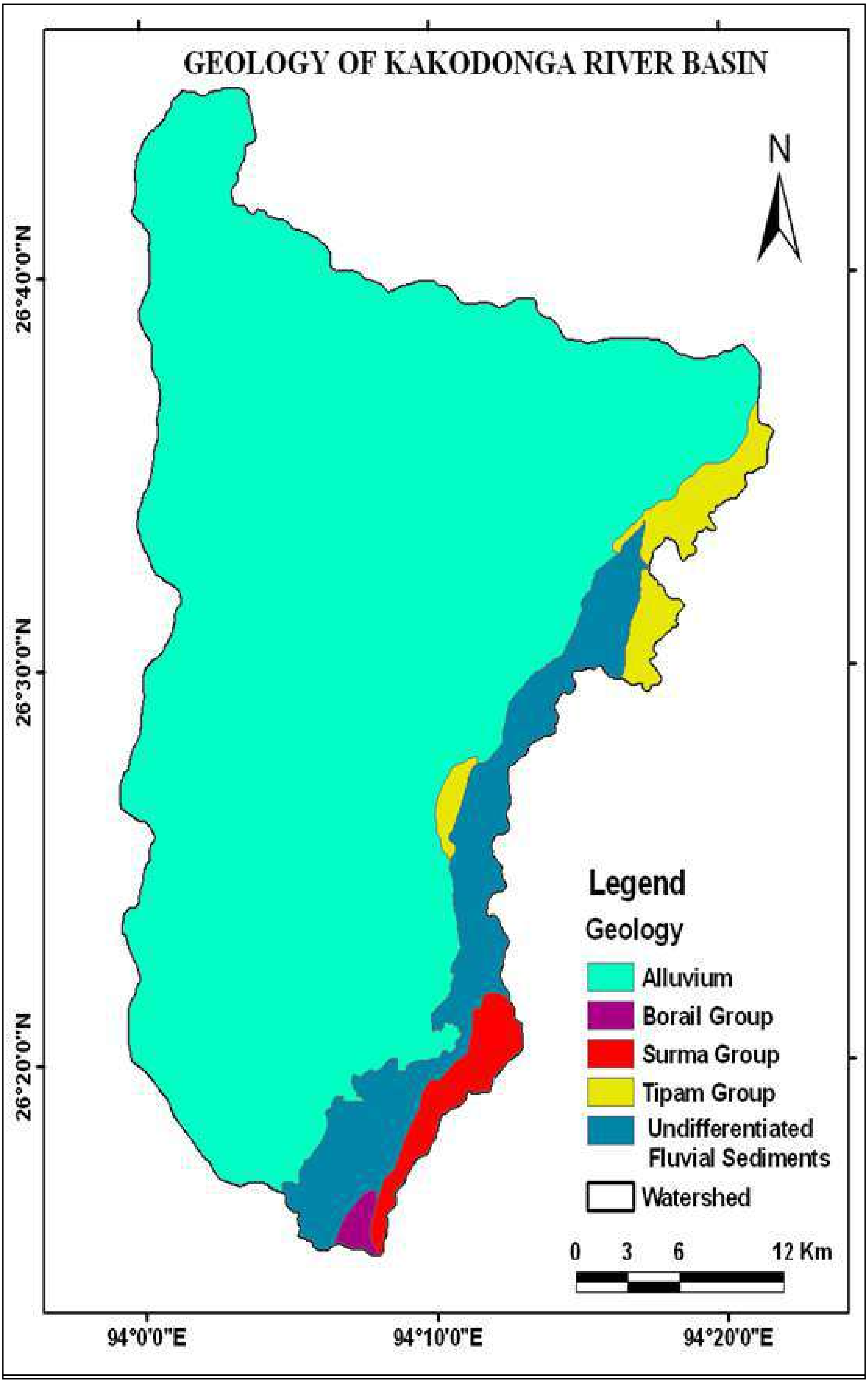
Fig. 2.3

takes its course towards northwestern and then turns towards northeastern direction. After taking Kasojan, Dholi and Doijan in its right side the river again turns towards north westerly direction and then flows towards north. Thereafter, it turns toward north-western side and again flows towards west to meet the Gelabil River. Gelabil, Bhogdoi and Dhansiri River finally discharge to the Brahmaputra River. The river Kakodonga forms innumerable numbers of small meanders in its course remarkably from the joining point of Ghiladhari river to its confluence with Gelabil River for a distance of about 74 km. About 95 % of the total course of the river is in plain area. Only 5% of its course is in hilly areas of Nagaland. The river is also administrative boundary between Golaghat and Jorhat districts of Assam.

2.4. Geology

Barring a few isolated patches, all the rock types in the plain are hidden below a thick blanket of alluvium. The geologically the basin is composed of mainly Archaen group comprising a metamorphic complex of gneisses and schist, the Pre-Cambrian group consisting of quartzite's and phyllites, the lower tertiary shelf (Eocene) sediments of Borail Group, Surma Group and Tipam Group, the Upper Tertiary (Oligo-Mio-Pliocene) shelf and unclassified Older and Newer Alluvium of Quaternary deposits (Anonymous, 1974).

The recent alluvium soil is deposited in the Kakodonga River's mouth and valley. It is formed of alluvium, gravel and calcareous tuff (Table 2.3 & Fig. 2.4). The majority of the area of the basin is covered by alluvium soils (85.88%), followed by undifferentiated fluvial sediments (8.76%). This group



GEOLOGY OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
Geology
Alluvium
Borail Group
Surma Group
Tipam Group
Undifferentiated Fluvial Sediments
Watershed
0 3 6 12 Km

Fig. 2.4

is spreading over south eastern border of the basin. The tip of the south-eastern part of the basin has Borail Group (0.40%), and Surma Group (1.98%) soil. The northeastern part of the basin is composed of Tipam Group (2.98%).

Table 2.3: Geology of the Kakodonga river basin

Sl. No.	Geology	Area of the basin (In sq. km)	Area in %
1.	Alluvium	955.76	85.88
2.	Borail Group	4.35	0.40
3.	Surma Group	22.05	1.98
4.	Tipam Group	33.21	2.98
5.	Undifferentiated Fluvial Sediments	97.49	8.76

Source: Geology department

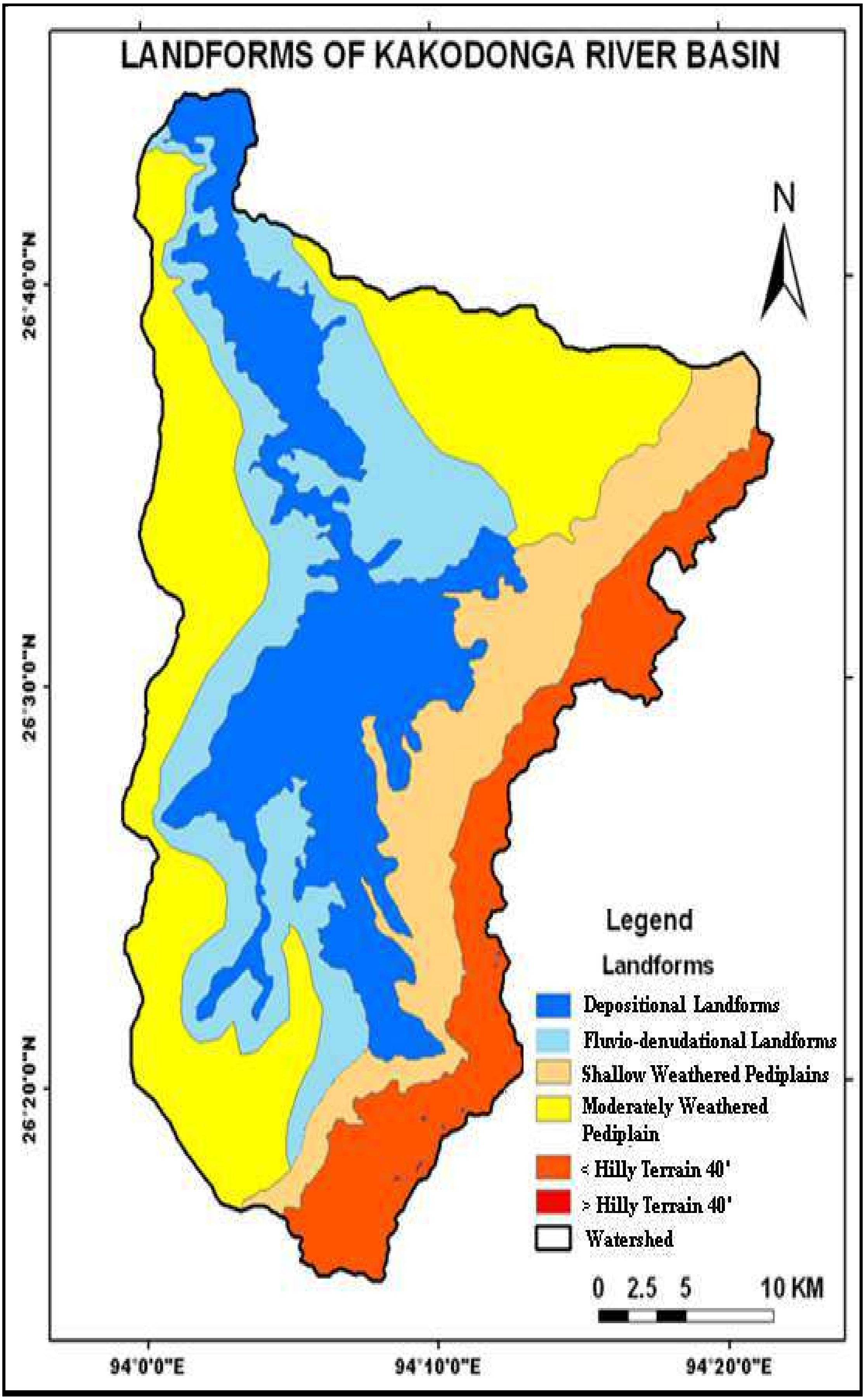
2.5. Landforms

On the basis of relief, slope, drainage and geological formations, the Kakodonga river basin can be divided into three major landform groups viz., denudational, fluvio-denudational and depositional landforms. The denudational landforms are formed of structural hills, structural valleys, piedmont plains, creep built plains and pediplains. The fluvio-denudational landforms build up of terraced plains, valley fills, bajada and wash plains. The fluvial landforms consist of fluvial plains, flood plains, fluvial terraces and natural levees. The depositional landforms develop on the flood plains, younger alluvial plains, older alluvial plains and upper piedmont plains of the basin. There are numerous alluvial fans formed by the alluvial deposits at the base of the hills orienting towards the plain. These alluvial fans vary in thickness and presence an undulating topography. These lands form the depositional lands which have undulating topography in many places (23.36%). The fluvio-denudational landform represents the area which remains under inundation during the floods (19.25%). It is derived from extensive deposits of alluvium brought down by upper streams. When the area is affected by frequent floods it is designated as active flood plain. The shallow weathered pediplains (29.07%) located in eastern part of the basin and also moderately pediplains (15.11%) found in northern and western parts of the basin. The hilly terrain less than and more than 40^0 slope mainly exist in Nagaland part (13.21%). The large number of streams of the basin originated from this terrain. This part of hills falls under reserved forests arera (Table 2.4 & Fig. 2.5).

Table 2.4: Landforms of the Kakodonga river basin

Sl. No.	**Landforms**	**Area of the basin (In sq. km)**	**Area in %**
1.	Depositional	300.08	23.36
2.	Fluvio-denudational	214.19	19.25
3.	Shallow Weathered Pediplains	323.47	29.07
4.	Moderately Weathered Pediplains	168.18	15.11
5.	< Hilly Terrain 40'	146.52	13.17
6.	> Hilly Terrain 40'	0.42	00.04

Source: Compiled data



LANDFORMS OF KAKODONGA RIVER BASIN
N
Legend
Landforms
Depositional Landforms
Fluvio-denudational Landforms
Shallow Weathered Pediplains
Moderately Weathered Pediplain
< Hilly Terrain 40'
> Hilly Terrain 40'
Watershed
0 2.5 5 10 KM
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E

Fig. 2.5

2.6. Soil

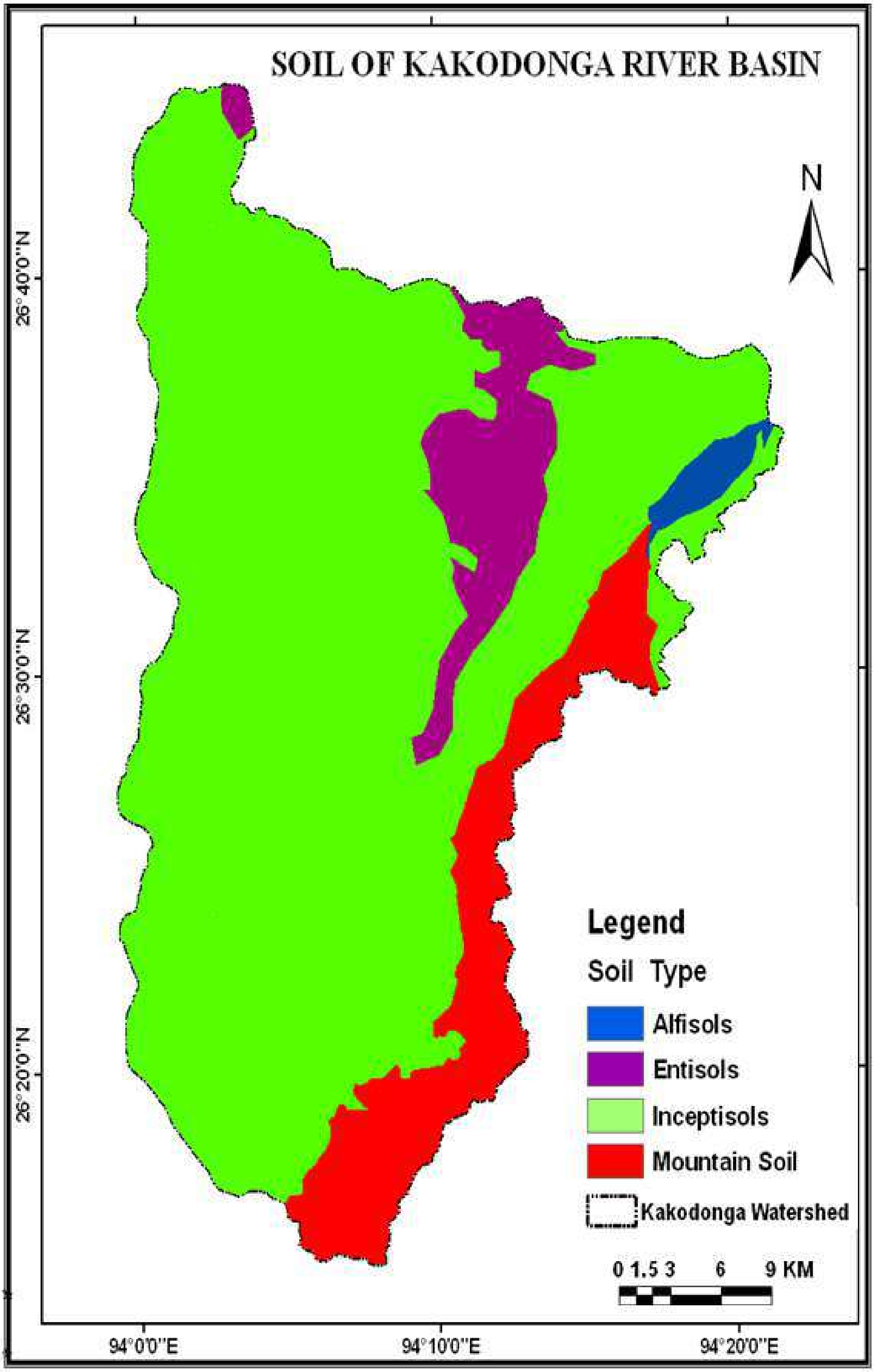
According to Sen *et al* (1999) different types of major soils are identified in Kakodonga river basin. It is observed that the Inceptisols (73.71%) are dominant soils of the basin followed by Entisols (13.45%), Alfisols (1.24%) and Mountain soils (11.6%). The old alluvial soils are classified as fine aquic dystric eutrochrepts, fine loamy aeric fluvaquents, fine

Table 2.5: Soil types and soil sub-groups of the Kakodonga river basin

Soil types	Area (In Km^2)	Area in %	Soil sub-groups	Area (In Km^2)	Area in %
Entisols (Recent alluvial soils)	149.69	3.45	Coarse loamy , Mollic Fluvaquents	3.22	0.29
			Fine loamy Aeric Haplaquepts	146.47	13.16
Inceptisols (Old alluvial soils)	820.24	73.71	Fine Aquic Dystric Eutrochrepts	100.20	9.01
			Fine loamy Aeric Fluvaquents	24.78	2.23
			Fine loamy Typic Dystrochrepts	539.34	48.46
			Fine loamy Umbric Dystrochrepts	15.74	01.41
			Coarse loamy Typic Dystrochrepts	140.18	12.60
Alfisols (Red soils)	13.80	01.24	Fine Loamy Typic Paleudalfs	13.80	01.24
Mountain Soil	129.13	11.60	Mountain Soil	129.13	11.60

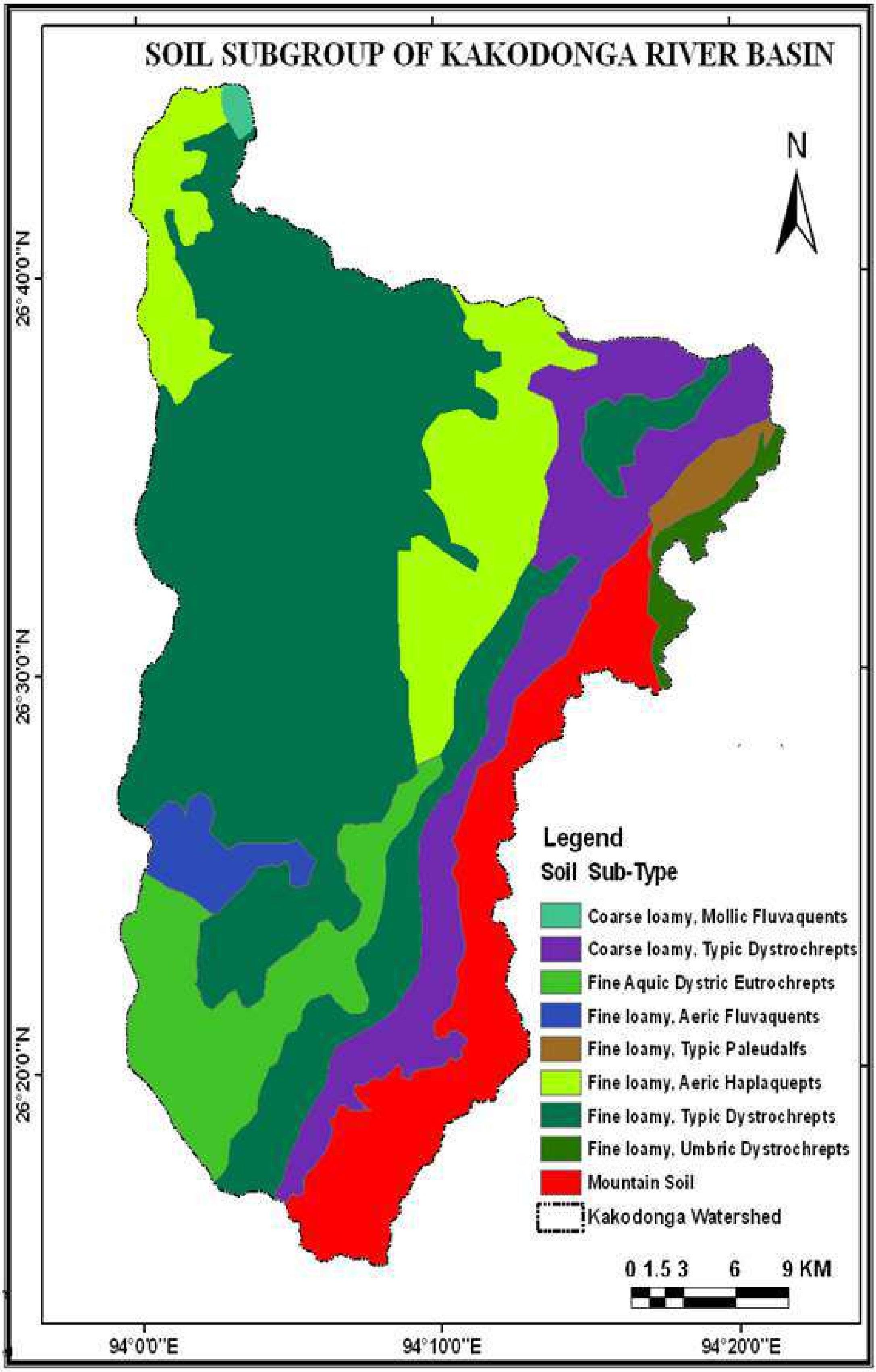
Source: National Bureau of Soil Survey & Land Use Planning

loamy typic dystrochrepts, fine loamy umbric dystrochrepts and coarse loamy typic dystrochrepts sub soil groups (Table 2.5, Fig. 2.6 & 2.7).These soils occupy majority of the plain area of Assam. The recent alluvial soils (Entisols) are classified as coarse loamy, mollic fluvaquents and fine loamy aeric



Source: National Breau of Soil Survey and Land Use Planning

Fig. 2.6



Source: National Breau of Soil Survey and Land Use Planning

Fig. 2.7

haplaquepts sub soil groups. These are present in northern and tip of northwestern parts of the basin. The Alfisols (Red Soils) are found in northeastern part. The mountain soils derived from gneisses and schist of the Archaean group. These soils form the eastern border of the basin.

2.7. Land Use Land Cover (LULC)

The land use and land cover of the Kakodonga river basin has been studied using IRS P6 LISS-III imagery 2011 and Survey of India topographic sheets on scale 1:50,000. The five categories of land use are identified.

Table 2.6: Land-Use and Land Cover of the Kakodonga River Basin

Class	Area (in sq. km)	Area in %	Sub class	Area (in sq. km)	Area in %
Built-up land	399.73	35.92	Built-up land	399.73	35.92
Agricultural land	549.31	49.36	Kharif	383.40	34.45
			Miscellaneous Crops	2.32	0.21
			Tea Estate	159.99	14.38
			Shifting cultivation	3.59	0.32
Water bodies	8.28	0.74	River	6.36	0.57
			Pond	1.13	0.10
			Beel	0.78	0.07
Wasteland	45.29	04.07	Marshy land	2.07	0.19
			Scrubland	12.13	1.09
			Degraded Forest	31.05	2.79
			Steep Sloping Area	0.04	0.0003
Natural Forest	110.36	09.91	Natural Forest	110.36	09.91

Source: IRS P6 LISS III Imagery

They are agricultural land (49.36%), built up land (35.92%), forest (9.91%), wastelands (4.07%) and water bodies (0.74%). The agricultural land is found in recent alluvial soils, fluvial plains and wash plains area and here dominating

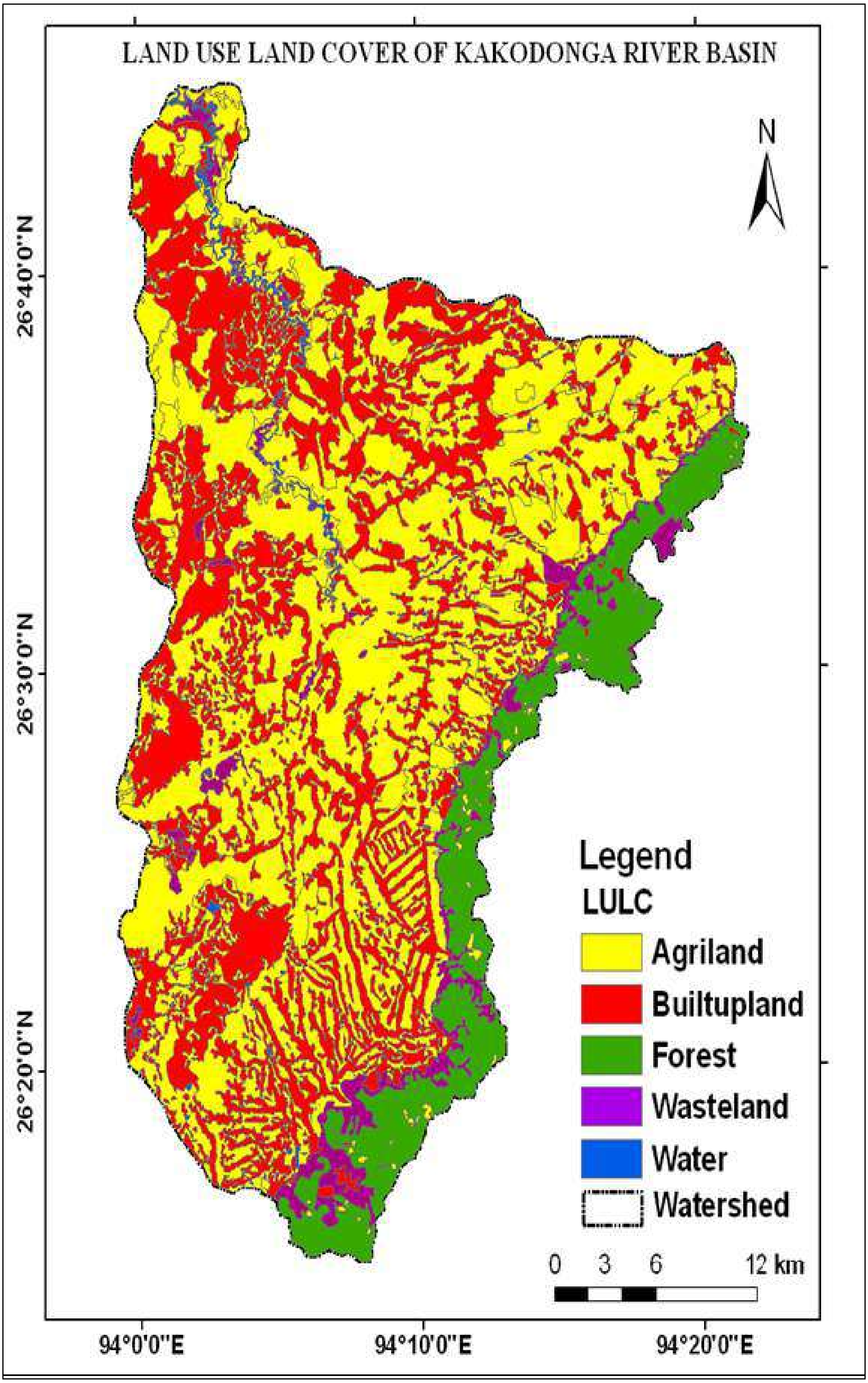

LAND USE LAND COVER OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
LULC
Agriland
Builtupland
Forest
Wasteland
Water
Watershed
0 3 6 12 km

Fig. 2.8

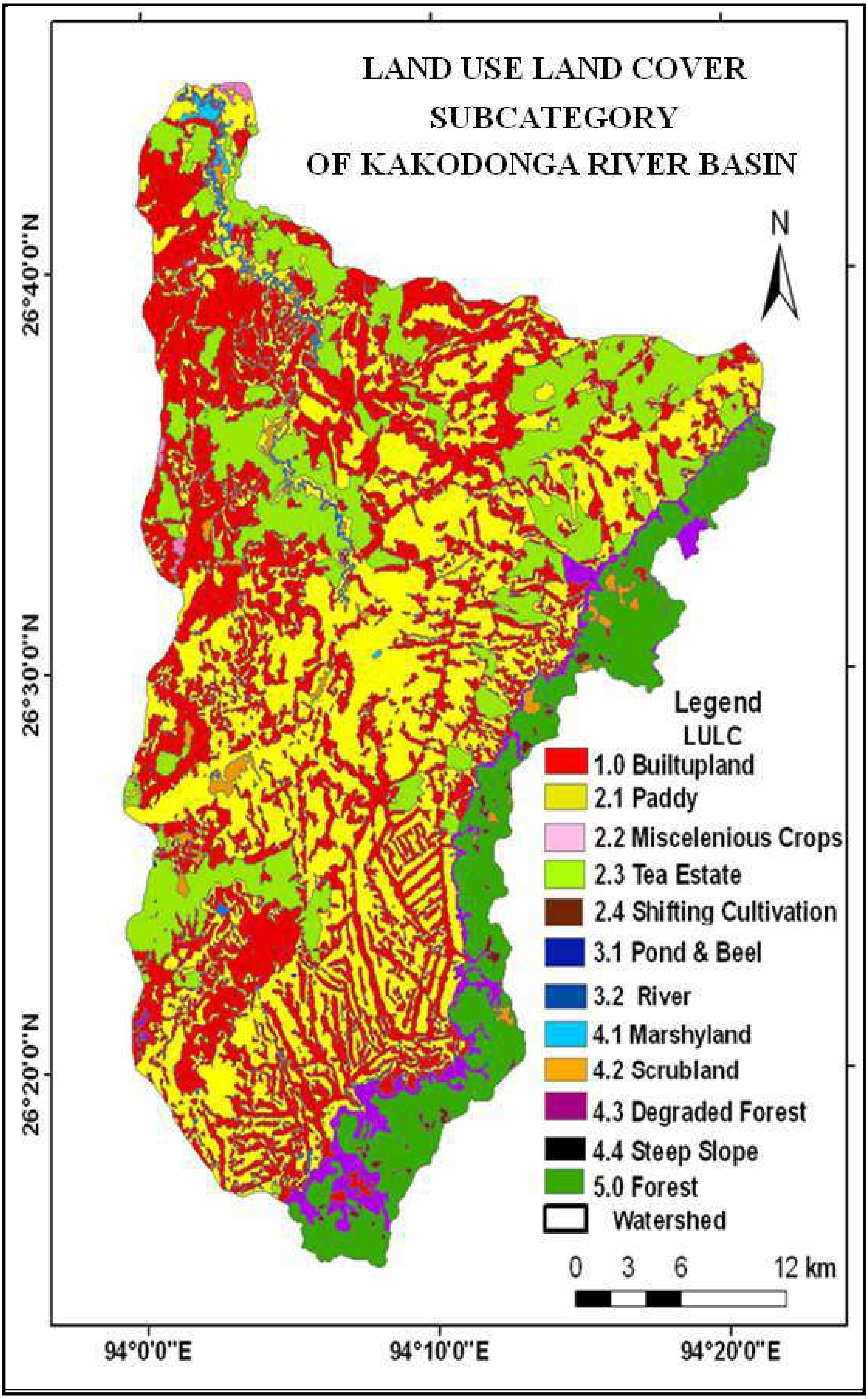

LAND USE LAND COVER
SUBCATEGORY
OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
LULC
1.0 Builtupland
2.1 Paddy
2.2 Miscelenious Crops
2.3 Tea Estate
2.4 Shifting Cultivation
3.1 Pond & Beel
3.2 River
4.1 Marshyland
4.2 Scrubland
4.3 Degraded Forest
4.4 Steep Slope
5.0 Forest
Watershed
0 3 6 12 km

Fig. 2.9

crops is paddy only. The built up land is noticed in old alluvial soils and pediplains. The tea crop is grown in pediplains and shifting cultivation is practiced in forest area. The waste lands are associated with degraded forest. A small stretch of forest is found in eastern part of the basin, basically in hilly area (Table 2.6, Fig. 2.8 & 2.9).

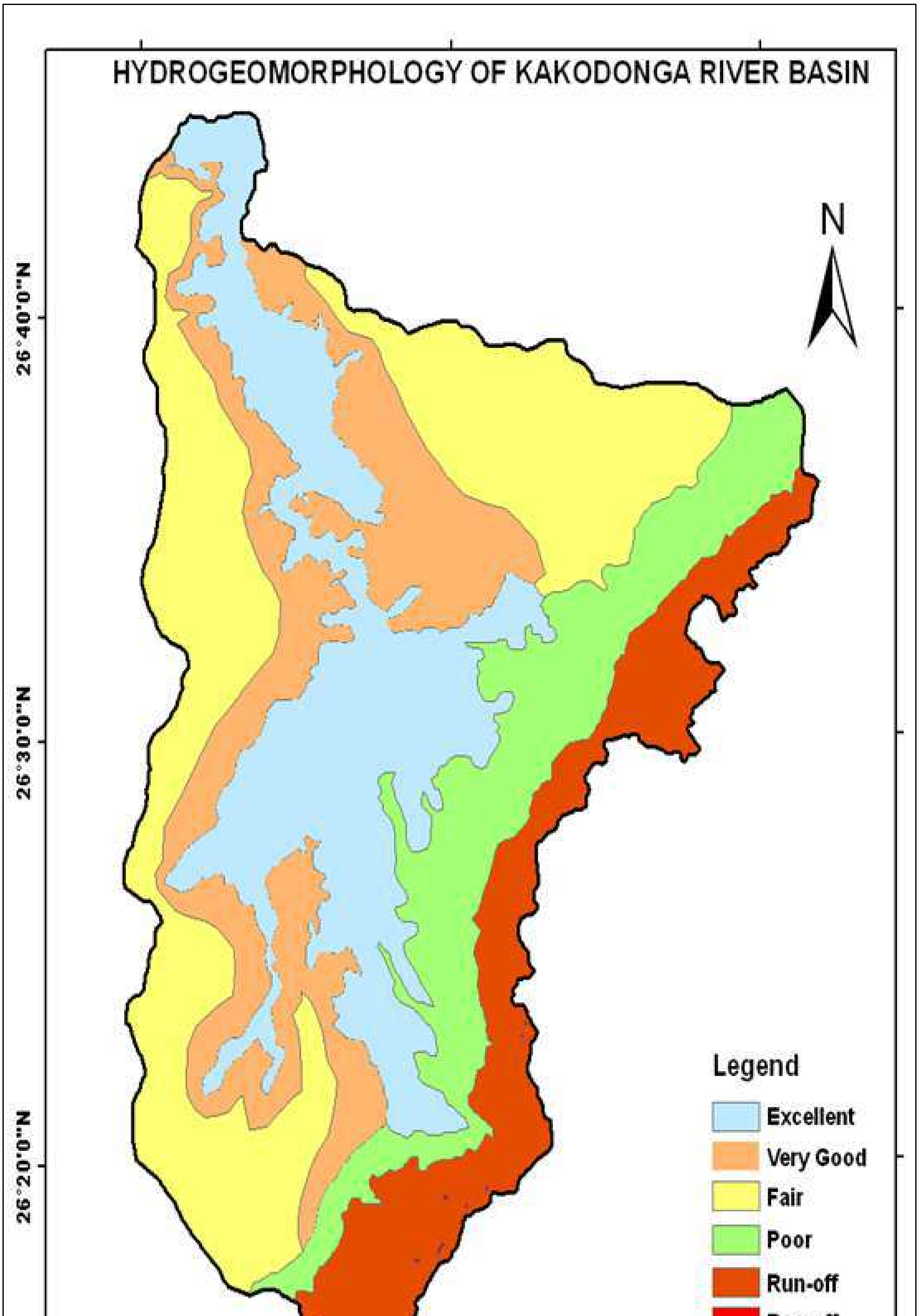
2.8. Hydrogeomorphology

The hydrogeomorphologically the Kakodonga basin is divided into five hydro-geomorphic zones. They are excellent, very good, fair, poor and run-off zones (Table 2.7 & Fig. 2.10). The excellent ground water potentiality is found in the fluvial plains of the Kakodonga basin (23.36%). The very good ground water potential zone is noticed in the wash plains and structural valleys (19.25%). The fair ground water potential zone is found in the moderately weathered pediplains (29.07%). The poor ground water potential zones are found in the shallow weathered pediplains (15.11%). Structural hills and residual hills are located in run-off zone (13.21%).

Table 2.7: Hydrogeomorphology of the Kakodonga river basin

Sl. No.	Hydrogeomorphology	Area of the basin (In sq. km)	Area in %
1.	Excellent	300.08	23.36
2.	Very good	214.19	19.25
3.	Fair	323.47	29.07
4.	poor	168.18	15.11
5.	Run-off	146.94	13.21

Source: Compiled data



HYDROGEOMORPHOLOGY OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
Excellent
Very Good
Fair
Poor
Run-off
Run-off
0 3 6 12 KM

Fig. 2.10

2.9. Intensity of soil erosion

Soil erosion is a serious problem in Assam especially in the hilly regions and in the flooded zones areas. Six classes of soil erosion intensity zone have been identified in the basin using Bhattacharyya *et al* (2002) method. The spatial distribution of the soil loss is estimated on the basis of this method (Table 2.8 & Fig. 2.11). From the study it is found that the intensity of soil erosion varies from 0 to 40 tonnes / hectare/ year. The intensity of soil erosion is very severe and very high in structural and residual hills. It is between 20 to >40 t/ ha/yr (3.26%) The intensity soil erosion is high (15-40 t/ha/yr) in shallow weathered pediplains. The intensity of soil erosion is medium (10-15 t/ha/yr) in moderately weathered pediplains. In fluvial plains and wash plains the intensity of soil erosion is poor and very poor respectively. It is less than 10t/ha/yr (79.28%).

Table 2.8: Intensity of Soil erosion of the Kakodonga river basin

Sl. No.	Intensity of Soil Erosion	Area of the basin (In sq. km)	Area in %
1.	Very severe (> 40 t/ha/yr)	03.06	0.27
2.	Very high (20-40 t/ha/yr)	33.27	2.99
3.	High (15-20 t/ha/yr)	94.89	8.52
4.	Medium (10-15 t/ha/yr)	99.48	8.94
5.	Poor (05-10 t/ha/yr)	507.86	45.64
6.	Very poor (<05 t/ha/yr)	374.30	33.64

Source: Compiled data

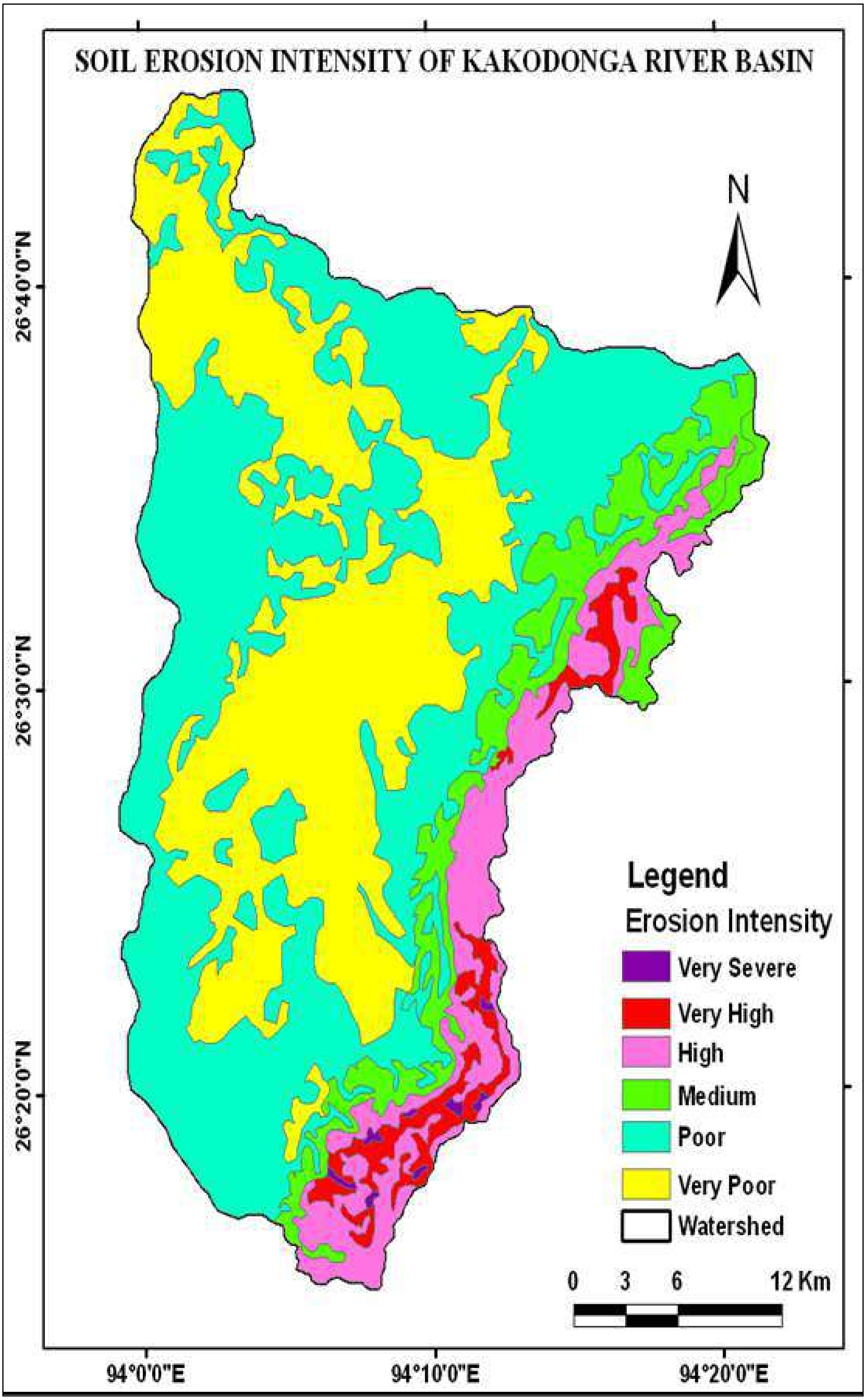

SOIL EROSION INTENSITY OF KAKODONGA RIVER BASIN
N
Legend
Erosion Intensity
Very Severe
Very High
High
Medium
Poor
Very Poor
Watershed
0 3 6 12 Km
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E

Fig. 2.11

2.10. Land capability Classification

The land capability classification has been evaluated based on the physical characteristics of the basin. Six classes of land are identified in the study area. They are Class – I (fluvial plains), Class – II (wash plains and valley fills), Class – III (moderately weathered pediplains), Class- IV (shallow weathered pediplains), Class – V (hilly terrain less than 40^0 slope), Class – VI (hilly terrain with greater than 40^0 slope) (Table 2.9 & Fig. 2.12).

CLASS – I

The Class – I land consists of fluvial plains deposited by major streams of Kakodonga river. They are located in central part and around the main stream of the river. In this class of land the slope is less than 5^0 and the ground water potentiality is excellent. The soil fertility is very good. The recharge is high. The intensity of soil erosion is very poor. The soil productivity is high. The soil and land irrigability are grouped under class – A & Class – 1 respectively. The major crops cultivated are paddy, rape and mustard and vegetables. The land development activities that could be carried out are land mulching, land levelling and land grading.

CLASS – II:

The Class – II land is comprised of wash plains and valley fills. The slope is less than 5^0. The ground water potential is very good. The recharge is also high. The soil fertility is good. The intensity of soil erosion is poor. The soil and land irrigability are grouped under class – A & Class – 2 respectively. The crops cultivated are paddy, rape and mustard, sugar cane and vegetables. The land development activities that could be carried out are land levelling, land mulching and land grading.

CLASS – III:

The Class – III land is composed of moderately weathered pediplains, which consist of red soil. The slope is less than 5^0. The ground water potential is fair. The soil fertility is moderate. The intensity of soil erosion is poor. The soil and land irrigability are grouped under class – B and Class – 3 respectively. The major crops cultivated are paddy, matikalai, mogu, masur, black pepper etc. The land development activities that could be carried out are land levelling, land mulching and land grading.

CLASS – IV:

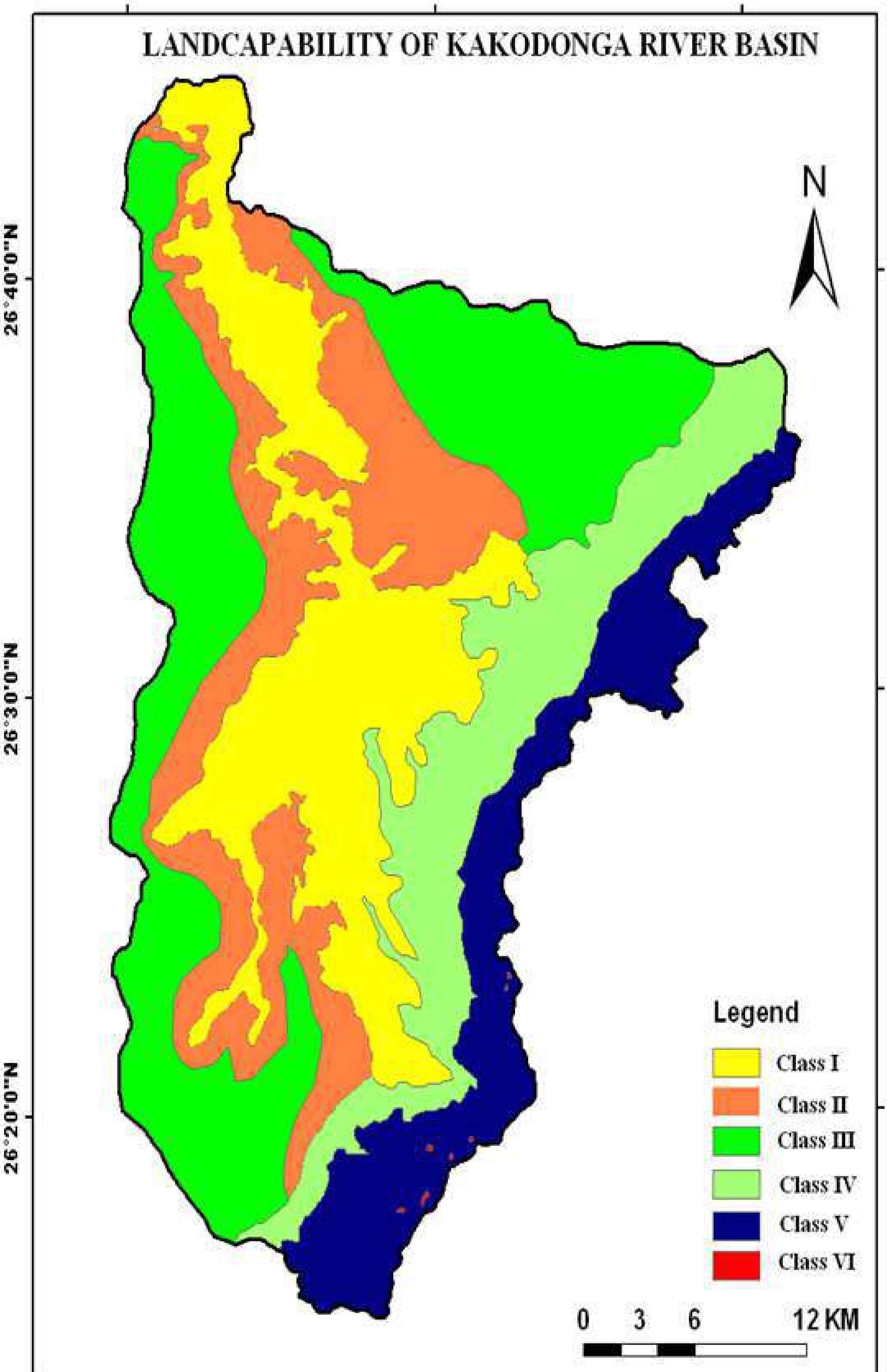
The Class – IV land consists of shallow weathered pediplains and piedmont plains. The slope varies from 5^0 to 10^0, 10^0 to 20^0 and 20^0 to 30^0. The soil fertility is moderate. The ground water potential is poor. The ground water recharge is moderate. The intensity of soil erosion is moderate. The crops cultivated are paddy, tea gardens, potato, onion and black pepper. The soil and land irrigability are Class –C and Class –3 respectively. The land development activities that could be carried out are land levelling, land mulching, land grading and land bunding.

CLASS – V:

The Class – V land consists of hilly terrain with less than 40^0 slope. The slope varies from 30^0 to 40^0. It is a run-off zone. The soil fertility is poor. The recharge is low. The intensity of soil erosion is very high. The soil and land irrigability are grouped under class –D and Class – 5. The crops cultivated are chilly, ginger, wheat and also practiced jhum cultivation. In this class of land forest with scrubs and degraded forest are noticed. The land development activities that could be carried out in this class are afforestation, terrace bunding, rock fill dams, contour bunding, land terracing and stone terracing.

CLASS – VI

The Class – VI land is comprised of hilly terrain with more than 40^0 slopes. The soil fertility is poor. It is a run-off zone. The intensity of soil erosion is very severe. The land development activities like land terracing, contour bunding, terrace bunding and rock fill dams should be carried out. This land should be used for the growth of natural forests. Biodiversity has to be maintained. The soil and land irrigability are grouped under class – D and Class – 5 respectively.



LANDCAPABILITY OF KAKODONGA RIVER BASIN
N
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
Legend
Class I
Class II
Class III
Class IV
Class V
Class VI
0 3 6 12 KM

Fig. 2.12

Table 2.9: Classification of Land capability of the Kakodonga river basin

Sl No	Class	Land Units	Slope	Soils Fertility	Ground Water Potential	Present Land Use	Soil Erosion Susceptibility	Land Development Activity
1.	I	Fluvial Plains	$<5^0$	Very good	Excellent	Cultivated (wet) Rice, rape and mustard	Poor	Land mulching, Land levelling and Land grading.
2.	II	Wash Plains & Valley fills	$<5^0$	Good	Very good	Cultivated (wet & dry) Rice, rape and mustard and sugarcane,	Poor	Land levelling, Land mulching and Land grading.
3.	III	Moderately Pediplains	$<5^0$	Moderate	Fair	Cultivated land (wet & dry) Rice, matikalai, mogu, masur, black pepper	Poor	Land levelling, Land mulching and Land grading.
4.	IV	Shallow Weathered Pediplains	5^0-10^0 10^0-20^0 20^0-30^0	Moderate	Poor	Cultivated (dry) Rice, tea gardens, potato, onion, black pepper	Moderate	Land levelling, Land mulching, Land grading and Land bunding.
5.	V	Hilly terrain less than 40^0	30^0-40^0	Poor	Run-off	Chilly, ginger, wheat, jhum cultivation, degraded forest and forest with scrubs	Very high	Afforestation, Terrace bunding, Rock fill dams, Contour bunding, Land terracing and Stone terracing.
6.	VI	Hilly terrain more than 40^0	$> 40^0$	Poor	Run-off	Forest	Very severe	Land terracing, Contour bunding, Terrace bunding and Rock fill dams

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Chapter-3

Morphometric Analysis of the Kakodonga River Basin

3

3. Introduction:

A river basin or a water body has distinct identity with its own set of landform, vegetation and climate. It captures rainfall and carries the overland flow and run-off to an outlet of the main flow channel. River basin is a broad concept for the understanding of such hydrological system. Basins are natural ideal unit for assessment of available resources and subsequent planning and implementation of various development programmes. Due to the rapid growth of population in India there is an urgent need for the efficient and proper management of the river basins for the ultimate benefit of human being as well as for sustainable development.

Quantitative measurement of drainage basin and its parameters provides lot of in-depth understanding about the nature of the drainage basin as well as the drainage system. Therefore morphometric parameters have been used in various studies of geomorphology and surface water hydrology, such as flood characteristics, sediment yield and evolution of river basin morphology. The infiltration of water with time depends on morphometric parameters of any catchment area. The morphometric parameter of Kakodonga River basin reveals distinct characteristics, which are linear, areal and relief parameters. At present GIS techniques are used for assessing different terrain and morphometric parameters of drainage basin, as they offer a good environment and powerful tool for analysis of spatial information.

The present study mainly focuses on:

1. Linear morphometric analysis like estimation of stream orders, number of streams, length of stream orders, mean stream length, bifurcation ratio, mean bifurcation ratio and regression.
2. Areal morphometric analysis of the basin like drainage density, stream frequency, texture ratio, circularity ratio, elongation ratio, form factor ratio, constant of channel maintenance and length of overland flow.
3. Relief parameter analyses including the parameters like basin relief, relief ratio and ruggedness number.

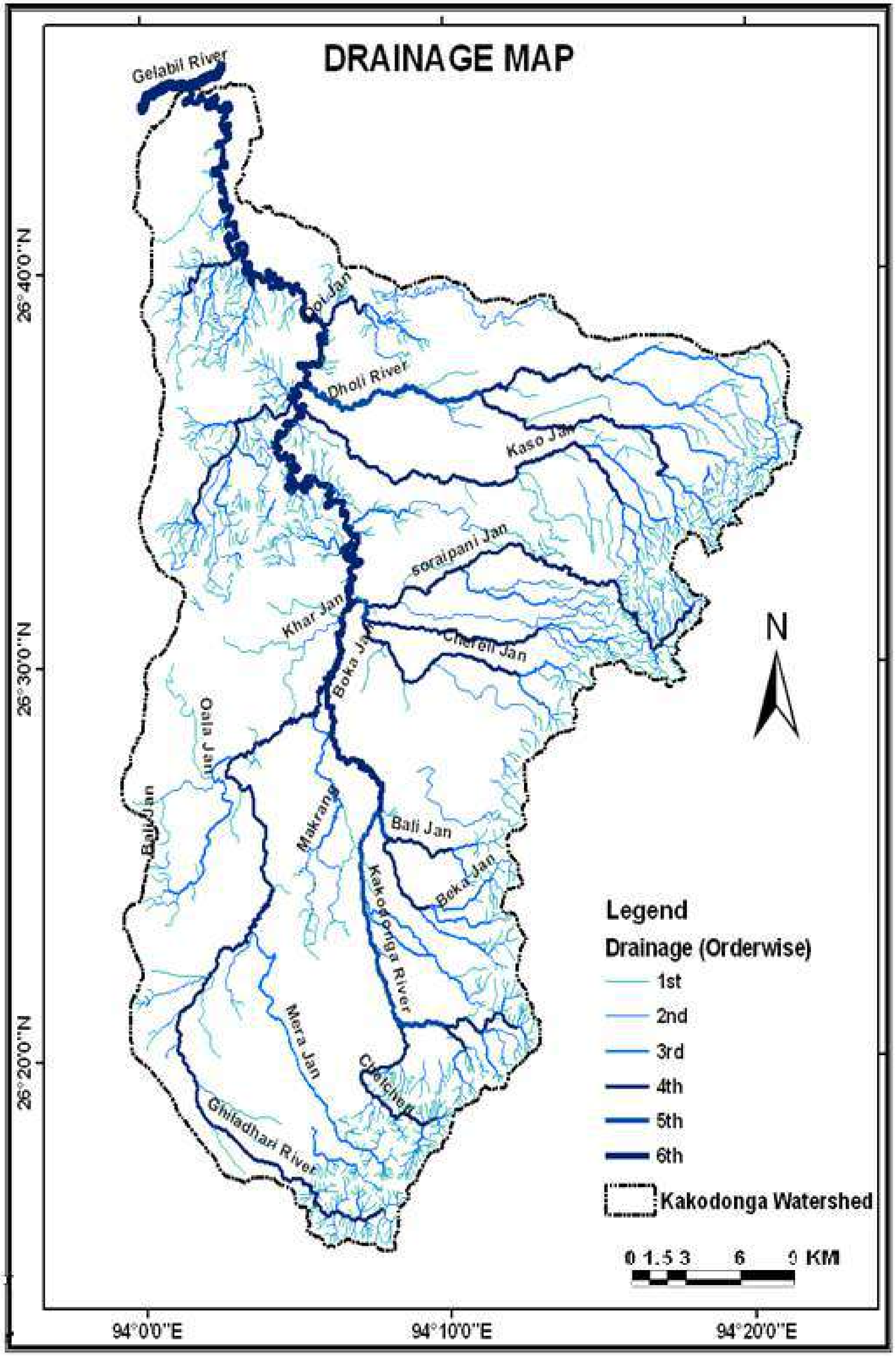
DRAINAGE MAP
Gelabil River
Doi Jan
Dholi River
Kaso Jan
soraipani Jan
Khar Jan
Boka Jan
Chereli Jan
Oala Jan
Bali Jan
Makrang
Bali Jan
Beka Jan
Kakodonga River
Mera Jan
Ghiladhari River
N
Legend
Drainage (Orderwise)
1st
2nd
3rd
4th
5th
6th
Kakodonga Watershed
KM
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E

Fig. 3.1

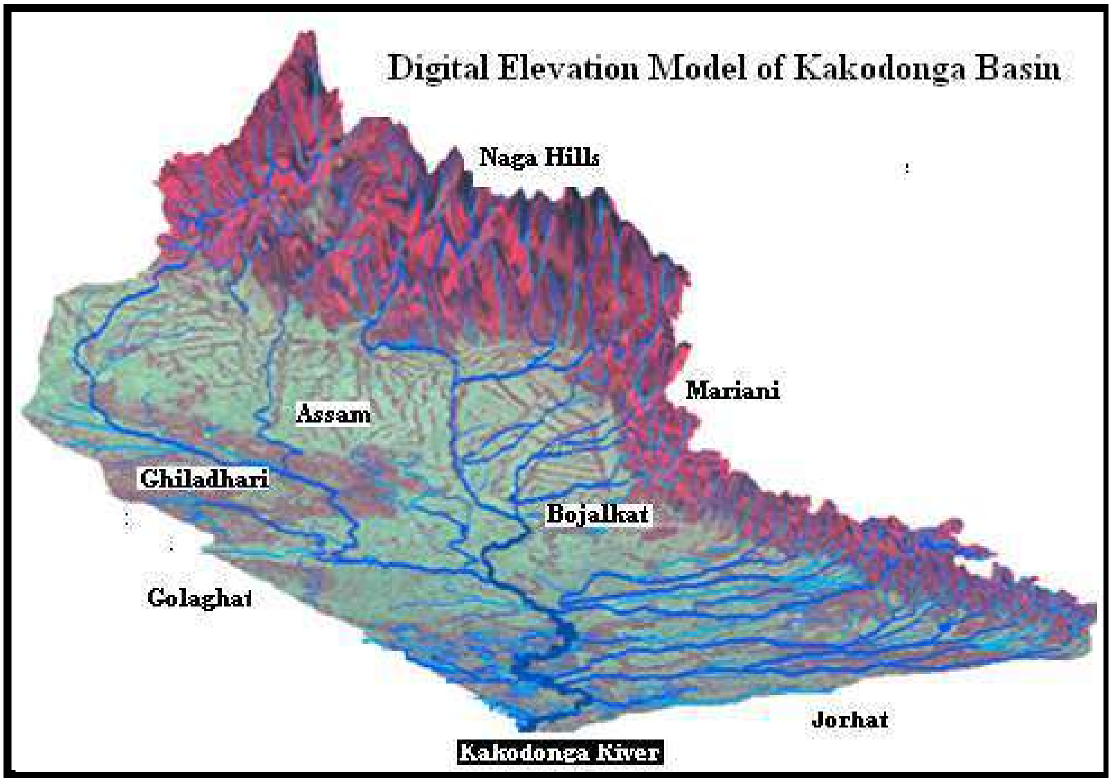

Fig. 3.2
Source: Based SOI Toposheet & IRSP6 LISS III Imagery (2011)

3.1 Linear morphometric characteristics

The linear morphometric parameters consist of Drainage order (u), Drainage numbers (Nu), Stream length (Lu), and Bifurcation ratio (Rb) etc. A critical analysis about these parameters is made with reference to the Kakodonga river basin. (Table 3.1).

3.1.1. Drainage Order (u)

Strahler's (1964) method is used for estimate the drainage orders of the basin. According to this method if two same order streams join then it form next higher order, for example 1st order and 1st order stream forms 2nd order, 2nd and 2nd order forms 3rd order and so on. But if 1st order stream joins in 2nd or other higher order then it can't form next higher order, which is applicable in other cases also. In Kakodonga river basin the drainage network ranges from 1st order to 6th order (Table 3.1, Fig. 3.1 & 3.2).

Table 3.1: Linear aspects of the drainage system

River Basin	Drainage Order	No. of Streams (Nu)	Stream Length (in km) (Lu)	Mean stream length		Bifucation Ratio (Rb)	Mean Bifurcation Ratio	Log Nu	Cummulative Mean Stream Length	Log Lu
				Lu/ Nu	Avg. Length (km)					
KAKADONGA	1st order	1030	672.57	0.65	1.07	3.81	4.06	3.013	672.57	2.828
	2nd order	270	311.90	1.16		4.03		2.431	984.47	2.494
	3rd order	67	191.32	2.86		4.19		1.826	1175.79	2.282
	4th order	16	192.87	12.05		4		1.204	1368.66	2.285
	5th order	04	31.02	7.76		4		0.602	1399.68	1.492
	6th order	01	84.65	84.65		0		0	1484.33	1.928
	Total	1388	1484.33							

Source: Based on Drainage Map of Kakodonga River (Fig. 3.1)

Where, Lu = Total Stream length of all orders,

Nu = Total number of streams of all orders,

N1 = Total number of 1st order streams, $\Pi = 3.14$, Rb=Nu/Nu+1,

3.1.2 Drainage Number (Nu)

The total number of streams are 1388 found in whole Kakodonga river basin, out of which 1030 streams belongs to 1st order, 270 streams in 2nd order, 67 streams in 3rd order, 16 streams in 4th order , 4 streams in 5th and 1 stream in 6th order (Table 3.1). Graphical representation of logarithm of number of streams versus stream order is presented in Fig. 3.3 (b). According to Horton (1945), the stream number as the coefficient of correlation is 0.967 and the percentage variance is 93.4 and the graph shows the former represents straight line. This means that the number of streams usually decreases in geometric progression as the stream order increases (Table 3.2).

Table 3.2: Regression Statistics of Stream Length (Log Lu) and Stream Order

Regression Statistics	
Regression	0.926
R Square	0.858
Adjusted R Square	0.811
Standard Error	0.213
Observations	6

Source: Computation is made based on linear aspects of the Kakodonga Drainage system (Table 3.1)

Table 3.3: Regression Statistics of Cumulative Mean Stream Numbers and Stream Order

Regression Statistics	
Regression	0.967
R Square	0.934
Adjusted R Square	0.912
Observations	6

Source: Computation is made based on linear aspects of the Kakodonga Drainage system (Table 3.1)

a) Regression of logarithm of stream lengths (Lu) versus stream order,

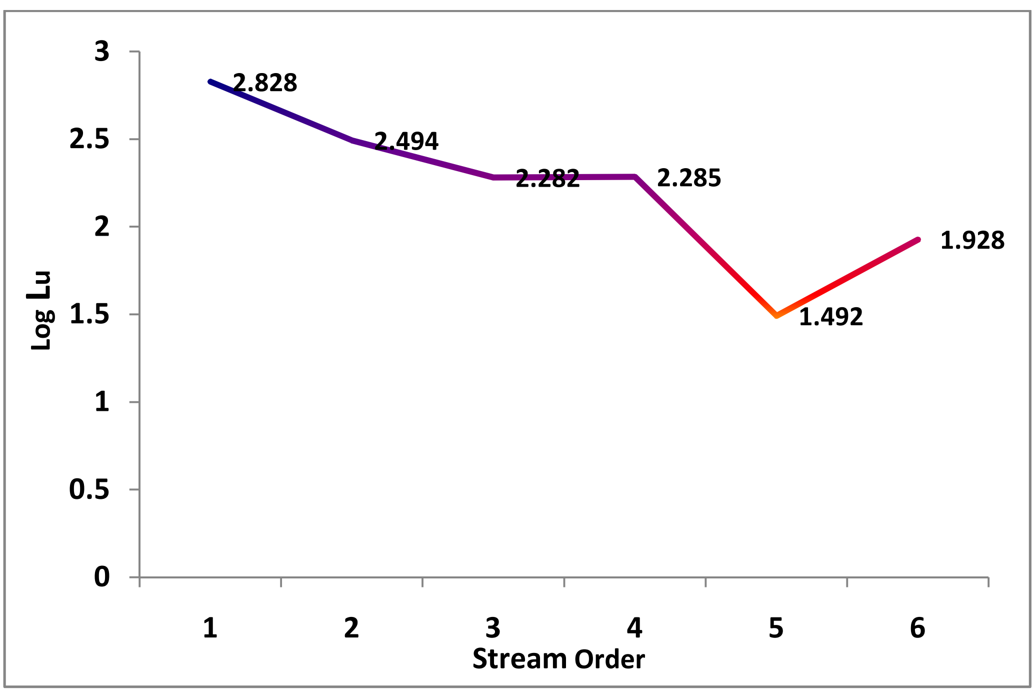

Fig 3.3 (a)

b) Regression of logarithm of number of streams (Nu) versus stream order

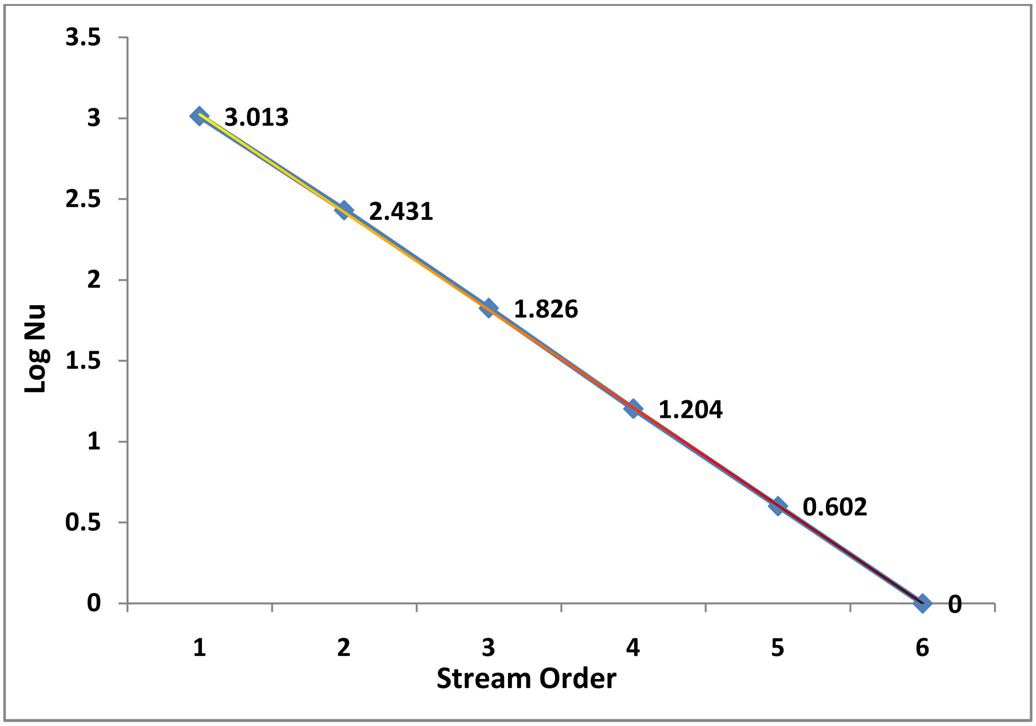

Fig. 3.3 (b)

3.1.3 Drainage Length (Lu)

The drainage length is a very important characteristic of watershed, it influence the catchment area and surface runoff. The length of all the streams of Kakodonga River is measured with the help of GIS software and total length comes to 1484.33 km with an average stream length of 1.07 km. There is increase in the mean stream length from 1st order to 4th order (0.65 to 12.05). In 5th order there is crash fall of length (7.76 km) but it sharply increases in 6th order that is 84.65 km. Graphical representation of stream length versus stream order is presented (Fig.3.3 a). According to Horton's law the total length of the stream segments is highest in 1st order stream and length decreases as the stream order increases. But here, there is an exception in case of 6th order stream (Table 3.2 & 3.3). The Stream length as coefficient of correlation is 0.926 and the percentage variance explained is 85.8. Fig. 3.3 (a) shows a non-linear pattern of stream length against the stream order which indicate heterogeneous rock material subjected to weathering-erosion characteristics of the basin.

3.1.4 Bifurcation Ratio (Rb)

It is the ratio of number of streams of any given order to the number in of streams in the next higher order (Horton, 1945). According to Strahler (1964) the Bifurcation ratio ranges between 3.0 and 5.0 for basin, its means do not distort geological structures of the drainage pattern. In Kakodonga river basin there is very slight variation in bifurcation ratio in all the stream orders which ranges from 3.81 to 4.19. It means that average bifurcation ratio is 4.06. The average bifurcation ratio of the basin indicates the less structural complexity in the drainage system.

3.2 Areal morphometric characteristics

Areal parameters includes the drainage density (Dd), stream frequency (Fs), texture ratio (Rt), elongation ratio (Re), form factor ratio (Rf), circularity ratio (Rc), constant of channel maintenance (C), and length of overland flow (Lg) etc. which are discussed (Table 3.4). These are essential indicators of landform analysis. Here, Area (A) of the basin means the total geographical area of the basin and Perimeter (P) is the length of the boundary of the entire basin which can be drawn from topographical maps.

Table 3.4: Areal aspects of the drainage system

Morphometric parameters	Symbol/ Formulas	Calculated Value
Area of the study area(In sq. KM)	(A)	1112.57
Perimeter of the study area (In KM)	(P)	183.06
Drainage Density	Dd = Lu/A	1.33
Stream Frequency	Fs = Nu/A	1.25
Texture ratio	Rt = Nu/P	7.58
Basin Length(In km)	Lb	126.06
Elongation Ratio	$Re = \frac{2\sqrt{A/\pi}}{Lb}$	0.30
Circularity ratio	$Rc = \frac{4\Pi a}{P^2}$	0.42
Form Factor Ratio	$Rf=A/Lb^2$	0.70
Constant of Channel maintenance	C= 1/Dd	0.75
Length of overland flow	Lg=1/2*Dd	0.38

Source: Based on Drainage Map of Kakodonga River (Fig. 3.1)

3.2.1 Drainage Density (Dd)

Drainage density is the ratio of cumulated total of all stream length of the basin to the area (A) of the basin. It could be express in terms of mile. / sq. km or km / sq. km. Drainage density shows the closeness of spacing of channels. Low drainage density indicates coarse drainage texture and high drainage density shows a fine drainage texture (Strahler, 1964). The drainage density of Kakodonga basin is 1.33 km / sq. km., which is comparatively low value and low drainage density (Nag, 1998) indicates that the basin has highly permeable sub soil and thick vegetation cover.

3.2.2 Stream Frequency (Fs)

Stream frequency is the ratio of the total number of stream segment of all orders per unit area (Horton, 1932), which is expressed as Fs = Nu/A. The stream frequency value is 1.25, which indicates positive correlation means the increases population area in streams with respect to increaseing in drainage density.

3.2.3 Texture Ratio (Rt)

According to Horton (1945), Rt is the total number of stream segments of all orders per perimeter of the basin area. Drainage texture ratio (Rt) = Nu/P. The drainage texture value of the basin is 7.58. The ratio is neither more nor less, which means near spacing of drainage basin.

3.2.4 Circularity Ratio (Rc)

It is the ratio of the area of the basin to the area of a circle having the same boundaries as the perimeter of the basin (Miller, 1953). Circularity ratio provides useful assessment about flood hazard, influenced by length and frequency of streams, geological structures, land use/ land cover, climate, relief and slope of the basin. Higher the value of Rc, higher is the flood hazard at a peak time at the outlet point while sub catchments associated with low values of Rc are prone to low flood hazard hardly noticeable at particular point of time at a place. Miller (1953) illustrates that basin circularity ratio ranges from 0.4 to 0.5, its means as strongly elongated and highly permeable homogeneous geologic materials. Circularity ratio of the basin is 0.42. It is indicated that, the basin is not much circular.

3.2.5 Elongation Ratio (Re)

According to Schumm (1956) elongation ratio (Re) is the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The highest values of Re reflect high elongation of the basin with less relief and steep slope. Values close to 1.0 are typical regions of very low relief (Strahler, 1964). The Re of the study area is 0.30 and it reveals that basin is highly elongated.

3.2.6 Form Factor Ratio (Rf)

Form Factor Ratio is the dimensionless ratio of the basin to the square of basin length (Horton, 1932). The value of Rf in the study area is relatively high i.e. 0.70 which indicates near to circular shape of the basin. Flood flow of such circular type of basin is difficult to manage and not much efficient discharge of flood at an outlet point.

3.2.7 Constant of Channel maintenance (C)

The Constant of Channel Maintenance is the inverse of the drainage density (Schumm, 1956). Therefore higher the drainage density lowers the constant of channel maintenance and vice versa. The C value in Kakodonga basin is 0.75, which indicates moderate Constant of Channel maintenance.

3.2.8 Length of overland flow (Lg)

The length of overland flow is calculated by 1/2*Dd. Lg value of the basin is 0.38 which indicates comparatively moderate overland flow.

3.3 Relief parameter analysis

The relief parameters analyses include basin relief, relief ratio and ruggedness number which plays an important role in drainage development, surface and sub-surface water flow, permeability, landform development and association features of the terrain (Table 3.5).

Table 3.5: Relief aspects of the drainage system

Morphometric parameters	Symbol/Formulas	Calculated Value
Maximum Elevation in the area (In meter)		764
Minimum Elevation in the area (In meter)		76
Basin Relief (mt)	H= Max. Elevation – Min. Elevation	688mt=0.69 km
Relief Ratio (Rh)	Rh=H/Lb	0.005
Ruggedness no.	Rn= H*Dd	0.92

Source: Based on Drainage Map of Kakodonga River (Fig. 3.1)

3.3.1 Basin Relief (H)

The vertical distance difference between point of maximum elevation and minimum elevation is the relief of basin. The basin relief of Kakodonga River is 688 meters or 0.69 km.

3.3.2 Relief Ratio (Rh)

The basin relief (H) is divided by maximum basin length (Lb) gives the relief ratio (Schumm, 1954). The relief ratio of Kakodonga river basin is 0.005, which indicates that the basin has strong relief and steep slope.

3.3.3 Ruggedness Number (Rn)

Ruggedness number estimated through basin relief and drainage density. Rn value of the basin is 0.92. With low ruggedness number indicates that the runoff speed of the water is less in the basin and as such there is high infiltration. It also further implies that the area is less susceptible to soil erosion.

This chapter mainly focused on morphometric aspects of Kakodonga river basin. Drainage network was digitized in GIS environment to estimate morphometric characteristics like linear, areal and relief. Stream order, number of stream, stream length, bifurcation ratio etc. are some important linear parameters. The stream length variation is occurred in the basin due to geological structure and slope. Estimated bifurcation ratio is 4.06, it means do not exceed the range. The Stream number coefficient of correlation is 0.967 and the percentage variance is 93.4. The Stream length as coefficient of correlation and the percentage variance are 0.926 and 85.8 respectively. The drainage density, circulatory ratio, stream frequency and elongation ratio are described under areal aspects. The drainage density value is 1.33, it shows positive correlation, and it is highlighting the increased drainage population with respect to increase in drainage density. The Circulatory ratio 0.42 indicates that the basin has strongly elongated shape, high flood potentiality and less population of drainage. Elongation ratio value is 0.30 reflects the flatter surface of the basin and high flood flow in rainy season. Further research is necessary for identification of features like flood zones, run-off and gully erosion etc. To harness the flood construction of the nalla bunds, small ponds, percolation ponds, stone wall, contour trenching, check dams, plantation and afforestation are very urgent in the basin.

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Chapter-4

Water Resources of the Kakodonga River Basin

4

4. Introduction

India is a developing country where agriculture is the main economic activity. With increasing population and decreasing per capita availability of water there is a need for careful planning and utilization of water resources. Watershed plays a crucial role in the optimum utilization and conservation of water. The study on water resources planning and development has been developed for the river basins. The surface water resources of a region should be carefully evaluate through a systematic study of the distribution of rainfall data collected from the available rain gauge stations over a period of time. Along the climatic parameters, rainfall is an important input, which controls the total cropped area under rainfed conditions. Timely occurrence of rainfall is important for crop growth. Any serious departure from the normal rainfall leads to a great stress. Moisture is another important factor in all the crop producing areas. The normal rainfall is necessary for successful crop production. The surface water resource evaluation is an important aspect for understanding the nature of vegetation and its peculiarities in its variations for planning and development of agriculture.

The rainfall data over a period of 31 years (1983-2013) are collected from ten rain-gauge stations. They are well distributed in and around the Kakodonga river basin to analyze the rainfall data on monthly, seasonal, and annual basis. The surface water resources of the basin also have been studied based on mean annual rainfall and geographical area of the basin. The statistical methods adopted by Bhargava (1977) are used for the analysis of annual mean rainfall, rainfall intensity, rainfall variability and rainfall ratio, which are mentioned below-

$$\text{Rainfall intensity} = \frac{\text{Average Rainfall}}{\text{Average number of rainy days}}$$

$$\text{Rainfall Variability} = \frac{\text{Standard Deviation (S.D.)}}{\text{Mean}} \times 100$$

$$\text{Rainfall Ratio} = \frac{P_{maximum} - P_{minimum}}{P_{average}} \times 100$$

According to Radhakrishna *et al* (1974) Method the groundwater recharge of the basin is 10% of the annual rainfall, but U. S. Geological Method (1962) express that the annual groundwater recharge of the basin is 15% of the annual rainfall, Seghals' (1973) has worked out the ground water recharge as $G = 2.5\,(P-16)^{0.5}$ where precipitation is in inches and according to Krishna Rao (1970) method the annual groundwater recharge as R = 0.20 (P-400) when precipitation is between 400mm to 600mm, R = 0.25 (P-400) when precipitation is 600 to 1000 mm and R = 0.35 (P-600) when precipitation is above 1000 mm. Based on ground water recharge and geographical area of the basin the ground water resources of the basin have been estimated.

4.1. Monthly analysis of rainfall of the Kakodonga river basin

4.1.1 January

The mean minimum precipitation in the month of January is 13 mm, which is observed in Golaghat, Khumtai and Sycota rain gauge stations and maximum is 32 mm, found in Borholla station (Table 4.1). The average precipitation in the basin is 18.1 mm. The minimum spatial distribution of precipitation has been noticed as 20 mm in northern, northwestern, western and southern parts of the basin (Fig. 4.1). The maximum distribution of precipitation spatially shows that more than 20 mm in central and northwestern parts of the basin. The rainfall intensity varies from 3 mm/ a rainy day in Golaghat and Sycota stations, to a maximum of 5 mm/ a rainy day in Borholla and Wokha stations. The average rainfall intensity is 3.9 mm /a rainy day of the basin. The spatial distribution shows that the rainfall intensity ranges from 3.5 mm to 4.5 mm/a rainy day in western and northeastern to central and southern parts of the basin. The rainfall variability during the month of January ranges from 53% in Sycota station to a maximum of 186% in Borholla station. The average rainfall variability is 89.4%. The spatial distribution of rainfall variability is less than 80% in all edges of the basin and Titabor station. The rainfall ratio ranges from 162% in Sycota station to a maximum of 873% in Borholla station. The average rainfall ratio of the January month is 340.1%. The spatial distribution shows that the rainfall ratio varies from 200% to 400% in northern, southern and central parts of the basin. It exceeds more than 400% in central part of the basin.

Table 4.1: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 - 2013)

(January)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	32	5	186	873
2.	Golaghat	13	3	75	388
3.	Honowal	20	4	74	286
4.	Jorhat	16	4	92	328
5.	Kamarbund	16	4	82	276
6.	Khumtai	13	3	110	304
7.	Negheriting	24	4	68	200
8.	Sycota	13	3	53	162
9.	Titabor	20	4	79	302
10.	Wokha	14	5	75	282

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITYAND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (JANUARY)

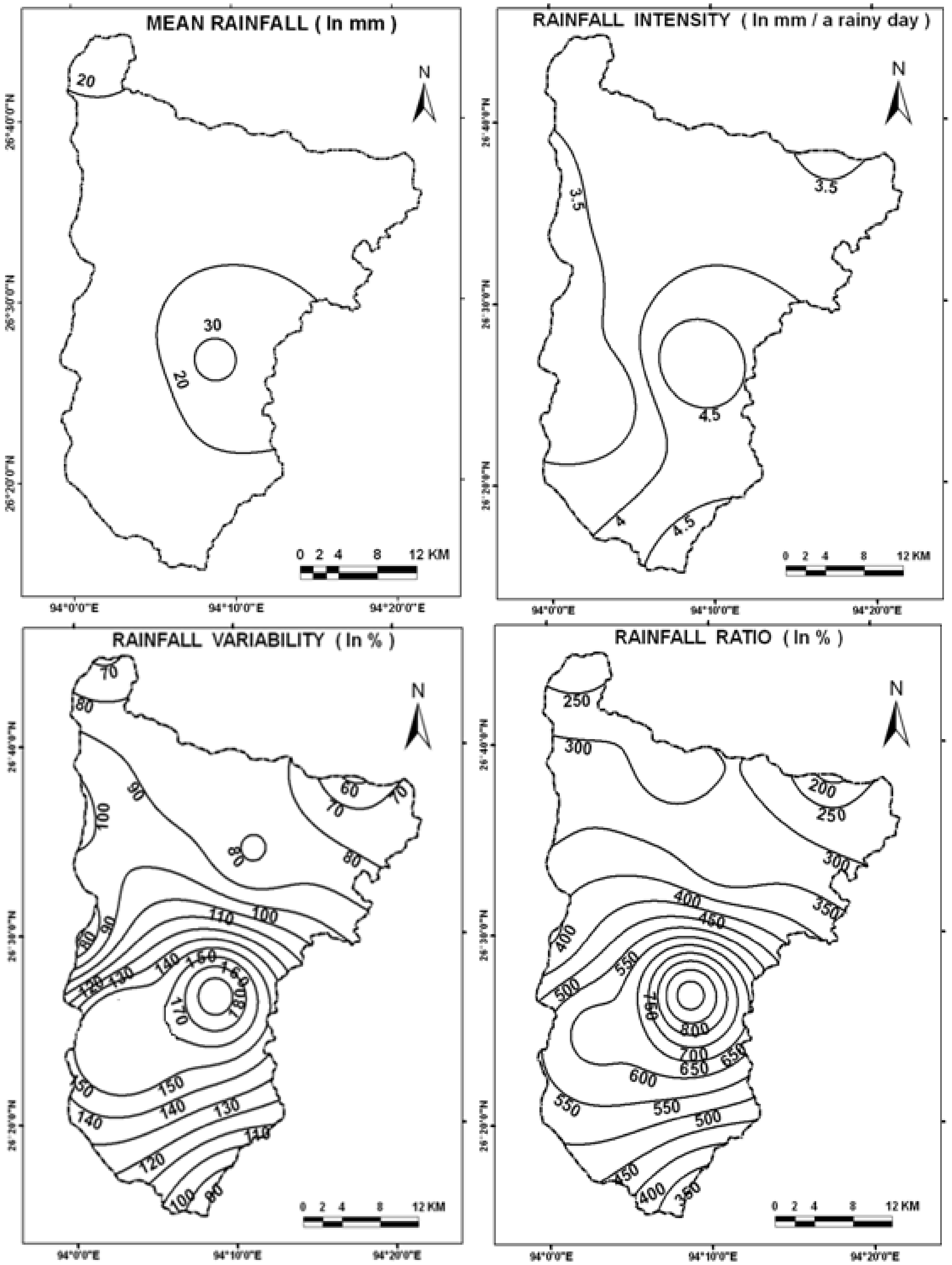


Fig. 4.1

4.1.2 February

In the month of February the mean monthly precipitation values vary from a minimum of 29 mm in Sycota station to a maximum of 58 mm in Negheriting station (Table 4.2). The average precipitation value is 38 mm. The spatial distribution shows that the precipitation value increases from 30 mm in southern and western parts to 40 mm in eastern, northeastern and extreme northwestern tip of the basin (Fig. 4.2). The rainfall intensity varies from 4 mm/ a rainy day in Khumtai station to a maximum of 7 mm/ a rainy day in Wokha station. The average rainfall intensity is 5.5 mm/a rainy day. Spatial distribution of the rainfall intensity ranges from 4.5 mm/a rainy day to 5.5 mm/ a rainy day in central, northern, northeastern and peak of southeastern parts of the basin. The rainfall variability ranges from 57% in Honowal station to a maximum of 108% in Borholla station. The average rainfall variability is 78%. The spatial distribution of rainfall variability found 60% in northeastern to 100% in central and southern parts of the basin. The rainfall ratio during the month of February ranges from 221% in Honowal station to a maximum of 501% in Borholla station. The average rainfall ratio is 307%. The spatial distribution shows that the rainfall ratio ranges from 200% to 400% in northern and southern parts of the basin and it exceeds 400% in central part of the basin.

Table 4.2: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(February)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	34	6	108	501
2.	Golaghat	32	5	106	312
3.	Honowal	45	6	57	221
4.	Jorhat	38	5	81	297
5.	Kamarbund	35	6	63	232
6.	Khumtai	30	4	68	223
7.	Negheriting	58	6	89	320
8.	Sycota	29	5	90	234
9.	Titabor	42	5	70	281
10.	Wokha	35	7	46	712

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (FEBRUARY)

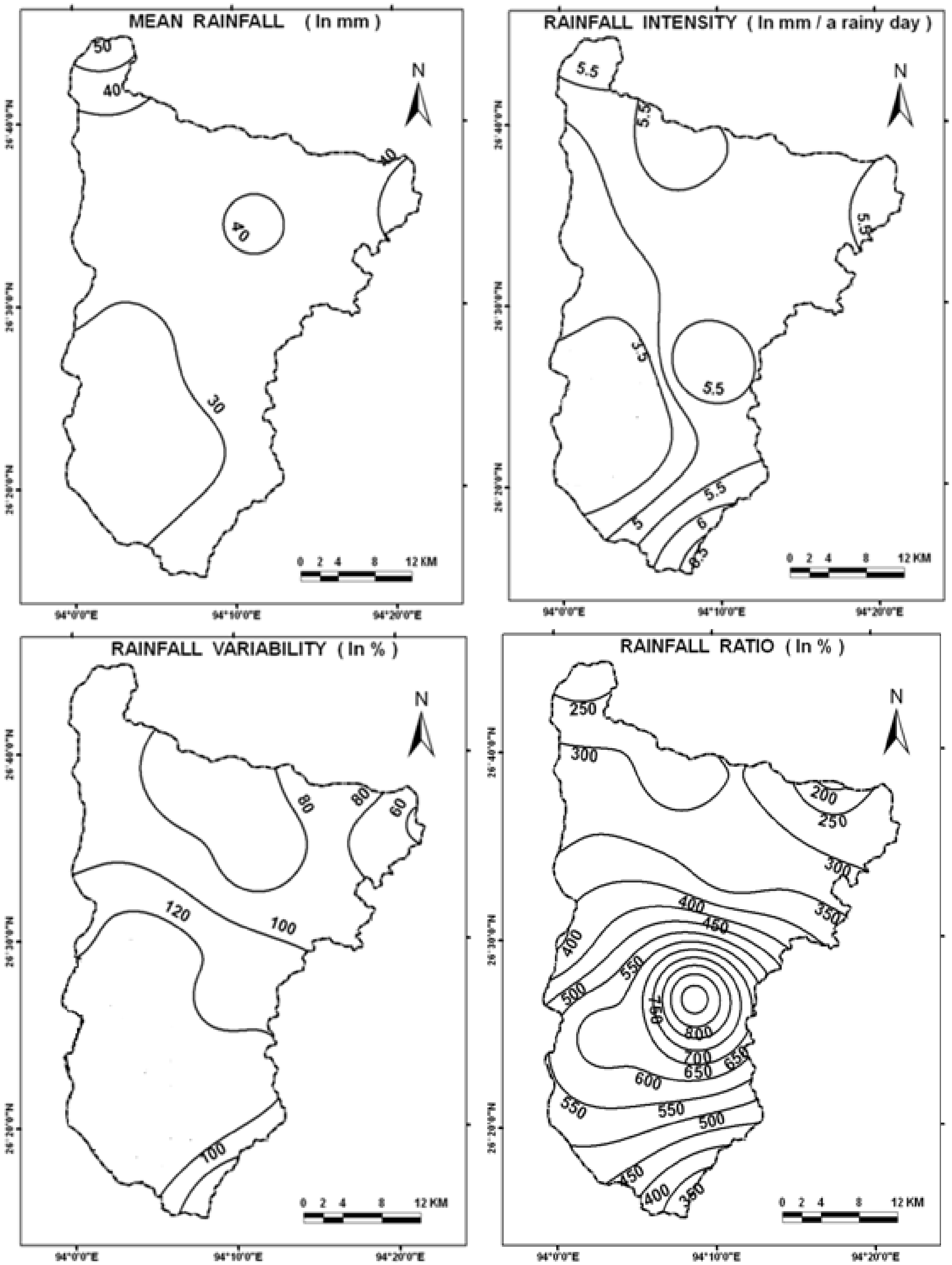


Fig. 4.2

4.1.3 March

The mean monthly precipitation values vary from a minimum of 48 mm in Sycota station to a maximum of 192 mm in Negheriting station (Table 4.3). The average precipitation value is 84 mm. The spatial distribution of precipitation ranges from 50 mm in southern and western parts to 90 mm in central and western parts of the basin and rainfall exceeds 180 mm in extremely northwestern part of the basin (Fig. 4.3). The rainfall intensity varies from 5 mm/ a rainy day in Sycota station to a maximum of 15 mm/ a rainy day in Wokha station. The average rainfall intensity is 7.9 mm/a rainy day. The rainfall intensity distribution over the basin varies from 6 mm/a rainy day to 7 mm/ a rainy day in southwestern, northeastern and central parts of the basin to 12 mm/a rainy day in southeastern part of the basin (Fig. 4.3). The rainfall variability ranges from 46% in Wokha station to a maximum of 169% in Negheriting station. The average rainfall variability is 82%. The spatial distribution of rainfall variability increases from 60% to 130% in north eastern parts to southwestern part of the basin. The rainfall ratio during the month of March ranges from 142% in Sycota station to a maximum of 712% in Wokha station. The average rainfall ratio is 370%. Spatial distribution of the rainfall ratio increases from 200% to 600% in northern and southern parts to central part of the basin. Rainfall ratio exceeds 650% in southeastern tip of the basin.

Table 4.3: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(March)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	91	13	54	195
2.	Golaghat	76	8	53	170
3.	Honowal	71	6	61	208
4.	Jorhat	69	6	72	310
5.	Kamarbund	77	6	83	274
6.	Khumtai	64	8	77	291
7.	Negheriting	192	11	169	640
8.	Sycota	48	5	49	142
9.	Titabor	63	6	69	250
10.	Wokha	89	15	46	712

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (MARCH)

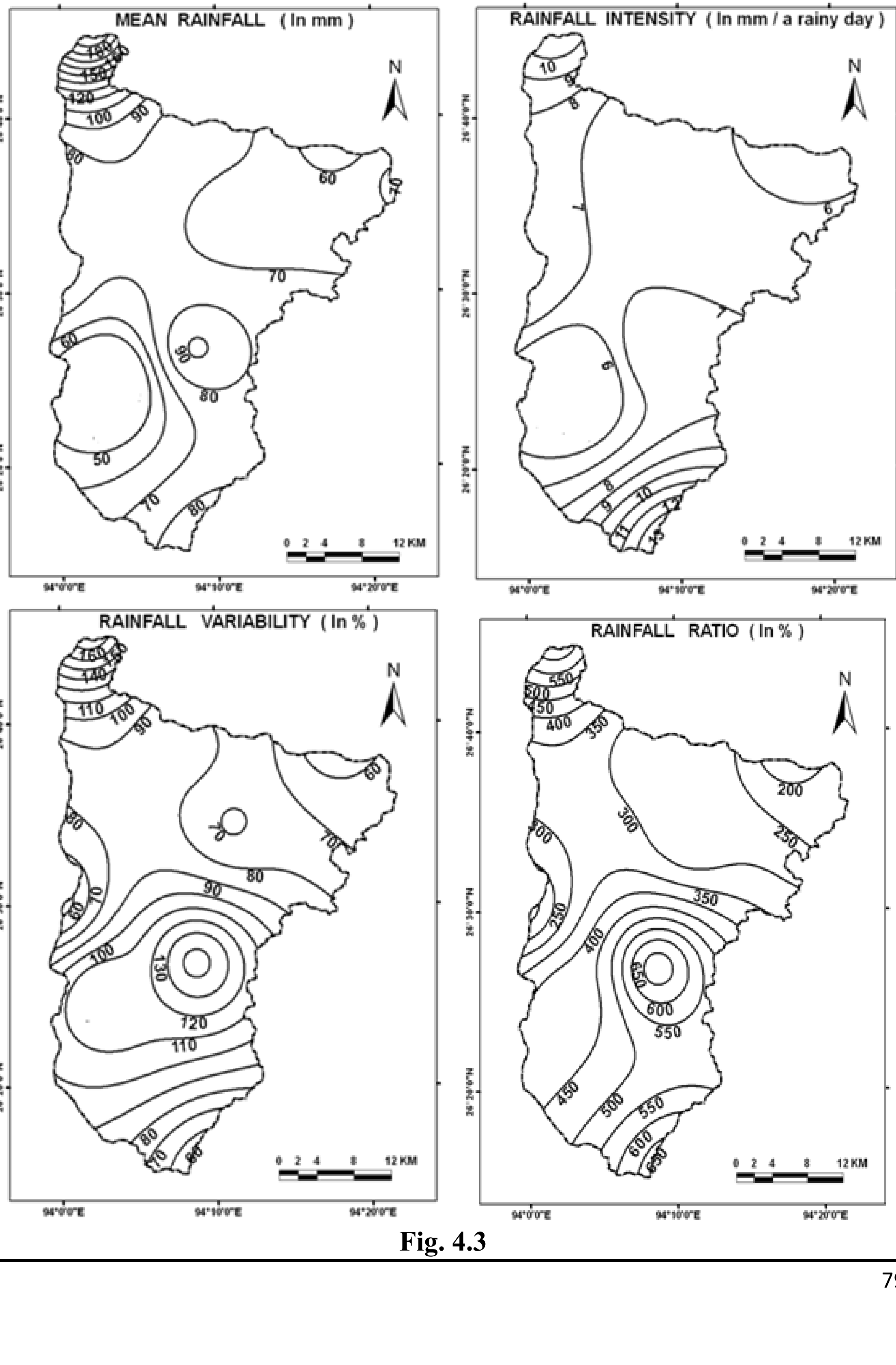


Fig. 4.3

4.1.4 April

The minimum mean precipitation in the month of April is recorded as 125 mm in Sycota rain gauge station and maximum is 302 mm in Negheriting station (Table 4.4). The average precipitation of the basin is 177 mm. The spatial distribution of the precipitation varies from 130 mm to 160 mm in northern and southern to central part of the basin. The maximum distribution of precipitation increases from 160 mm to 200 mm above central part to northeastern tip and northwestern tip of the basin (Fig. 4.4). The rainfall intensity varies from 9 mm/ a rainy day in Sycota station to a maximum of 14 mm/ a rainy day in Negheriting station. The average rainfall intensity is 10.8 mm /a rainy day. The fig. 4.4 reflects that the rainfall intensity fluctuate from 10 mm to 13 mm/a rainy day in eastern and northeastern to central, southern and northwestern parts of the basin. The rainfall variability ranges from 32% in Golaghat and Negheriting stations to a maximum of 103% in Sycota station. The average rainfall variability is 54%. The spatial distribution of the rainfall variability reveals that it increases from 40% to 100% in southern, southeastern part to northern and northeastern part of the basin. The rainfall ratio varies from 110% in Negheriting station to a maximum of 326% in Sycota station. The average rainfall ratio of the April month is 205.6%. The spatial distribution shows that the rainfall ratio varies from 150% to 300% in northwestern, southeastern to central part of the basin.

Table 4.4: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(April)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	159	11	75	320
2.	Golaghat	167	10	32	201
3.	Honowal	213	11	55	192
4.	Jorhat	161	10	42	149
5.	Kamarbund	153	10	47	145
6.	Khumtai	175	10	48	205
7.	Negheriting	302	14	32	110
8.	Sycota	125	9	103	326
9.	Titabor	161	10	68	284
10.	Wokha	154	13	38	124

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN

(APRIL)

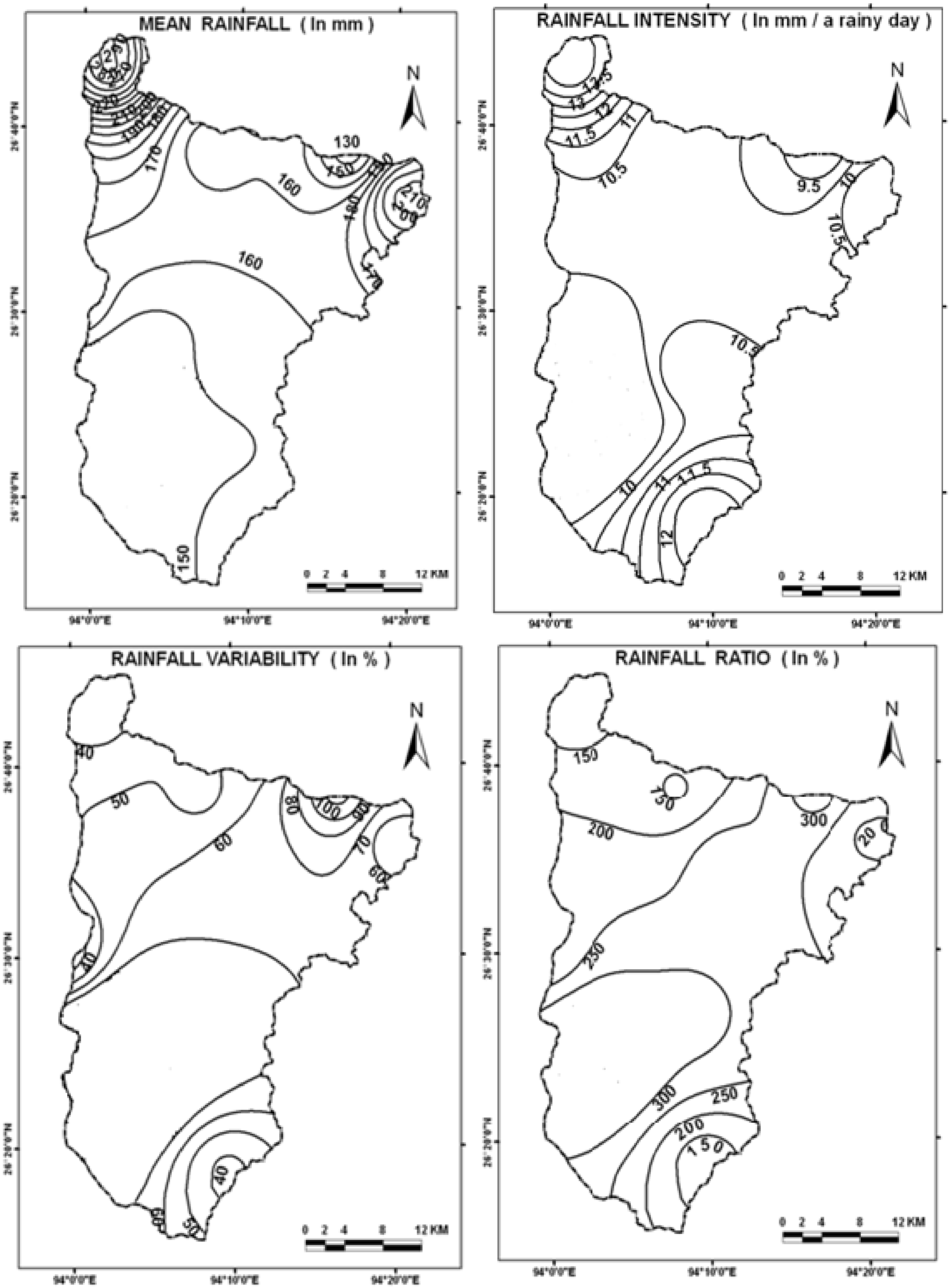


Fig. 4.4

4.1.5 May

In the month of May the mean monthly precipitation values vary from a minimum of 168 mm in Golaghat station to a maximum of 408 mm in Negheriting station (Table 4.5). The average precipitation value is 243 mm in the basin. The spatial distribution shows that the precipitation value increases from 200 mm in southwestern part of the basin to 240 mm central part of the basin. The maximum precipitation is identified in northwestern tip of the basin (Fig. 4.5). The rainfall intensity varies from 11 mm/ a rainy day in Golaghat station to a maximum of 18 mm/ a rainy day in Negheriting station. The average rainfall intensity of the basin is 13 mm/a rainy day. Spatial distribution map of rainfall intensity expose that the intensity varies from 12 mm/a rainy day to 17 mm/ a rainy day in southwestern and southeastern part to northwestern tip of the basin. The rainfall variability ranges from 33% in Khumtai station to a maximum of 137% in Borholla station. The average rainfall variability is 51%. Rapid increase of rainfall variability i.e. 40% to 120% is observed in the study area, spatially from northeastern and southeastern parts to central part of the basin. The rainfall ratio during the month of May ranges from 103% in Khumtai station to a maximum of 467% in Borholla station. The average rainfall ratio is 177%. The spatial distribution shows that the rainfall ratio increases from 150% to 300% in northern and southern to central part of the basin and it exceed 300% in central part of the basin.

Table 4.5: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(May)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	243	13	137	467
2.	Golaghat	168	11	37	114
3.	Honowal	252	12	42	140
4.	Jorhat	223	12	49	186
5.	Kamarbund	215	13	50	172
6.	Khumtai	229	12	33	103
7.	Negheriting	408	18	47	150
8.	Sycota	190	12	38	122
9.	Titabor	224	12	42	164
10.	Wokha	277	15	38	153

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (MAY)

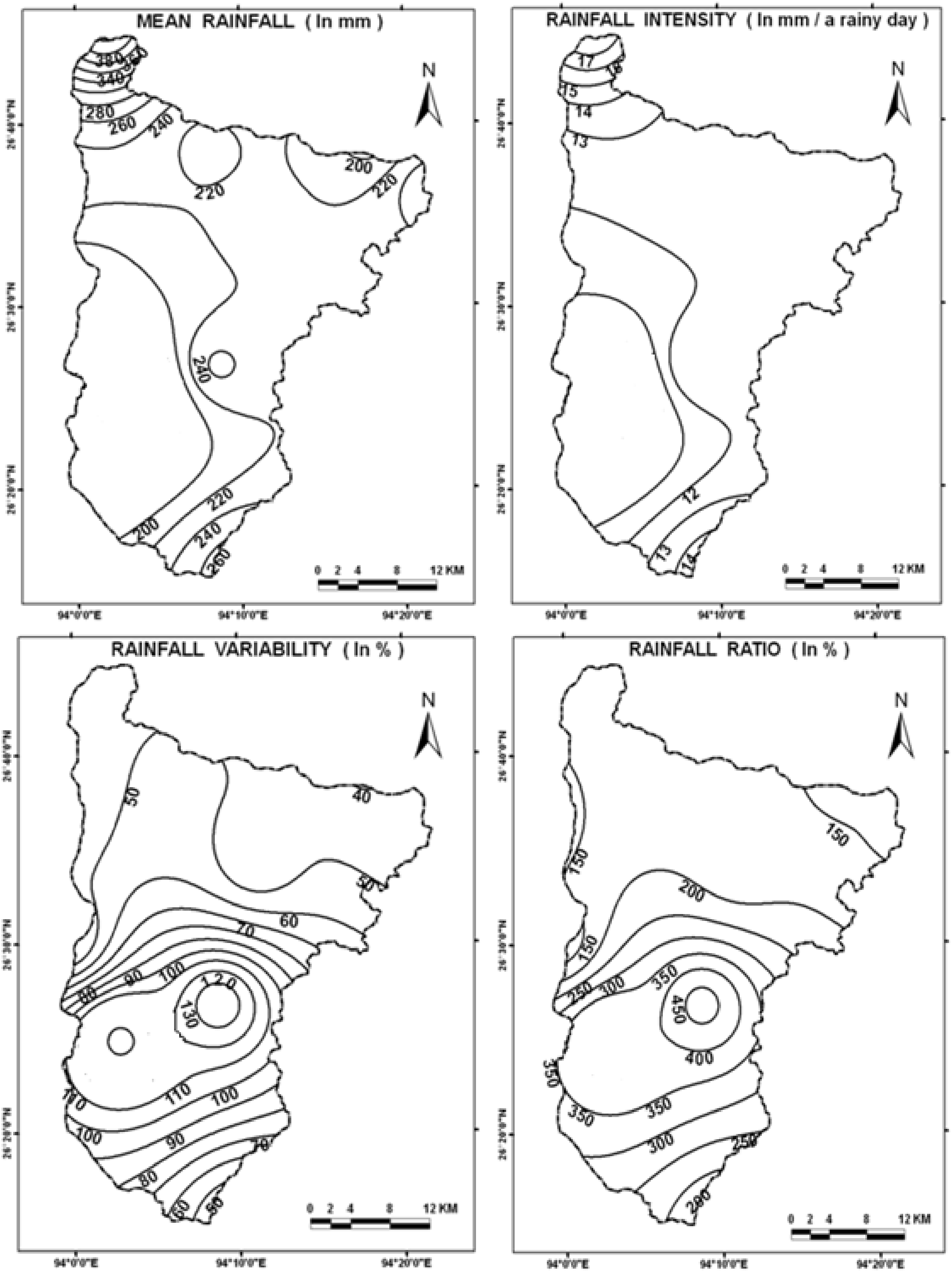


Fig. 4.5

4.1.6 June

The mean rainfall ranges from 169 mm in Sycota rain gauge station to a maximum of 493 mm in Negheriting station (Table 4.6). The average precipitation of the basin is 284 mm. The spatial distribution of the precipitation shows that it is less than 200 mm in northern and central parts of the basin (Fig. 4.6). The maximum distribution of precipitation spatially shows that more than 300 mm rainfall concentrated in southeastern and northwestern parts of the basin. The rainfall intensity varies from 9 mm/ a rainy day in Sycota station, to a maximum of 21 mm/ a rainy day in Negheriting station. The average rainfall intensity is 13 mm /a rainy day. The spatial distribution shows that the minimum rainfall intensity found 10 mm/a rainy day in northeastern part of the basin. The maximum rainfall intensity distribution is found as 21 mm/ a rainy day in northwestern tip of the basin. The rainfall variability during this month ranges from 22% in Golaghat station to a maximum of 54% in Sycota station. The average rainfall variability is 37%. The spatial distribution map of rainfall variability expresses that less than 30% variability found in northeastern and southeastern parts of the basin. The maximum rainfall variability increased from southern part to northern parts of the basin. The rainfall ratio ranges from 61% in Golaghat station to a maximum of 179% in Titabor station. The average rainfall ratio of the June month is 135%. The spatial distribution shows that the rainfall ratio varies from 100% to 150% in northeastern, southeastern parts to central part of the basin. It is exceeds more than 150% identified in northwestern tip of the basin.

Table 4.6: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin. (1983 – 2013)

(June)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	247	12	44	155
2.	Golaghat	215	11	22	61
3.	Honowal	287	12	23	85
4.	Jorhat	259	12	35	134
5.	Kamarbund	239	11	49	177
6.	Khumtai	284	14	29	119
7.	Negheriting	493	21	42	170
8.	Sycota	169	9	54	177
9.	Titabor	261	12	43	179
10.	Wokha	388	16	28	96

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (JUNE)

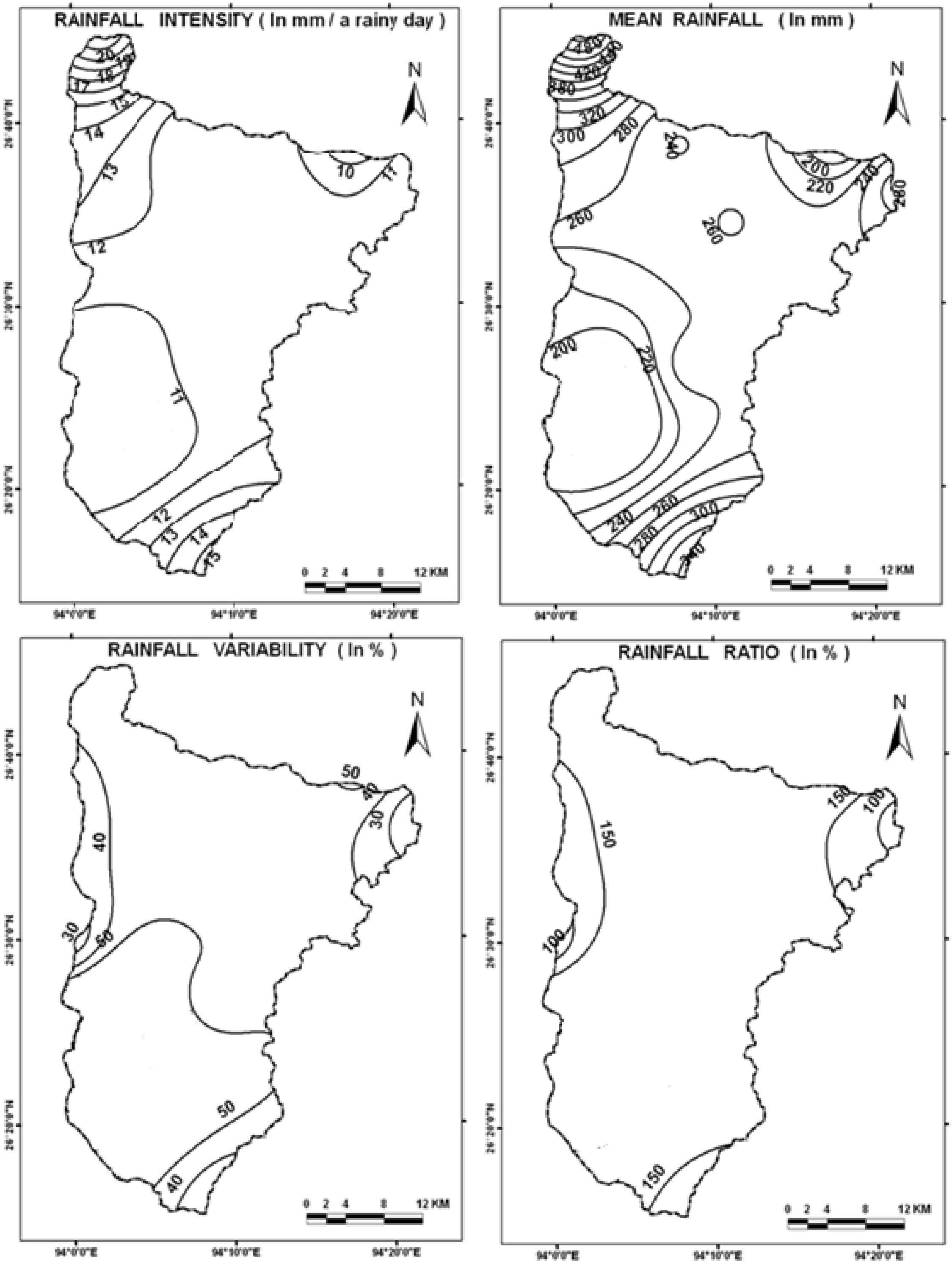


Fig. 4.6

4.1.7 July

In the month of July the mean monthly precipitation values vary from a minimum of 271 mm in Sycota station to a maximum of 569 mm in Negheriting station (Table 4.7). The average precipitation value is 342 mm in the basin. The spatial distribution shows that the precipitation value increases from 280 mm in central part to 340 mm south-eastern, northeastern, and extreme northwestern tip of the basin (Fig. 4.7). The rainfall intensity varies from 12 mm/ a rainy day in Golaghat, Kamarbund, and Sycota station to a maximum of 23 mm/ a rainy day in Negheriting station. The average rainfall intensity of the basin is 14.3 mm/a rainy day. The rainfall intensity spatially distributed ranges from 12 mm/a rainy day in central part of the basin to 15 mm/ a rainy day in southeastern part of the basin. The maximum rainfall intensity found in extreme northwestern part of the basin. The rainfall variability ranges from 16% in Golaghat and Wokha stations to a maximum of 42% in Borholla station. The average rainfall variability is 27.5%. Rainfall variability increases from 20% to 40% in central part to southern part of the basin as shown in the fig.4.7. The rainfall ratio during this month ranges from 43% in Golaghat station to a maximum of 175% in Borholla station. The average rainfall ratio is 98.4%. The spatial distribution shows that the rainfall ratio ranges from 100% to 150% in northern to southern part of the basin.

Table 4.7: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin. (1983 – 2013)

(July)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	275	13	42	175
2.	Golaghat	291	12	16	43
3.	Honowal	344	14	31	119
4.	Jorhat	334	14	27	106
5.	Kamarbund	286	12	19	60
6.	Khumtai	312	13	32	113
7.	Negheriting	569	23	29	90
8.	Sycota	271	12	35	97
9.	Titabor	346	14	28	113
10.	Wokha	389	16	16	68

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (JULY)

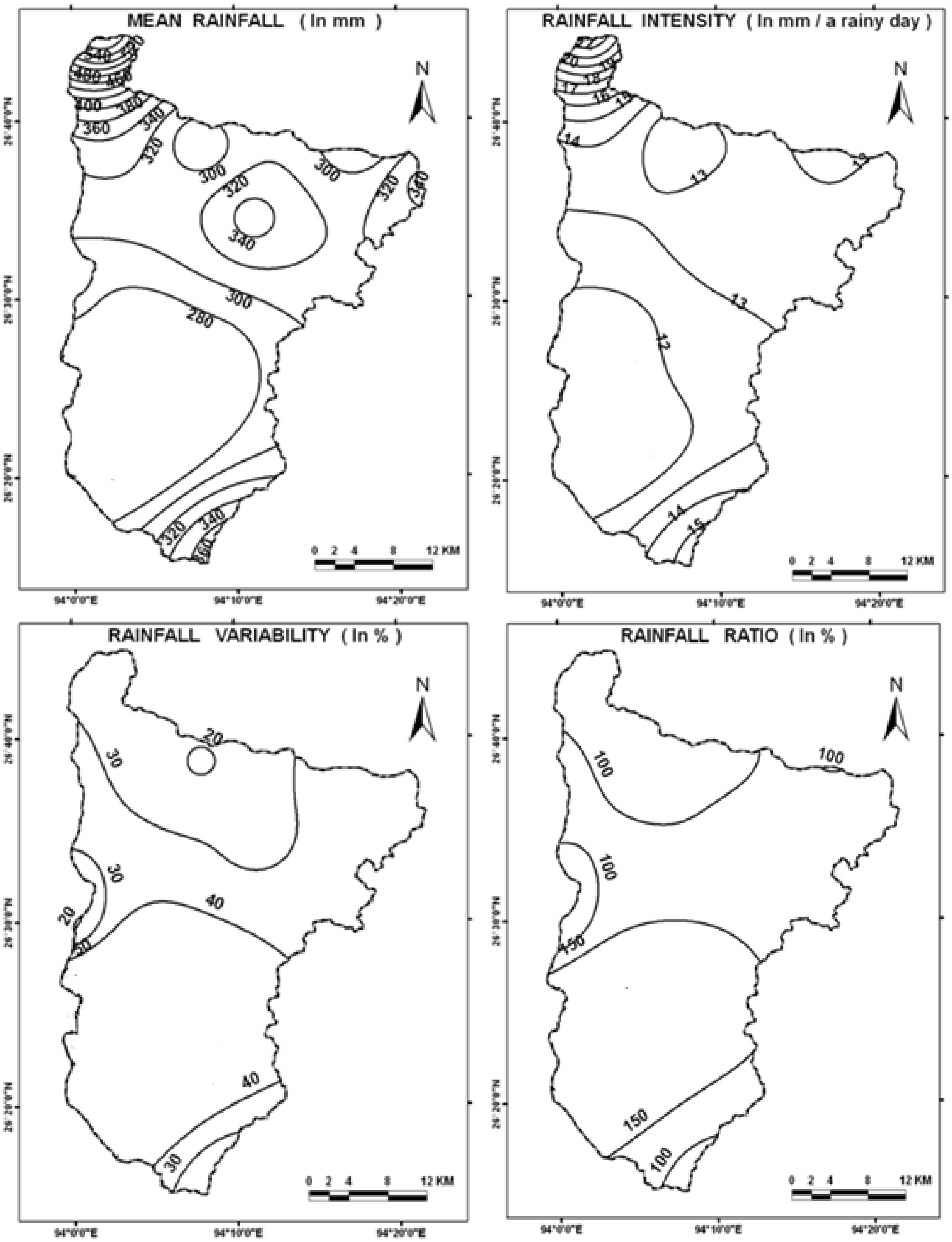


Fig. 4.7

4.1.8 August

Minimum mean monthly precipitation in the month of August is 224 mm noticed in Golaghat rain gauge stations and maximum is 450 mm recorded in Negheriting station (Table 4.8). The average precipitation of the basin is 304.2 mm. The spatial distribution of precipitation shows that it varies from less than 260 mm to 300 mm in northern, southern parts to central part of the basin (Fig. 4.8). The rainfall intensity varies from 12 mm/ a rainy day in Golaghat and Sycota stations, to a maximum of 19 mm/ a rainy day in Negheriting station. The average rainfall intensity is 14 mm /a rainy day of the basin. The spatial distribution shows that the rainfall intensity increases from 12 mm to 14 mm/a rainy day in western part to southeastern and northern parts of the basin, but it extremely increases towards northwestern part of the basin. The rainfall variability during this month ranges from 23% in Golaghat station to a maximum of 61% in Khumtai station. The average rainfall variability is 35.8%. Map depicting spatially distribution of rainfall variability reveals that it increases from 30% to 50% in northern and southern parts to western part of the basin. The rainfall ratio ranges from 69% in Golaghat station to a maximum of 230% in Khumtai station. The average rainfall ratio is 128%. The spatial distribution shows that the rainfall ratio increases from 100% to 200% in northwestern and southeastern parts to western part of the basin.

Table 4.8: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(August)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	305	14	40	160
2.	Golaghat	224	12	23	69
3.	Honowal	314	14	38	132
4.	Jorhat	295	14	26	100
5.	Kamarbund	284	13	29	112
6.	Khumtai	318	13	61	230
7.	Negheriting	450	19	27	90
8.	Sycota	237	12	57	180
9.	Titabor	304	14	31	109
10.	Wokha	311	15	26	95

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (AUGUST)

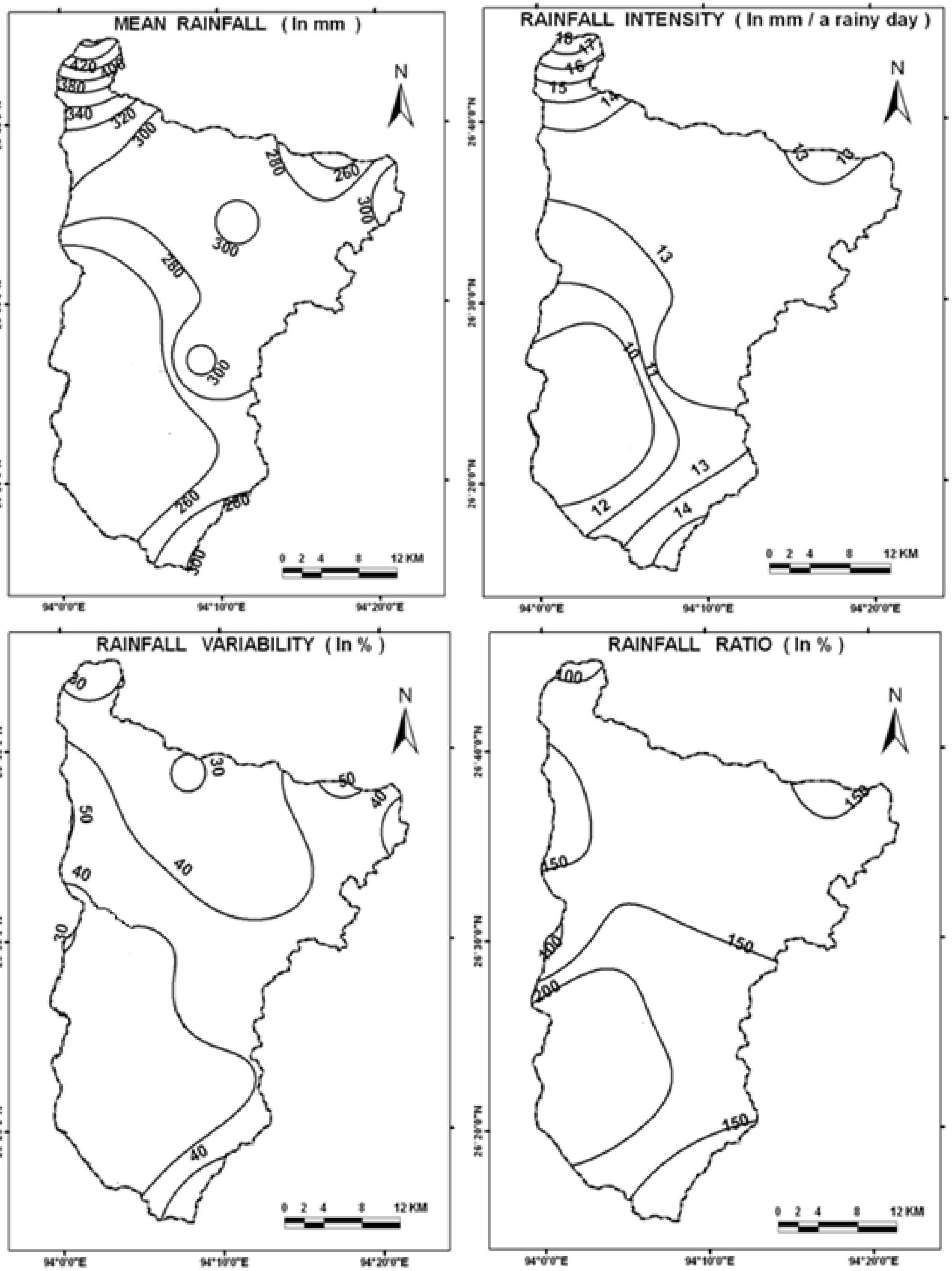


Fig. 4.8

4.1.9 September

The mean monthly precipitation values vary from a minimum of 134 mm in Sycota station to a maximum of 407 mm in Negheriting station (Table 4.9). The average precipitation value is 233 mm in the basin. The spatial distribution shows that the precipitation value increases from 160 mm in central part of the basin to northern and southeastern part and extreme precipitation is observed in northwestern part of the basin (Fig. 4.9). The rainfall intensity varies from 9 mm/ a rainy day in Sycota station to a maximum of 187 mm/ a rainy day in Negheriting station. The average rainfall intensity of the basin is 13 mm/a rainy day. Spatial distribution of rainfall intensity ranges from 10 mm/a rainy day to 14 mm/ a rainy day in western and southeastern parts of the basin. The maximum precipitation has been identified as more than 14 mm/a rainy day in northwestern part of the basin. The rainfall variability ranges from 28% in Golaghat station to a maximum of 63% in Khumtai station. The average rainfall variability is 39%. Around 40% rainfall variability is found in northeastern and southeastern part of the basin and maximum rainfall variability (60%) increases towards western part of the basin. The rainfall ratio ranges from 97% in Golaghat station to a maximum of 253% in Khumtai station. The average rainfall ratio is 142%. The spatial distribution shows that the rainfall ratio ranges from 150% to 250% in eastern to central and western part of the basin.

Table 4.9: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(September)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	181	12	35	130
2.	Golaghat	164	10	28	96
3.	Honowal	261	15	34	126
4.	Jorhat	218	13	39	136
5.	Kamarbund	217	11	30	114
6.	Khumtai	267	13	63	253
7.	Negheriting	407	18	44	150
8.	Sycota	134	9	32	103
9.	Titabor	234	12	55	188
10.	Wokha	245	15	30	124

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (SEPTEMBER)

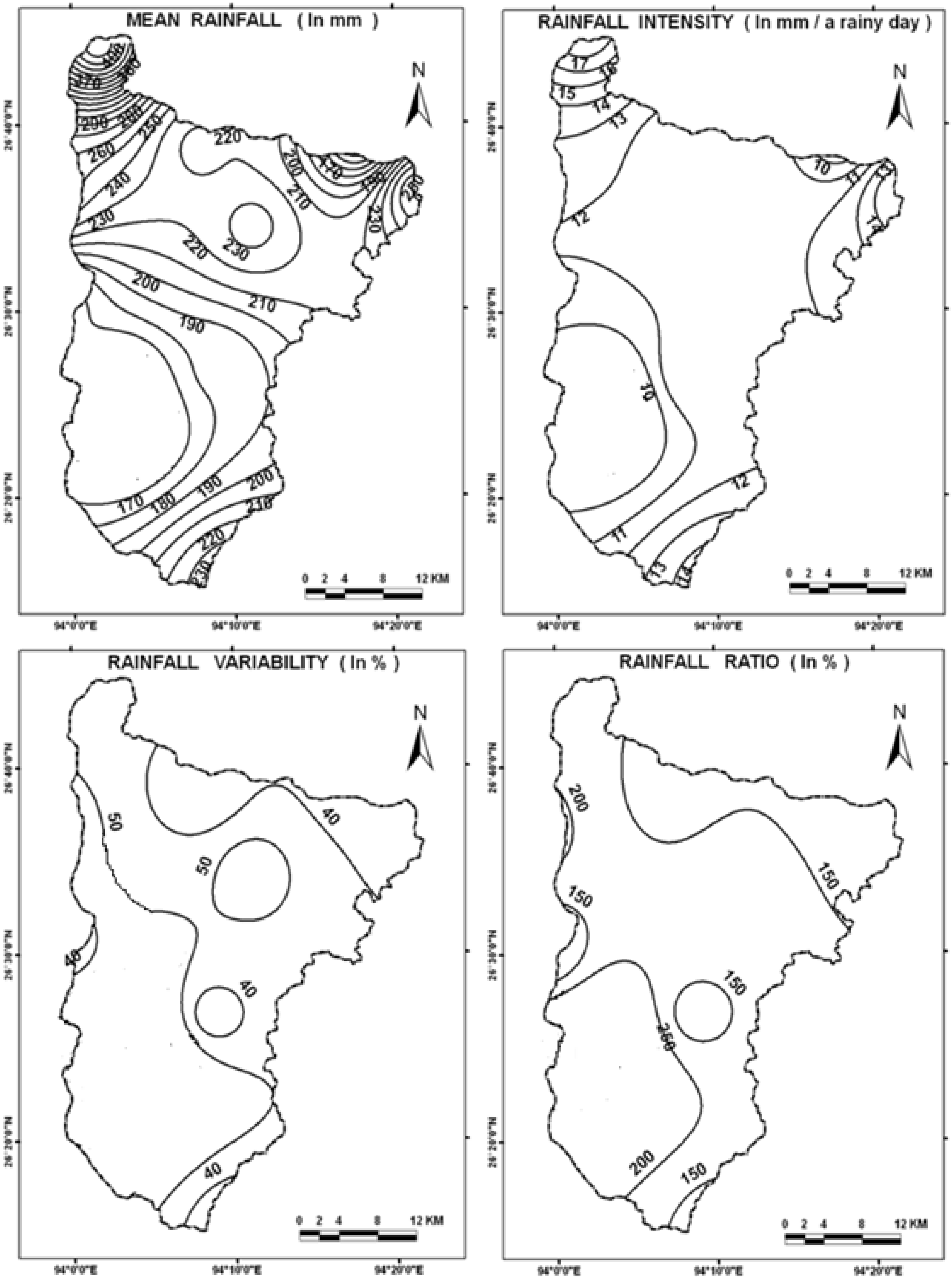


Fig. 4.9

4.1.10 October

In this month minimum mean precipitation is recorded in Sycota (81 mm) and maximum in Negheriting i.e. 223 mm. The average precipitation of the basin is 119.4 mm. The spatially distribution of precipitation shows that is less than 100 mm precipitation areas are located in western and central part of the basin (Fig. 4.10). Above 220 mm rainfall areas are concentrated in northwestern part of the basin. The rainfall intensity varies from 6 mm/ a rainy day in Khumtai station, to a maximum of 13 mm/ a rainy day in Borholla and Negheriting stations. Maximum no. of raingauge stations rainfall intensity is 12 mm/ a rainy day. The average rainfall intensity is also 12 mm /a rainy day of the basin. The spatial distribution shows that the rainfall intensity ranges from 10 mm to 12.5 mm/a rainy day in western to central and northeastern parts of the basin. The rainfall variability ranges from 52% in Golaghat station to a maximum of 92% in Sycota station. The average rainfall variability is 67%. The spatial distribution map reflects that less than 60% rainfall variability is found in central and northern part of the basin. The maximum rainfall variability is 80%, which is concentrated in northeastern part of the basin .The rainfall ratio ranges from 161% in Titabor station to a maximum of 293% in Sycota station. The average rainfall ratio is 214%. The spatial distribution shows that the rainfall ratio varies from 150% to 250% in northern, southern part to central part of the basin. It is exceeds more than 250% located in northeastern part of the basin.

Table 4.10: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(October)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	103	13	54	195
2.	Golaghat	95	12	52	172
3.	Honowal	110	12	61	219
4.	Jorhat	110	12	71	231
5.	Kamarbund	112	12	85	241
6.	Khumtai	116	6	76	215
7.	Negheriting	223	13	65	190
8.	Sycota	81	12	92	293
9.	Titabor	113	11	53	161
10.	Wokha	131	12	56	223

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (OCTOBER)

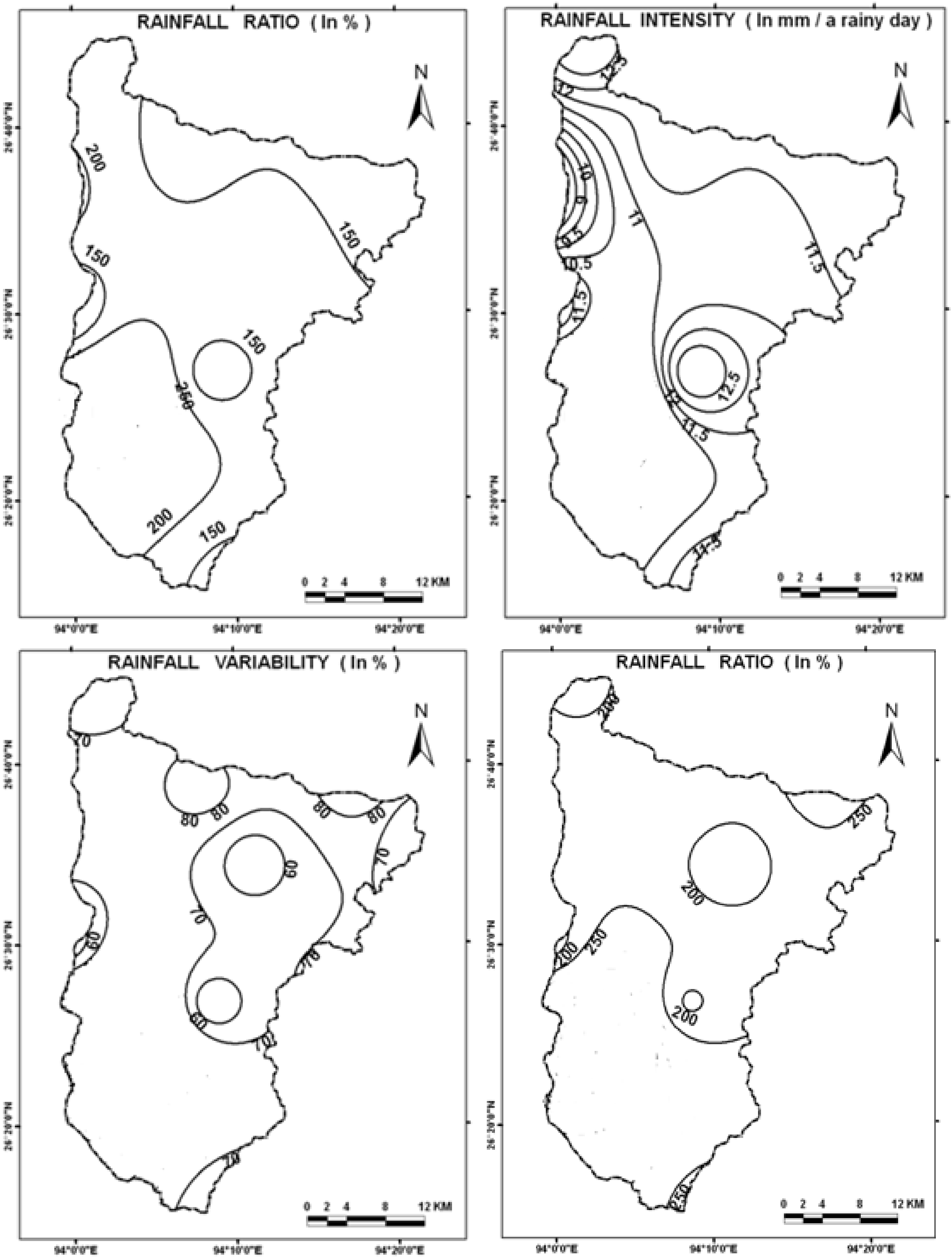


Fig. 4.10

4.1.11 November

In the month of November the mean monthly precipitation values vary from a minimum of 10 mm in Golaghat station to a maximum of 31 mm in Honowal station (Table 4.11). The average precipitation value is 22 mm. The spatial distribution shows that the precipitation value increases from 15 mm in western part to 25 mm in eastern, northeastern and extreme northwestern tip of the basin (Fig. 4.11). The rainfall intensity varies from 3 mm/ a rainy day in Golaghat station to a maximum of 8 mm/ a rainy day in Kamarbund station. The average rainfall intensity of the basin is 5.8 mm/a rainy day. The spatial distribution of rainfall intensity ranges from 3.5 mm/a rainy day to 7.5 mm/ a rainy day in western, central part to northern part of the basin. The rainfall variability ranges from 82% in Titabor station to a maximum of 133% in Kamarbund station. The average rainfall variability is 99%. The spatial distribution of rainfall variability varies from 90% to 130% in northeastern, southeastern and northern part of the basin. The rainfall ratio occurred in the month of November ranges from 239% in Titabor station to a maximum of 397% in Borholla station. The average rainfall ratio is 313%. The spatial distribution shows that the rainfall ratio increases from 250% to 400% in northern to central part of the basin and decreases from central to southeastern and western parts of the basin.

Table 4.11: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(November)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	19	6	110	397
2.	Golaghat	10	3	84	241
3.	Honowal	31	6	86	295
4.	Jorhat	22	7	96	328
5.	Kamarbund	30	8	133	257
6.	Khumtai	20	4	107	340
7.	Negheriting	26	5	107	370
8.	Sycota	18	6	89	278
9.	Titabor	18	6	82	239
10.	Wokha	26	7	99	387

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (NOVEMBER)

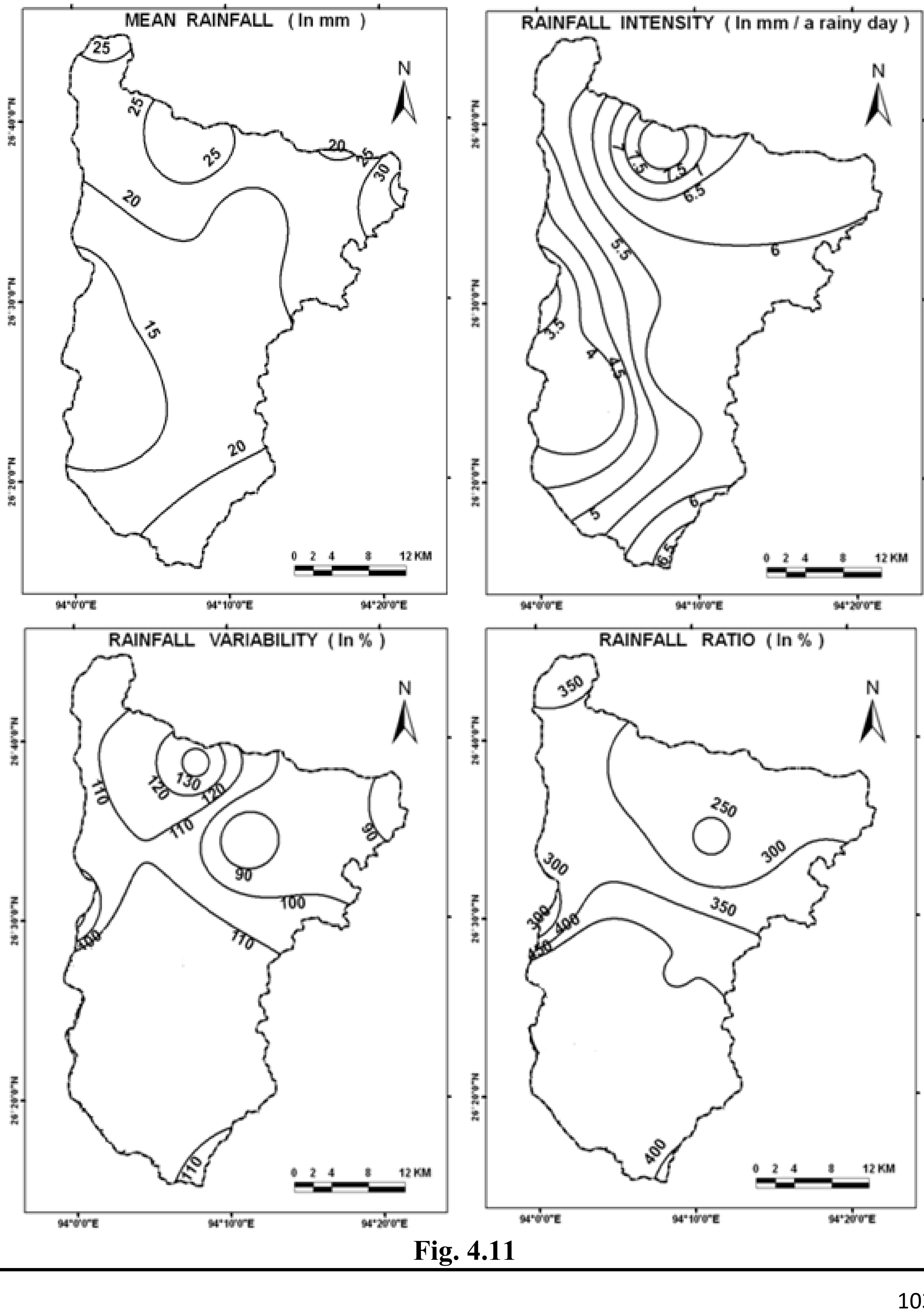


Fig. 4.11

4.1.12 December

The mean precipitation in the month of December varies from a minimum of 3 mm in Golaghat rain gauge station to a maximum of 17 mm in Negheriting rain gauge station (Table 4.12). The average precipitation of the basin is 11 mm. The spatially distribution of precipitation shows that it is less than 10 mm in northern, western and southern parts of the basin (Fig. 4.12). The maximum distribution of precipitation spatially depict that it is 15 mm in extreme northwestern part of the basin. The rainfall intensity varies from 1 mm/ a rainy day in Golaghat station to a maximum of 5 mm/ a rainy day present in Jorhat station. The average rainfall intensity is 4 mm /a rainy day of the basin. Minimum rainfall intensity increases from 1.5 mm/ a rainy day in central part to 4 mm/a rainy day in northern part of the basin. The rainfall variability during the month of December ranges from 90% in Golaghat station to a maximum of 253% in Khumtai station. The average rainfall intensity is 163%. Less than 120% spatial distribution of rainfall variability is found in northeastern, southern and western parts of the basin. The maximum rainfall variability noticed as 160% in central and northwestern parts of the basin. The rainfall ratio ranges from 277% in Golaghat station to a maximum of 933% in Khumtai station. The average rainfall ratio is 559%. The spatial distribution shows that the rainfall ratio varies from 400% to 700% northern, southern to central parts of the basin. It is exceeds more than 800% in western part of the basin.

Table 4.12: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983 – 2013)

(December)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	8	4	180	708
2.	Golaghat	3	1	90	277
3.	Honowal	14	4	151	517
4.	Jorhat	9	5	151	636
5.	Kamarbund	12	4	206	737
6.	Khumtai	8	2	253	933
7.	Negheriting	17	4	199	560
8.	Sycota	8	4	123	288
9.	Titabor	13	4	159	608
10.	Wokha	13	4	114	326

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (DECEMBER)

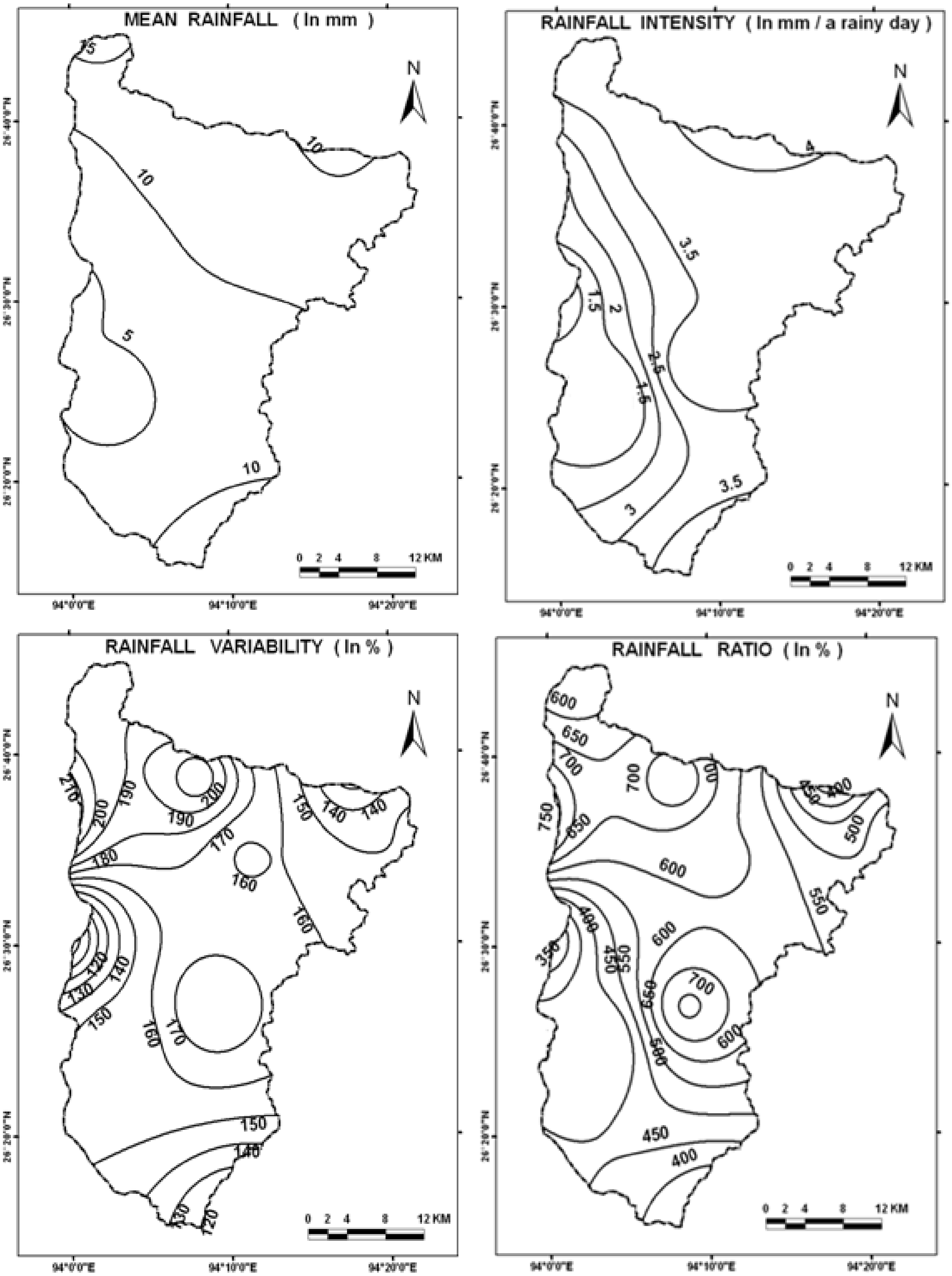


Fig. 4.12

4.2.0 Mean monthly rainfall analysis of the Kakodonga river basin

From the analysis of the mean monthly annual rainfall, it may be concluded that the mean rainfall is less than 100 mm in five months that is November, December, January, February and March months (Table 4.13 & Fig. 4.13). Out of these five months the November, December, January, and February receive rainfall less than 50 mm except Negheriting station where rainfall in the month of February is 58 mm. In March again Negheriting rain-gauge station shows rainfall more than 100 mm (192 mm). The mean rainfall ranged from 100 mm to 250 mm in the months of April, May and October excluding Negheriting station. During these months Negheriting stations receives rainfall more than 250 mm. The mean rainfall is above 250 mm in June, July, August and September months. The Golaghat rain-gauge station receives very less rainfall that is 3 mm in December month and maximum mean rainfall identified in Negheriting rain-gauge station is 569 mm in the month of July. Finally the Negheriting rain gauge station shows highest rainfall in all the months. The mean monthly analysis of average rainfall intensity denotes that during January, February, November and December months it is less than 10 mm / a rainy day. Out of these four months the December and January experience 5mm and less than 5 mm/ a rainy day. The average rainfall intensity varies from 15 mm to 20 mm / a rainy day in March, April, May, August and September months. The average rainfall intensity is more than 20 mm / a rainy day in June and July months. The monthly analysis of rainfall variability shows that during June, July, August and September months, the variability is less than 75%. The mean rainfall variability ranges from 75% to 150% in the months of October, November, February, April and May. It is more than 150% in January, March and December months. The rainfall ratio value exceeds 400% in December, January, February and May months. The ratio values range from 200% to 400% in April, August, September, October and November months. The rainfall ratio values are less than 200% in June and July months

Table 4.13: Mean rainfall (1983-2013) of the Kakodonga river basin

Sl. No.	Rain gauge Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Borholla	32	34	91	159	243	247	275	305	181	103	19	8
2.	Golaghat	13	32	76	167	168	215	291	224	164	95	10	3
3.	Honowal	20	45	71	213	252	287	344	314	261	110	31	14
4.	Jorhat	16	38	69	161	223	259	334	295	218	110	22	9
5.	Kamarbund	16	35	77	153	215	239	286	284	217	112	30	12
6.	Khumtai	13	30	64	175	229	284	312	318	267	116	20	8
7.	Negheriting	24	58	192	302	408	493	569	450	407	223	26	17
8.	Sycota	13	29	48	125	190	169	271	237	134	81	18	8
9.	Titabor	20	42	63	161	224	261	346	304	234	113	18	13
10.	Wokha	14	35	89	154	277	388	389	311	245	131	26	13

Source: Water Resources Department (Rainfall)

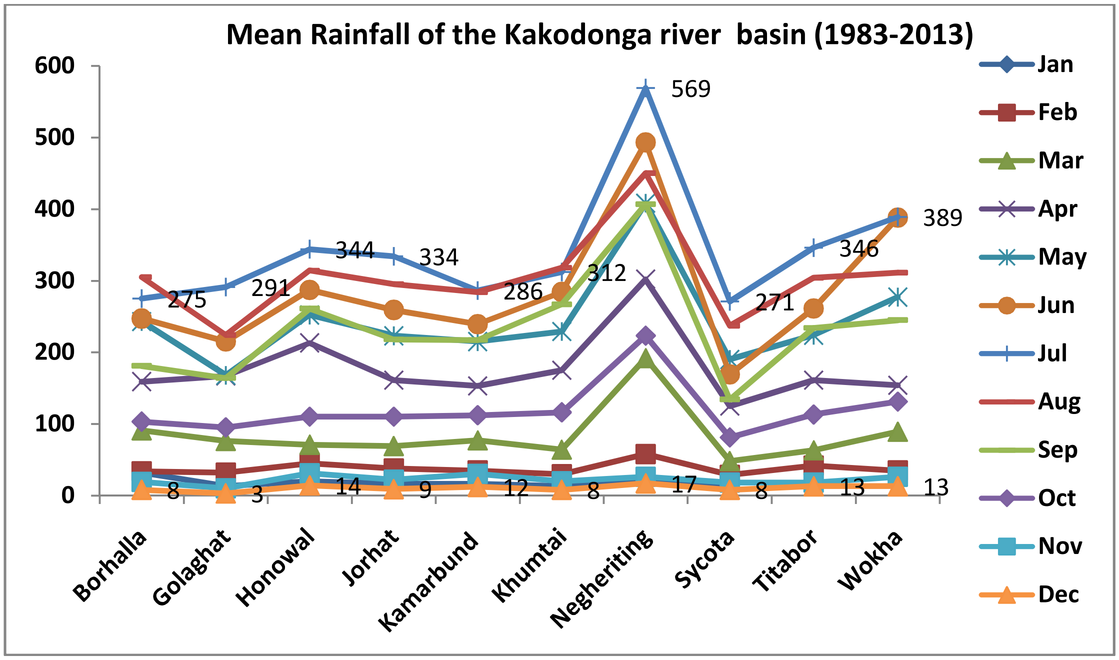


Fig. 4.13

4.3. The analysis of seasonal rainfall of the Kakodonga river basin

4.3.1 Winter

The mean winter seasonal rainfall varies from 48 mm in Golaghat station to a maximum of 99 mm in Negheriting station (Table. 4.14). The average winter precipitation of the basin is 67 mm. The spatial distributions show that the precipitation is less than 50 mm in southern and southwestern parts of the basin (Fig. 4.14). It ranges from 50 mm to 70 mm in central and northeastern parts of the basin and exceeds 70 mm in northwestern part of the basin. The rainfall intensity is found minimum of 9 mm /a rainy day in Golaghat and Khumtai stations to a maximum of 16 mm /a rainy day in Wokha station. The average rainfall intensity is 13 mm / a rainy day. The spatial distribution shows that it varies from 10 mm / a rainy day in western and southwestern parts to a maximum of 15 mm / a rainy day in northeastern, northwestern and southeastern parts of the basin. The rainfall variability values increases from 261% in Wokha station to a maximum of 474% in Borholla station. The spatial distribution shows that rainfall variability during this season is less than 300% in northeastern and southeastern parts of the basin. It exceeds 300% from southern central to south central part of the basin. The rainfall ratio values increase from 684% in Sycota station to a maximum of 2082% found in Borholla station. The average rainfall ratio is 1187%. The spatial distribution shows that the rainfall ratio ranges from 800% in northeastern part to a maximum of 2000% and above found in central and southeastern parts of the basin.

Table 4.14: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983-2013)

(Winter)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	74	15	474	2082
2.	Golaghat	48	9	271	977
3.	Honowal	79	14	282	1024
4.	Jorhat	63	14	324	1261
5.	Kamarbund	63	14	351	1245
6.	Khumtai	51	9	431	1460
7.	Negheriting	99	14	356	1080
8.	Sycota	50	12	266	684
9.	Titabor	75	13	308	1191
10.	Wokha	62	16	261	870

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (WINTER)

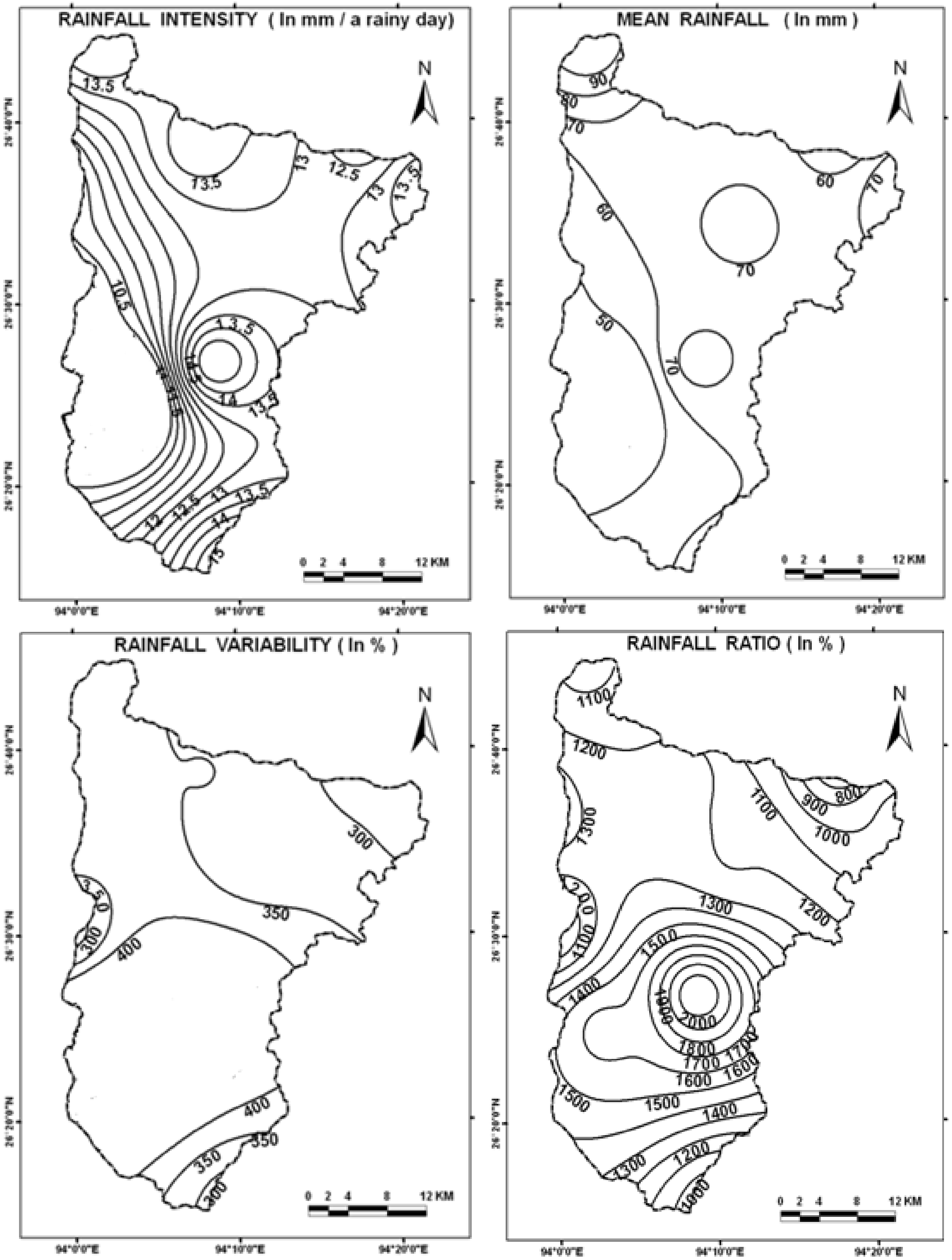


Fig. 4.14

4.3.2 Pre-monsoon

In pre-monsoon season rainfall values varies from a minimum of 363 mm in Sycota station to a maximum of 901mm in Negheriting station (Table. 4.15). The average precipitation value of the basin is 504 mm. The spatial distribution shows that the precipitation value increases from 400 mm in southwestern and southeastern to 480 mm in central and northeastern parts of the basin (Fig.4.15). The maximum precipitation identified in northwestern tip of the basin. The rainfall intensity ranges from 26 mm / a rainy day in Sycota station to a maximum of 43 mm / a rainy day in Wokha and Negheriting stations. The average rainfall intensity is 32 mm / a rainy day. The spatial distribution shows that in the pre-monsoon season the rainfall intensity is less than 30 mm / a rainy day in central part of the basin. It exceeds 40 mm / a rainy day in northwestern and southeastern parts of the basin. The rainfall variability ranges from 122% in Wokha station to a maximum of 355% in Borholla station. The spatial distribution shows that the variability is less than 200% in northeastern and southeastern parts of the basin. It exceeds 300% in central part of the basin. The rainfall ratio during this season varies from 485% in Golaghat station to a maximum of 1459% in Borholla station. The spatial distribution of rainfall ratio increases from 600% in western and northeastern parts to more than 1200% found in central part of the basin.

Table 4.15: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983-2013)

(Pre-monsoon)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	492	32	355	1459
2.	Golaghat	411	29	152	485
3.	Honowal	536	29	158	540
4.	Jorhat	453	29	163	645
5.	Kamarbund	445	29	180	591
6.	Khumtai	467	30	158	599
7.	Negheriting	901	43	248	900
8.	Sycota	363	26	190	590
9.	Titabor	449	28	179	698
10.	Wokha	520	43	122	989

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (PRE-MONSOON)

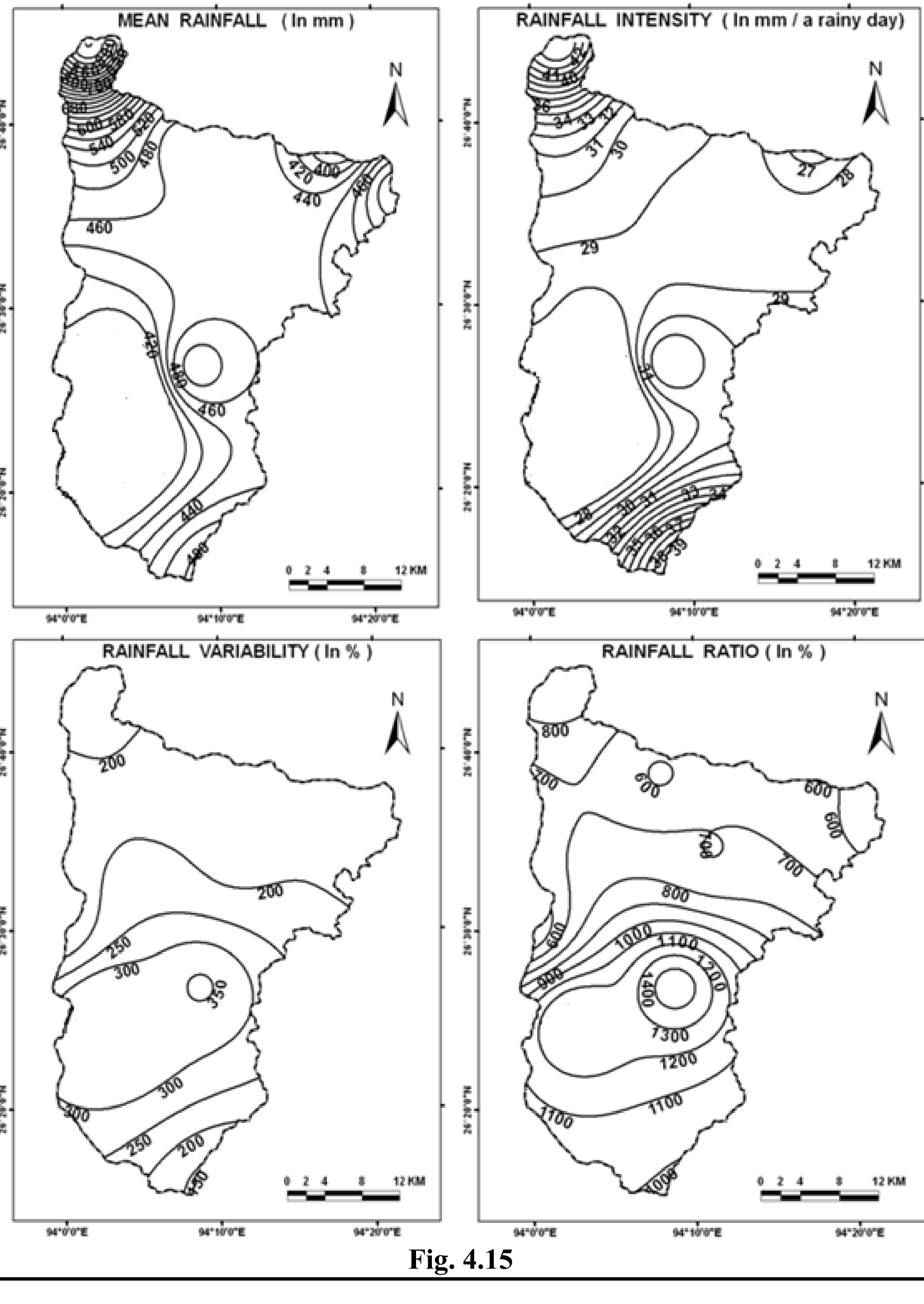


Fig. 4.15

4. 3.3 Monsoon

In monsoon mean precipitation varies from 677 mm in Sycota station to a maximum of 1511mm in Negheriting station (Table. 4.16). The average precipitation of the basin is 930 mm. The spatial distribution shows that the precipitation is less than 800 mm in central part of the basin (Fig.4.16). It ranges from 800 mm to 900 mm in central and northeastern parts of the basin. It exceeds more than 1300 mm in northwestern part of the basin. The rainfall intensity ranges from 33 mm / a rainy day in Sycota station to a maximum of 63 mm / a rainy day in Negheriting station. The average rainfall intensity is 41 mm / a rainy day. The spatial distribution shows that the rainfall intensity is less than 40 mm / a rainy day in central and northern parts of the basin. It increases from 40 mm to 60mm / a rain day southeastern to northwestern tip of the basin. The rainfall variability ranges from 61% in Golaghat station to a maximum of 146% in Sycota station. The spatial distribution shows that it is about 100% in northeastern, northwestern and western parts of the basin. The minimum rainfall ratio value of 173% is observed in Golaghat station and a maximum of 490% is found in Borholla station. The spatial distribution shows that the rainfall ratio is less than 300% in southeastern part of the basin. It exceeds 400% in central part of the basin.

Table 4.16: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983-2013)

(Monsoon)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	828	39	126	490
2.	Golaghat	730	35	61	173
3.	Honowal	946	40	92	336
4.	Jorhat	888	40	88	337
5.	Kamarbund	809	36	97	349
6.	Khumtai	913	40	122	462
7.	Negheriting	1511	63	98	350
8.	Sycota	677	33	146	454
9.	Titabor	912	40	102	401
10.	Wokha	1088	47	70	259

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (MONSOON)

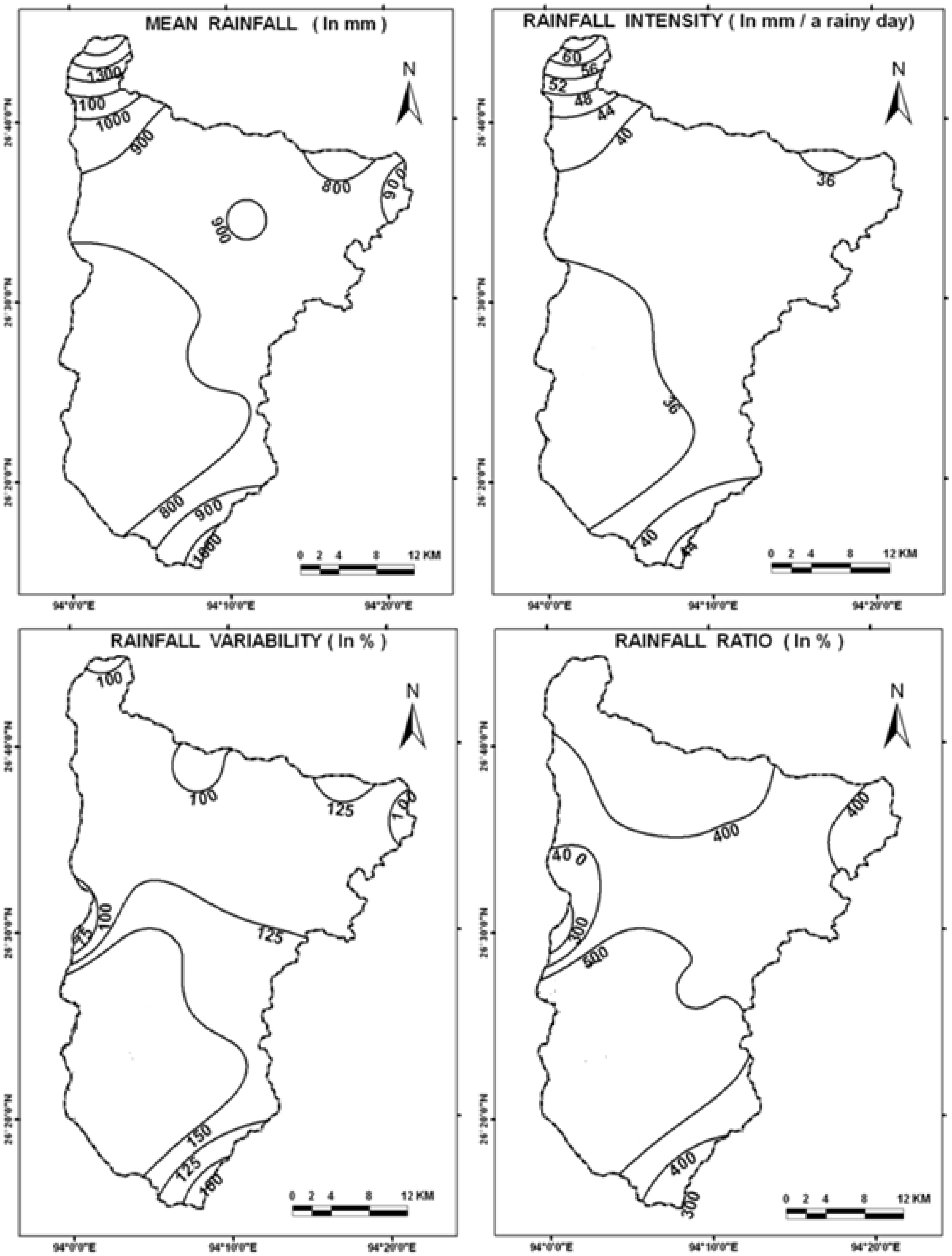


Fig. 4.16

4.3.4 Post-monsoon

In this post-monsoon the mean precipitation values vary from a minimum of 233 mm in Sycota station to a maximum of 656 mm in Negheriting station (Table. 4.17). The average precipitation value of the basin is 374 mm. The spatial distribution shows that the precipitation value increases from 300 mm in southwestern part of the basin to 350mm in the southeastern and northeastern parts of the basin (Fig. 4.17). The rainfall intensity varies from 24 mm / a rainy day in Golaghat station to a maximum of 36 mm / a rainy day in Negheriting station. The average rainfall intensity is 30 mm / a rainy day. The spatial distribution shows that in the post-monsoon season the rainfall intensity increases from 30 mm / a rainy day in southwestern to southeastern, northeastern and central parts of the basin. The rainfall variability ranges from 164% in Golaghat station to a maximum of 248% in Kamarbund station. The spatial distribution map depicts that it is about 200% in central and northeastern parts of the basin. It exceeds 225% in southeastern and northern parts of the basin. The rainfall ratio ranges from a minimum of 509% in Golaghat station to a maximum of 808% in Khumtai station. The spatial distribution reveals that the rainfall ratio value is less than 700% in northern and southeastern parts of the basin. It exceeds 800% in western part of the basin.

Table 4.17: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983-2013)

(Post-monsoon)

S. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1	Borholla	302	31	199	722
2	Golaghat	269	24	164	509
3	Honowal	403	33	181	640
4	Jorhat	350	32	206	695
5	Kamarbund	360	31	248	612
6	Khumtai	403	23	246	808
7	Negheriting	656	36	216	710
8	Sycota	233	27	213	674
9	Titabor	364	29	190	588
10	Wokha	402	34	185	734

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (POST-MONSOON)

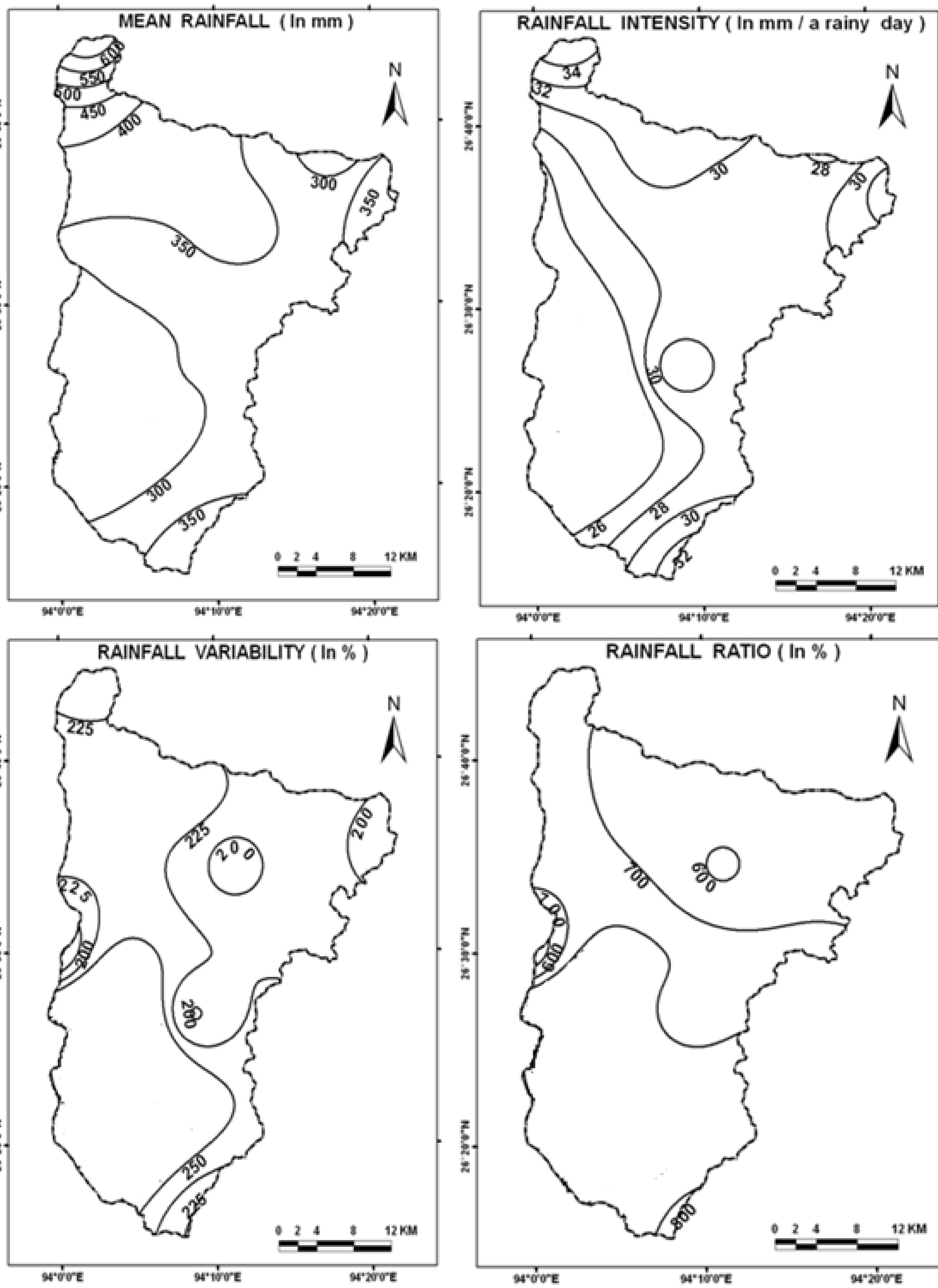


Fig. 4.17

The seasonal analysis of the mean rainfall depict that the basin received the maximum rainfall in monsoon season i.e. 930 mm. During pre-monsoon period rainfall is 504 mm and in post-monsoon period it is 374 mm. In winter period the mean average rainfall is 67 mm (Table 4.19). The seasonal analysis of rainfall intensity indicates that in winter period it is less than 13 mm / a rainy day. During pre-monsoon and post-monsoon periods it varies from 32 mm to 30 mm / a rainy day. It exceeds 41 mm / a rainy day in monsoon period. The rainfall ratio values are above 332% during winter period. During pre-monsoon and post-monsoon period it varies from 191% to 205%. In monsoon period the rainfall variability is less than 100%. The rainfall ratio values are above 1187% in winter period. The rainfall ratio values vary from 700% to 669% in pre-monsoon and post-monsoon periods. During monsoon period rainfall ratio has greater stability, which is 361%. From the analysis of seasonal mean rainfall, rainfall intensity, rainfall variability and rainfall ratio it is found that during monsoon months the stability of rainfall is good. During winter months there is high instability because of low rainfall.

4.4. The analysis of annual rainfall of the Kakodonga river basin

The mean annual precipitation varies from 1322 mm in Sycota station to a maximum of 3168 mm in Negheriting station (Table 4.18). The average annual precipitation of the basin is 1875 mm. The spatial distribution of the precipitation highlights that it is less than 1500 mm in southwestern and northeastern parts of the basin (Fig. 4.18). It ranges from 1500 mm to 1800 mm in central and southeastern parts of the basin. The precipitations more than 1800 mm is observed in northwestern tip of the basin. The rainfall intensity ranges from a minimum of 97 mm / a rainy day in Golaghat station to a maximum of 156 mm / a rainy day in Negheriting station. The average rainfall intensity is 116 mm / a rainy day. The spatial distribution shows that the rainfall intensity is less than 100 mm / a rainy day in western part and 110 mm / a rainy day in central and northeastern parts of the basin. It exceeds 150 mm/ a rainy day in northwestern part of the basin. The rainfall variability varies from 638% in Wokha station to a maximum of 1154% in Borholla station. The average rainfall variability is 828% of the basin. The spatial distribution shows that the rainfall variability is less than 800% in northeastern and southeastern parts of the basin. It exceeds 1100% in central part of the basin. The rainfall ratio ranges from 2144% in Golaghat station to a maximum of 4753% in Borholla station. The spatial distribution shows that it ranges from 2400% in western part to a maximum of 4400% and above in central part of the basin.

Table 4.18: Mean rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983-2013)

(Annual)

Sl. No.	Rain gauge Station	Mean rainfall in mm	Rainfall intensity in mm / a rainy day	Rainfall variability in %	Rainfall ratio in %
1.	Borholla	1697	117	1154	4753
2.	Golaghat	1458	97	648	2144
3.	Honowal	1964	116	713	2539
4.	Jorhat	1754	115	782	2938
5.	Kamarbund	1678	110	876	2797
6.	Khumtai	1835	102	957	3329
7.	Negheriting	3168	156	918	3040
8.	Sycota	1322	98	815	2402
9.	Titabor	1799	110	779	2878
10.	Wokha	2072	140	638	2852

Source: Water Resources Department (Rainfall)

Table 4.19: Season Wise Mean Rainfall, Rainfall intensity, Rainfall variability and Rainfall ratio of the Kakodonga river basin (1983-2013)

Seasons	Mean Rainfall in mm	Rainfall Intensity in mm/ a rainy day	Rainfall Variability in %	Rainfall Ratio in %
Winter	67	13	332	1187
Pre-monsoon	504	32	191	750
Monsoon	930	41	100	361
Post-monsoon	374	30	205	669

Source: Water Resources Department (Rainfall)

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF THE KAKODONGA RIVER BASIN (ANNUAL)

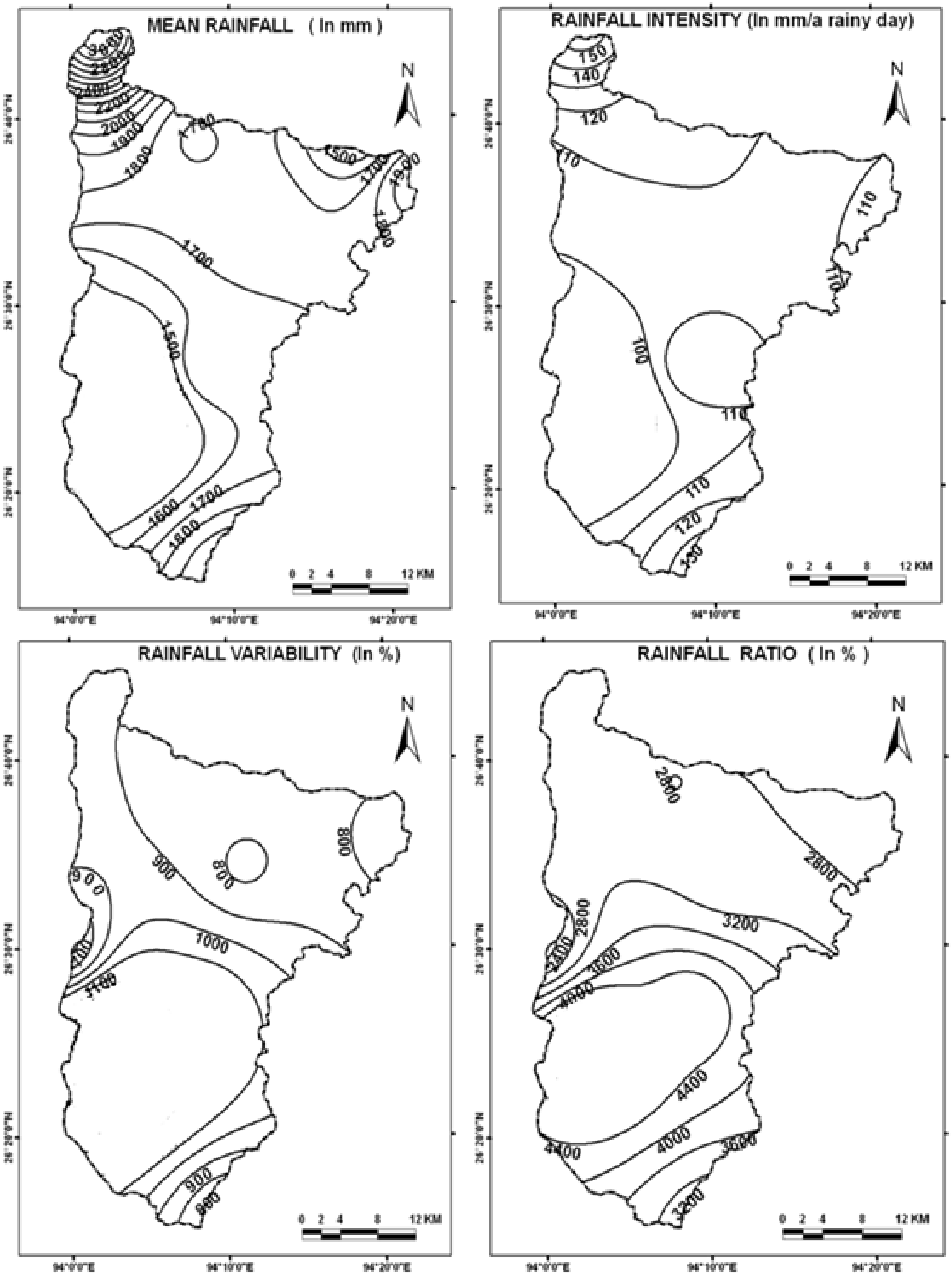


Fig. 4.18

4.5. The annual groundwater recharge of the Kakodonga river basin

The annual groundwater recharge of the Kakodonga river basin has been worked out using Radhakrishna *et al.,* Method (1974), U. S. Geological Method (1962), Seghal's Method (1970) and Krishna Rao (1970) Method.

According to Radhakrishna *et al.,* (1974) method the groundwater recharge of an area or basin is 10% of the rainfall. The groundwater recharge varies from a minimum of 132 mm in Sycota station to a maximum of 317 mm in Negheriting station (Table 4.20 & Fig. 4.20). The average of annual groundwater recharge is 188 mm. The spatial distribution shows that the annual groundwater recharge is less than 200 mm in eastern and western and central part of the basin and more than 200 mm in northwestern and southeastern parts of the basin (Fig. 4.19).

According to U. S. Geological method (1962) the annual groundwater recharge of an area or a basin is 15% of the annual rainfall. According to this method the minimum annual recharge (198 mm) is found in Sycota station and the maximum recharge (475 mm) is recorded in Negheriting station. The annual recharge of the basin is 281 mm. The spatial distribution shows that the annual recharge is less than 300 mm in eastern, western and central parts of the basin, more than 300 mm in northwestern and southwestern parts of the basin.

The Seghal's (1973) method expressed water recharge as $G = 2.5\ (P\text{-}16)^{0.5}$ where precipitation is in inches. According to this method the annual rainfall recharge are relatively high. They vary from a minimum of 253 mm in Sycota station to a maximum of 899 mm in Negheriting station. The average annual recharge of the basin is 446 mm. The spatial distribution shows that the annual recharge is less than 450 mm in eastern, western and central parts of the basin. The annual recharge exceeds 450 mm in southern, northeastern and northwestern parts of the basin (Fig, 4.19).

According to Krishna Rao (1970) method, the annual groundwater recharge R = 0.20 (P-400) when precipitation is between 400 mm to 600mm, R = 0.25 (P-400) when precipitation is 600 to 1000mm and R = 0.35 (P-600) when precipitation is 1000mm and above. The annual recharge varies from a minimum of 381 mm in Sycota station to a maximum of 662 mm in Negheriting station. The average annual recharge of the basin is 447 mm. The spatial distribution shows that the annual recharge is less than 500 mm in eastern, western and central parts of the basin and more than 500 mm in southeastern and northwestern parts of the basin (Fig. 4.19).

The average rainfall of the four methods is taken into consideration for each station in the Kakodonga river basin. The average annual groundwater recharge varies from a minimum of 241 mm in Sycota station to a maximum of 588 mm in Negheriting station. The average groundwater recharge of the basin is 348 mm. The total groundwater resources of the basin have been estimated to be (total geographical area × mean annual recharge) 387,324,000 m^3

Table 4.20: Annual groundwater recharge of the Kakodonga river basin (1983-2013)

(All values in mm)

Sl. No.	Rain gauge Station	Average Annual Rainfall in mm	Radha Krishna *et al* Method (1974)	U.S. Geological Method (1962)	Seghal's Method (1973)	Krishna Rao Method (1970)	Average Recharge in mm
1	Borholla	1697	170	255	384	453	315
2	Golaghat	1458	146	219	300	408	268
3	Honowal	1964	196	295	477	497	366
4	Jorhat	1754	175	263	404	463	326
5	Kamarbund	1678	168	252	377	449	311
6	Khumtai	1835	184	275	432	476	342
7	Negheriting	3168	317	475	899	662	588
8	Sycota	1322	132	198	253	381	241
9	Titabor	1799	180	270	420	470	335
10	Wokha	2072	207	311	515	514	387

Source: Water Resources Department (Rainfall)

ANNUAL GROUNDWATER RECHARGE OF THE KAKODONGA RIVER BASIN

(Recharge in mm)

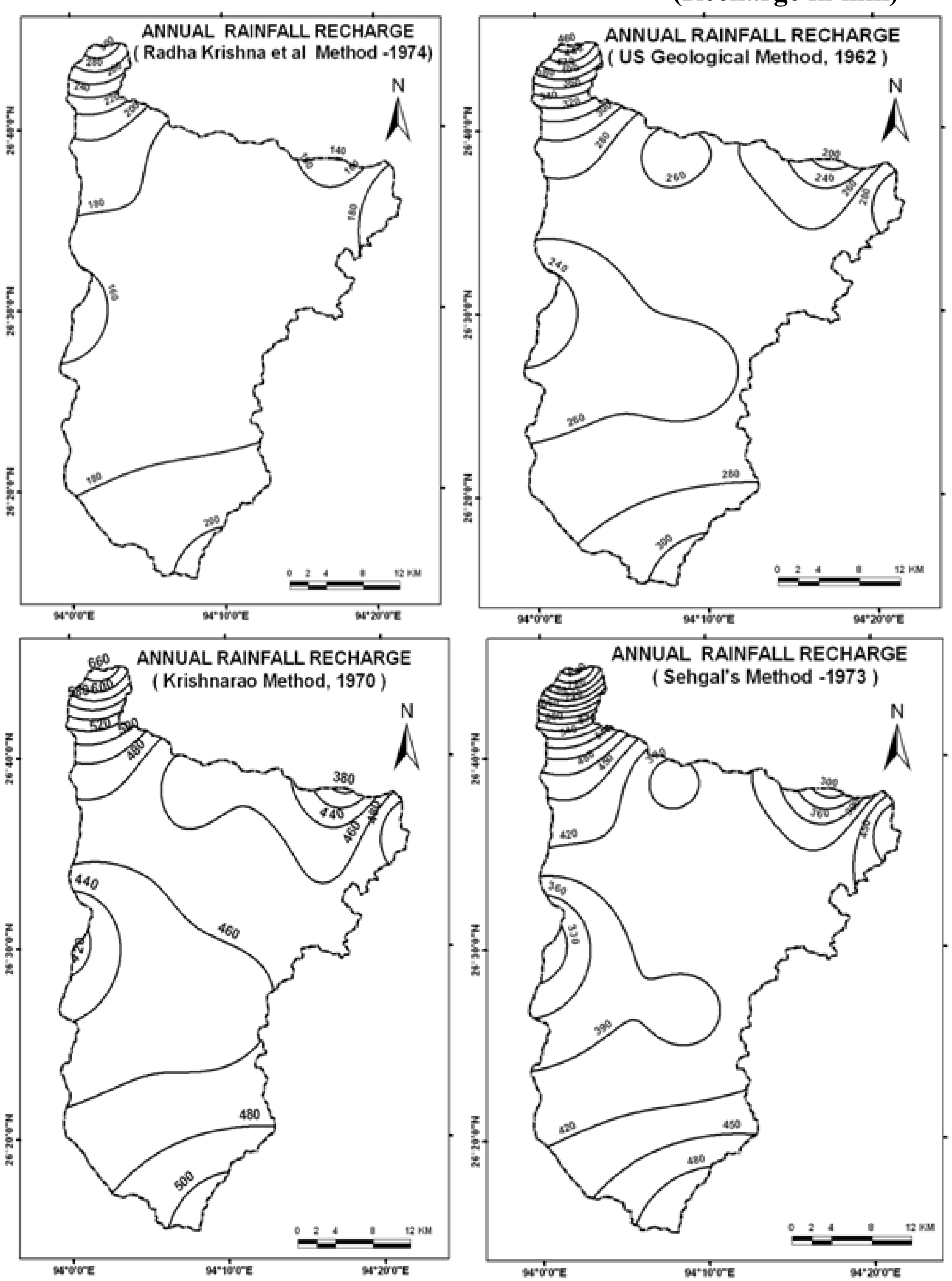
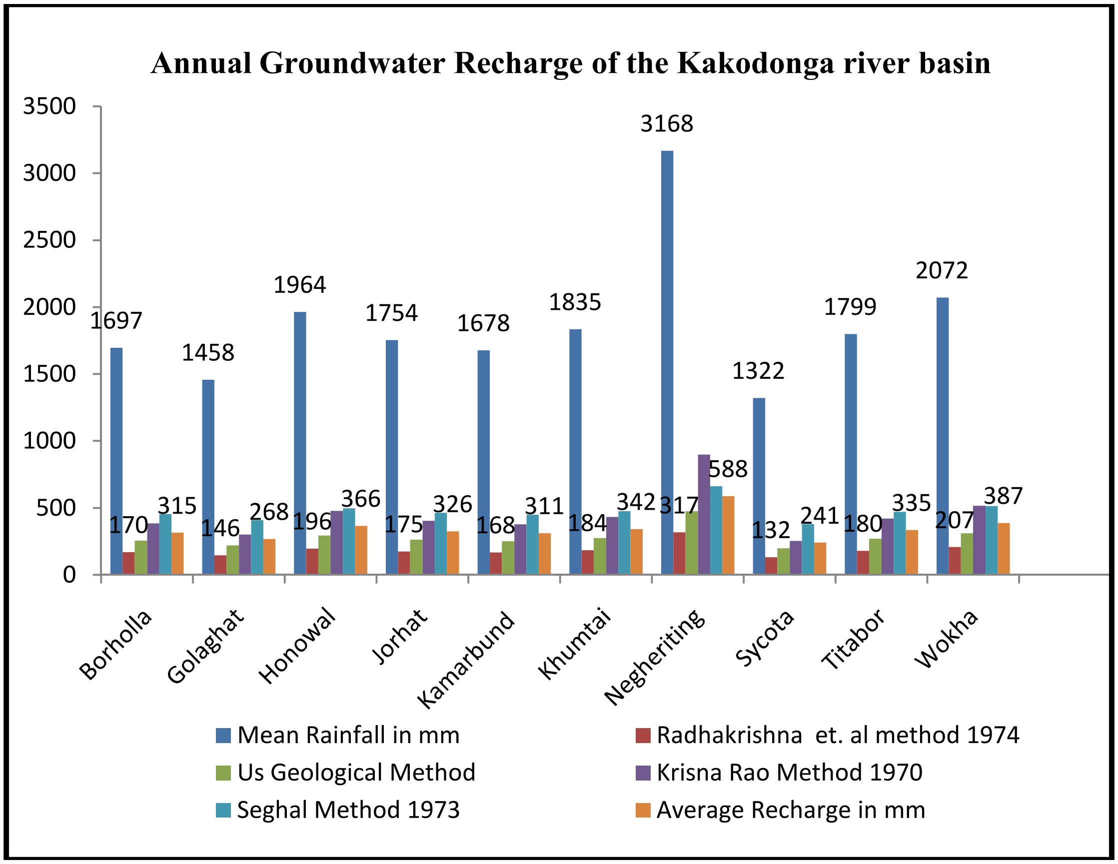


Fig. 4.19



Source: Based on rainfall data of water resource department

Fig. 4.20

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Chapter-5

Water Balance Elements of the Kakodonga River Basin

5

5.0.0. Introduction

Water Balance is an important study of water input in the form of rainfall and water loss in the form evaporation and evapotranspiration. It is a part of Applied Climatology used for identification of water surplus and water deficit zones in a region or basin. It plays an important role in development of agriculture, hydrology and especially for water resources management. It is well established that water supply to a region is primarily through precipitation and water loss is entirely due to evaporation and evapotranspiration. Water balance method gives a highly realistic idea of the arid and wet conditions of India.

The major income is the precipitation and expenditure is the evaporation and evapotranspiration. The potential evapotranspiration is expressed as an exponential function of the mean monthly temperature. When precipitation and potential evapotranspiration are exactly equal in amount there is neither deficiency of moisture nor surplus for wasteful run-off. When the precipitation is greater than potential evapotranspiration, the humid climate prevails. When the potential evapotranspiration is greater than precipitation, the result is arid climate. The relation between water surplus and water deficit constitute the index of the humidity. The index humidity is the ratio between water deficiencies to water need. Moisture index is calculated by taking into account the seasonal and annual water surplus in counter acting the effects of drought through stored up soil moisture.

Thornthwaite and Mather (1955) have evolved an elegant book keeping procedure for computing water balance parameters. They are precipitation, potential evapotranspiration, actual evapotranspiration, water surplus, water deficit, moisture adequacy, aridity index, moisture index and climatic classification. The monthly rainfall data and temperature over a period of 31 years (1983-2013) have been collected from ten rain-gauge stations. They are well distributed in and around the Kakodonga river basin to analyze the rainfall data on monthly, seasonal, annual basis and rain gauge stations wise.

5.1 The Monthly Analysis of Water Balance Elements

5.1.1 January

The mean monthly precipitation during January varies from 13 mm in Golaghat and Khumtai stations to a maximum of 32 mm in Borholla station

(Table. 5.1). The average precipitation of the basin is 18.1 mm. The minimum potential evapotranspiration (75 mm) during the month of January is found in

Table 5.1 Water Balance Elements of the Kakodonga river basin 1983 – 2013 (January)

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	32	80	48	32	0	60	40	-24	C_1
2	Golaghat	13	80	25	55	0	31	68.75	-41.25	D
3	Honowal	20	80	30	50	0	38	62.5	-37.5	D
4	Jorhat	16	80	65	15	0	81	18.75	-11.25	C_1
5	Kamarbund	16	80	30	50	0	38	62.5	-37.5	D
6	Khumtai	13	80	43	37	0	54	46.25	-27.75	C_1
7	Negheriting	24	80	45	35	0	56	43.75	-26.25	C_1
8	Sycota	13	80	43	37	0	54	46.25	-27.75	C_1
9	Titabor	20	80	45	35	0	56	43.75	-26.25	C_1
10	Wokha	14	75	35	40	0	47	53.33	-32	C_1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index, Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

Wokha station only and remaining all the rain-gauge stations have 80 mm. potential evapotranspiration. The average potential evapotranspiration of the basin is 79.50 mm. The actual evapotranspiration values range from 25 mm in Golaghat station to a maximum of 65 mm in Jorhat station. The average actual evapotranspiration of the basin is 40.90 mm. The water deficit during this month ranges from a minimum of 15 mm in Jorhat station to a maximum of 55 mm in Golaghat station. The average water deficit of the basin is 38.6 mm. There is no water surplus in the basin during this month in all the stations. Moisture adequacy values vary from 31% in Golaghat station to a maximum of 60% in Borholla station. The average moisture adequacy of the basin is 51.5%. The Aridity Index value varies from 18.75% in Jorhat station to a maximum of 68.79% in Golaghat station. The average Aridity Index value of the basin in this month is 48.58%. Climatologically the Moisture Index values show that dry subhumid type of climate prevails in majority of the stations. But Golaghat, Honowal and Kamarbund stations reveal semi arid type of climate.

5.1.2 February

In the month of February the mean monthly precipitation values vary from a minimum of 29 mm in Sycota station to a maximum of 58 mm in Negheriting station (Table 5.2). The average precipitation value of the basin is 37.80 mm. The potential evapotranspiration values range from a minimum of 85 mm in Kamarbund, Khumtai, Negheriting and Wokha stations to a maximum of 110 mm in Golaghat station. The average potential evapotranspiration value of the basin is 91 mm. The actual evapotranspiration value ranges from 38 mm in Wokha station to a maximum of 70 mm in Jorhat station. The average actual evapotranspiration value is 50.7 mm. The water deficit during the month of February ranges from 20 mm in Negheriting station to a maximum of 70 mm in Golaghat station. The average water deficit of the basin in this month is 40.3 mm. In the month of February there is no water surplus in all the stations of the basin. The moisture adequacy value varies from 36% in Golaghat station to a maximum of 76% in Negheriting station. The average moisture adequacy value of the basin is 56.1%.

Table 5.2 Water Balance Elements of the Kakodonga river basin(1983 - 2013) (February)

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	34	90	52	38	0	58	42.22	-25.33	C1
2	Golaghat	32	110	40	70	0	36	63.64	-38.18	D
3	Honowal	45	95	48	47	0	51	49.47	-29.68	C1
4	Jorhat	38	95	70	25	0	74	26.32	-15.79	C1
5	Kamarbund	35	85	45	40	0	53	47.06	-28.24	C1
6	Khumtai	30	85	45	40	0	53	47.06	-28.24	C1
7	Negheriting	58	85	65	20	0	76	23.53	-14.12	C1
8	Sycota	29	90	49	41	0	54	45.56	-27.33	C1
9	Titabor	42	90	55	35	0	61	38.89	-23.33	C1
10	Wokha	35	85	38	47	0	45	55.29	-33.18	C1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index, Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid,C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

The Aridity Index value ranges from 23.53% in Negheriting station to a maximum of 63.64% in Golaghat station. The average Aridity Index value of the basin is 43.9%. Climatologically the Moisture Index values reveals that all the nine stations prevaile dry sub-humid type of climate except Golaghat station, which shows semiarid type of climate.

5.1.3 March

The mean monthly precipitation during March varies from 48 mm in Sycota station to a maximum of 192 mm in Negheriting station (Table. 5.3). The average precipitation of the basin is 84 mm. Minimum potential evapotranspiration i.e.110 mm recorded in Borholla, Negheriting, Titabor and Wokha stations and maximum potential evapotranspiration identified in Kamarbund station i.e. 116 mm. The average potential evapotranspiration of the basin is 113 mm. The actual evapotranspiration values range from 40 mm in Wokha station to a maximum of 110 mm in Negheriting station. The average actual evapotranspiration of the basin is 74.7 mm. The water deficit during this month ranges from a minimum of 0 mm in Negheriting station to a maximum of 70 mm in Wokha station. The average water deficit of the basin is 38.4 mm. The water surplus (82 mm) identified in Negheriting station only. Moisture adequacy values vary from 36% in Wokha station to a maximum of 100% found in Negheriting station only. The average moisture adequacy of the basin is 66.1%.

Table 5.3 Water Balance Elements of the Kakodonga river basin (1983 – 2013) (March)										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	91	110	95	15	0	86	13.64	-8.18	C1
2	Golaghat	76	115	78	37	0	68	32.17	-19.3	C1
3	Honowal	71	115	75	40	0	65	34.78	-20.87	C1
4	Jorhat	69	115	80	35	0	70	30.43	-18.26	C1
5	Kamarbund	77	116	80	36	0	69	31.03	-18.62	C1
6	Khumtai	64	115	69	46	0	60	40	-24	C1
7	Negheriting	192	110	110	0	82	100	0	42.71	B2
8	Sycota	48	115	55	60	0	48	52.17	-31.3	C1
9	Titabor	63	110	65	45	0	59	40.91	-24.55	C1
10	Wokha	89	110	40	70	0	36	63.64	-38.18	D

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

The Aridity Index value varies from 0% in Negheriting station to a maximum of 63.64% in Wokha station. The average Aridity Index value of the basin in this month is 33.88%. Climatologically the majority of the stations have dry subhumid type of climate according to Moisture Index values. Wokha station shows semiarid type of climate and humid type of climate exist in Negheriting station.

5.1.4 April

The mean monthly precipitation values vary from a minimum of 125 mm in Sycota station to a maximum of 302 mm in Negheriting station (Table 5.4). The average precipitation value of the basin is 177 mm. The potential evapotranspiration values range from a minimum of 115 mm in Jorhat and Wokha stations to a maximum of 125 mm in Golaghat, Honowal and Kamarbund stations and followed by majority of the stations that is 120 mm.

Table 5.4 Water Balance Elements of the Kakodonga river basin 1983 - 2013(April)

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	159	120	120	0	39	100	0	25	B1
2	Golaghat	167	125	125	0	42	100	0	25	B1
3	Honowal	213	125	125	0	88	100	0	41	B2
4	Jorhat	161	115	115	0	46	100	0	29	B1
5	Kamarbund	153	125	125	0	28	100	0	18	C2
6	Khumtai	175	120	120	0	55	100	0	31	B1
7	Negheriting	302	120	120	0	182	100	0	60	B3
8	Sycota	125	120	120	0	5	100	0	4	C2
9	Titabor	161	120	120	0	41	100	0	25	B1
10	Wokha	154	115	115	0	39	100	0	25	B1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

The average potential evapotranspiration value of the basin is 120.5 mm. The actual evapotranspiration value ranges from 115 mm in Jorhat and Wokha stations to a maximum of 125 mm in Golaghat, Honowal and Kamarbund stations and followed by majority of the stations (120 mm). The average actual evapotranspiration value is 120.5 mm. There is no water deficit in all stations; it means there is no Aridity Index. The water surplus varies from 5 mm in Sycota station to a maximum of 182 mm in Negheriting station of the basin. The average water surplus value is 56.5 mm. The Moisture adequacy exposes 100% in all stations. Climatologically the Moisture Index reveals that moist sub-humid type of climate found in two stations and remaining all stations exhibit humid type of climate.

5.1.5 May

The mean monthly precipitation varies from 168 mm in Golaghat station to a maximum of 408 mm in Negheriting station (Table. 5.5). The average precipitation of the basin is 242.9 mm. The potential evapotranspiration during the month of May is 125 mm (minimum) in Khumtai and Wokha stations and 150 mm (maximum) in Jorhat station and 140 mm in Golaghat station. Remaining majority of the stations has 135 mm potential evapotranspiration. The average potential evapotranspiration of the basin is 135 mm.

Table 5.5 Water Balance Elements of the Kakodonga river basin (1983 2013) May										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	243	135	135	0	108	100	0	44.44	B2
2	Golaghat	168	140	140	0	28	100	0	16.67	C2
3	Honowal	252	135	135	0	117	100	0	46.43	B2
4	Jorhat	223	150	150	0	73	100	0	32.74	B1
5	Kamarbund	215	135	135	0	80	100	0	37.21	B1
6	Khumtai	229	125	125	0	104	100	0	45.41	B2
7	Negheriting	408	135	135	0	273	100	0	66.91	B3
8	Sycota	190	135	135	0	55	100	0	28.95	B1
9	Titabor	224	135	135	0	89	100	0	39.73	B1
10	Wokha	277	125	125	0	152	100	0	54.87	B2

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

The actual evapotranspiration values range from 125 mm in Khumtai and Wokha stations to a maximum of 150 mm in Jorhat station and followed by remaining stations. The average actual evapotranspiration is 135 mm. Water deficiency is nil in all the rain gauge stations; it means there is no Aridity Index. The water surplus varies from 28 mm in Golaghat station to a maximum of 273 mm in Negheriting station of the basin. The average water surplus value is 107.9 mm. The Moisture adequacy shows 100% in all selected rain gauge stations. Climatologically the Moisture Index expose that humid type of climate dominated in all the stations except Golaghat station, it experienced moist subhumid type of climate.

5.1.6 June

In the month of June the mean monthly precipitation values vary from 169 mm in Sycota station to a maximum of 493 mm in Negheriting station (Table 5.6). The average precipitation of the basin is 284.2 mm. The minimum potential evapotranspiration is found in Khumtai station i.e. 135 mm and there after 140 mm in Wokha station and remaining all stations have maximum potential evapotranspiration value of 150 mm. The average potential evapotranspiration value of the basin is 147.5 mm. The actual evapotranspiration value ranges from 135 mm in Khumtai station to a maximum of 150 mm in eight stations except Wokha station (140 mm). The average actual evapotranspiration value is 147.5 mm of the basin. There is no water deficit exhibit in all stations; it means there is no Aridity Index. The water surplus varies from 19 mm in Sycota station to a maximum of 343 mm in Negheriting station and immediately followed by 248 mm in Wokha station of the basin. The average water surplus value is 136.7 mm. The Moisture adequacy exposes 100% in all stations. Climatologically the Moisture Index reveals that humid type of climate prevails in all the stations excluding Sycota station, which shows moist subhumid type of climate.

Table 5.6 Water Balance Elements of the Kakodonga river basin (1983 – 2013) June										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	247	150	150	0	97	100	0	39.27	B1
2	Golaghat	215	150	150	0	65	100	0	30.23	B1
3	Honowal	287	150	150	0	137	100	0	47.74	B2
4	Jorhat	259	150	150	0	109	100	0	42.08	B2
5	Kamarbund	239	150	150	0	89	100	0	37.24	B1
6	Khumtai	284	135	135	0	149	100	0	52.46	B2
7	Negheriting	493	150	150	0	343	100	0	69.57	B3
8	Sycota	169	150	150	0	19	100	0	11.24	C2
9	Titabor	261	150	150	0	111	100	0	42.53	B2
10	Wokha	388	140	140	0	248	100	0	63.92	B3

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

5.1.7 July

The mean monthly precipitation during July varies from 271 mm in Sycota station to a maximum of 569 mm in Negheriting station (Table. 5.7). The average precipitation of the basin is 341.70 mm. Minimum potential evapotranspiration during the month of July is 135 mm, observed in Kamarbund and Khumtai stations and maximum value identified as 160 mm concentrated in Sycota station.

Remaining majority of stations is getting 150 mm potential evapotranspiration. The average potential evapotranspiration of the basin is 147.5 mm. The actual evapotranspiration values range from 135 mm in Khumtai and Kamarbund stations to a maximum of 160 mm in Sycota station. The average actual evapotranspiration of the basin is 147.5 mm. Water deficiency is nil in almost all

Table 5.7 Water Balance Elements of the Kakodonga river basin (1983 - 2013) July

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	275	150	150	0	125	100	0	45.45	B2
2	Golaghat	291	150	150	0	141	100	0	48.45	B2
3	Honowal	344	155	155	0	189	100	0	54.94	B2
4	Jorhat	334	150	150	0	184	100	0	55.09	B2
5	Kamarbund	286	135	135	0	151	100	0	52.8	B2
6	Khumtai	312	135	135	0	177	100	0	56.73	B2
7	Negheriting	569	150	150	0	419	100	0	73.64	B3
8	Sycota	271	160	160	0	111	100	0	40.96	B2
9	Titabor	346	150	150	0	196	100	0	56.65	B2
10	Wokha	389	140	140	0	249	100	0	64.01	B3

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

stations; it's indicated that there is no Aridity Index. The water surplus varies from 111 mm in Sycota station to a maximum of 419 mm in Negheriting station of the basin. The average water surplus value is 194.2 mm.The moisture adequacy exposes 100% in almost all stations. Climatologically the Moisture Index value indicates that almost all stations have humid type climate.

5.1.8 August

In the month of August the mean monthly precipitation values vary from a minimum of 224 mm in Golaghat station to a maximum of 450 mm in Negheriting station (Table 5.8). The average precipitation value of the basin is 304.2 mm. The potential evapotranspiration values range from a minimum of 135 mm in Khumtai station to a maximum of 160 mm in Negheriting, Sycota, and Titabor stations. The average potential evapotranspiration value of the basin is 151.5 mm. The actual evapotranspiration values range from a minimum of 135 mm in Khumtai station to a maximum of 160 mm in Negheriting, Sycota, and Titabor stations. The average actual evapotranspiration value of the basin is 151.5 mm. There is no water deficit in all stations; its shows there are no Aridity Index. The water surplus varies from 74 mm in Golaghat station to a maximum of 290 mm in Negheriting station of the basin. The average water surplus value is 152.7 mm. The Moisture adequacy exposes 100% in all stations. Climatologically the Moisture Index reveals that almost all stations have humid type of climate..

Table 5.8 Water Balance Elements of the Kakodonga river basin (1983 - 2013) August										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	305	150	150	0	155	100	0	50.82	B2
2	Golaghat	224	150	150	0	74	100	0	33.04	B1
3	Honowal	314	155	155	0	159	100	0	50.64	B2
4	Jorhat	295	150	150	0	145	100	0	49.15	B2
5	Kamarbund	284	150	150	0	134	100	0	47.18	B2
6	Khumtai	318	135	135	0	183	100	0	57.55	B2
7	Negheriting	450	160	160	0	290	100	0	64.44	B3
8	Sycota	237	160	160	0	77	100	0	32.49	B1
9	Titabor	304	160	160	0	144	100	0	47.37	B2
10	Wokha	311	145	145	0	166	100	0	53.38	B2

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration, WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index, Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid,
C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

5.1.9 September

The mean monthly precipitation varies from 134 mm in Sycota station to a maximum of 407 mm in Negheriting station (Table. 5.9). The average precipitation of the basin is 232.8 mm. The potential evapotranspiration during this month is found minimum in Khumtai station (130 mm) and rest of the stations have maximum value i.e. 150 mm. The average potential evapotranspiration of the basin is 145.5mm. The actual evapotranspiration values range from 130 mm in Sycota station to a maximum of 150 mm in almost all stations except Wokha station. The average actual evapotranspiration of the basin is 145.3 mm. Sycota station has water deficiency of 2 mm. Aridity Index is identified as 1.33% for the same station. The water surplus varies from 0 mm in Sycota station to a maximum of 257 mm in Negheriting station of the basin.

Table 5.9 Water Balance Elements of the Kakodonga river basin (1983 – 2013) September

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	181	150	150	0	31	100	0	17.13	C2
2	Golaghat	164	150	150	0	14	100	0	8.54	C2
3	Honowal	261	150	150	0	111	100	0	42.53	B2
4	Jorhat	218	135	135	0	83	100	0	38.07	B1
5	Kamarbund	217	150	150	0	67	100	0	30.88	B1
6	Khumtai	267	130	130	0	137	100	0	51.31	B2
7	Negheriting	407	150	150	0	257	100	0	63.14	B3
8	Sycota	134	150	148	2	0	99	1.33	-0.8	C1
9	Titabor	234	150	150	0	84	100	0	35.9	B1
10	Wokha	245	140	140	0	105	100	0	42.86	B2

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid..

The average water surplus value is 88.9 mm. The Moisture adequacy expose 100% in almost all stations excluding Sycota station, the station has 99% Moisture adequacy. Moisture Index reveals that dry subhumid type of climate is indentified in Sycota station, moist subhumid type of climate is found in Borholla and Golaghat stations and humid type of climate exhibit in rest of the stations.

5.1.10 October

In the month of October the mean monthly precipitation values vary from a minimum of 81 mm in Sycota station to a maximum of 223 mm in Negheriting station (Table 5.10). The average precipitation value of the basin is 119.40 mm. The potential evapotranspiration values range from a minimum of 125 mm in Jorhat, Khumtai and Wokha stations to a maximum of 140 mm in Golaghat station and remaining majority of the stations have 130 mm potential evapotranspiration. The average potential evapotranspiration value of the basin is 129.5 mm. The actual evapotranspiration value ranges from 105 mm in Sycota station to a maximum of 130 mm in Negheriting station. The average actual evapotranspiration value is 122.10 mm. The water deficit during the month of October ranges from 0 mm in Negheriting and Wokha stations to a maximum of 30 mm in Golaghat station. The average water deficit of the basin in this month is 7.40 mm. In the month of October, water surplus is identified in Negheriting

Table 5.10 Water Balance Elements of the Kakodonga river basin (1983 – 2013) October										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	103	130	126	4	0	97	3.08	-1.85	C1
2	Golaghat	95	140	110	30	0	79	21.43	-12.86	C1
3	Honowal	110	130	125	5	0	96	3.85	-2.31	C1
4	Jorhat	110	125	120	5	0	96	4	-2.4	C1
5	Kamarbund	112	130	128	2	0	98	1.54	-0.92	C1
6	Khumtai	116	125	124	1	0	99	0.8	-0.48	C1
7	Negheriting	223	130	130	0	93	100	0	41.7	B2
8	Sycota	81	130	105	25	0	81	19.23	-11.54	C1
9	Titabor	113	130	128	2	0	98	1.54	-0.92	C1
10	Wokha	131	125	125	0	6	100	0	4.58	C2

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

station only i.e. as 93 mm. The moisture adequacy value varies from 79% in Golaghat station to a maximum of 100% in Negheriting and Wokha stations. The average moisture adequacy value of the basin is 94.4%. The Aridity Index value ranges from 0% in Negheriting and Wokha stations to a maximum of 21.43% in Golaghat station. The average Aridity Index value of the basin is 5.55%.

Climatologically the Moisture Index values shows that dry-sub humid type of climate is found in eight stations and rest of the station experienced moist sub-humid and humid type of climate.

5.1.11 November

The mean monthly precipitation during November varies from 10 mm in Golaghat station to a maximum of 31 mm in Honowal station (Table. 5.11). The average precipitation of the basin is 22 mm. A minimum of 110 mm potential evapotranspiration exist in majority of the stations, nearly four stations have maximum value (115 mm), mainly occurred in Golaghat, Honowal, Jorhat and Sycota stations. The average potential evapotranspiration of the basin is 112 mm. The actual evapotranspiration values range from 60 mm in Golaghat station to a maximum of 106 mm in Negheriting station. The average actual evapotranspiration of the basin is 82.4 mm. The water deficit during this month ranges from a minimum of 4 mm in Negheriting station to a maximum of 55 mm in Golaghat station. The average water deficit of the basin is 29.60 mm. There is no water surplus in all the stations. Moisture adequacy values vary from 52% in Golaghat station to a maximum of 96% in Negheriting station. The average moisture adequacy of the basin is 73.7%. The Aridity Index value varies from 3.64% in Negheriting station to a maximum of 47.83% in Golaghat station. The average Aridity Index value of the basin in this month is 26.34%.

Climatologically the Moisture Index values show that dry sub humid type of climate occurred in almost all stations.

Table 5.11 Water Balance Elements of the Kakodonga river basin (1983 – 2013) November										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	19	110	80	30	0	73	27.27	-16.36	C1
2	Golaghat	10	115	60	55	0	52	47.83	-28.7	C1
3	Honowal	31	115	85	30	0	74	26.09	-15.65	C1
4	Jorhat	22	115	95	20	0	83	17.39	-10.43	C1
5	Kamarbund	30	110	80	30	0	73	27.27	-16.36	C1
6	Khumtai	20	110	90	20	0	82	18.18	-10.91	C1
7	Negheriting	26	110	106	4	0	96	3.64	-2.18	C1
8	Sycota	18	115	75	40	0	65	34.78	-20.87	C1
9	Titabor	18	110	78	32	0	71	29.09	-17.45	C1
10	Wokha	26	110	75	35	0	68	31.82	-19.09	C1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

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5.1.12 December

The mean monthly precipitation values vary from a minimum of 3 mm in Golaghat station to a maximum of 17 mm in Negheriting station (Table 5.12).

Table 5.12 Water Balance Elements of the Kakodonga river basin (1983 – 2013) December										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	8	85	58	27	0	68	31.76	-19.06	C1
2	Golaghat	3	90	50	40	0	56	44.44	-26.67	C1
3	Honowal	14	85	60	25	0	71	29.41	-17.65	C1
4	Jorhat	9	110	85	25	0	77	22.73	-13.64	C1
5	Kamarbund	12	90	50	40	0	56	44.44	-26.67	C1
6	Khumtai	8	85	65	20	0	76	23.53	-14.12	C1
7	Negheriting	17	90	75	15	0	83	16.67	-10	C1
8	Sycota	8	85	62	23	0	73	27.06	-16.24	C1
9	Titabor	13	85	63	22	0	74	25.88	-15.53	C1
10	Wokha	13	85	55	30	0	65	35.29	-21.18	C1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

The average precipitation value of the basin is 10.5 mm. The potential evapotranspiration values ranges from a minimum of 85 mm in Borholla, Honowal, Khumtai, Sycota, Titabor and Wokha stations to a maximum of 110 mm in Jorhat station. The average potential evapotranspiration value of the basin is 89 mm. The actual evapotranspiration value ranges from 50 mm in Golaghat and Kamarbund stations to a maximum of 85 mm in Jorhat station. The average Actual evapotranspiration value is 62.3 mm. The water deficit ranges from 15 mm in Negheriting station to a maximum of 40 mm in Golaghat and Kamarbund stations. The average water deficit of the basin in this month is 26.7 mm. In this month there is no water surplus in all the stations of the basin. The moisture adequacy value varies from 56% in Golaghat and Kamarbund stations to a maximum of 83% in Negheriting station. The average moisture adequacy value of the basin is 69.9%. The Aridity Index value ranges from 16.67% in Negheriting station to a maximum of 44.44% in Golaghat and Kamarbund stations. The average Aridity Index value of the basin is 30.12%. Climatologically the Moisture Index values show dry-sub humid type of climate in almost all stations.

From the analysis of the monthly water balance elements it may be accomplished that the mean Precipitation is less than 100 mm in five months (January, February, March, November and December). Out of these five months the November, December, January and February months receive rainfall less than 50 mm but in the month of February and March rainfall is 58 mm and 192 mm in Negheriting station respectively. In April, May and October months the mean rainfall varied from 100 mm to 250 mm. The mean rainfall ranged from 50 mm to 100 mm in May, June, July, August and November months. The mean rainfall is above 250 mm in June, July, August and September months. The Golaghat rain-gauge station experience very less rainfall that is 3 mm in December month and maximum mean rainfall identified as 569 mm in Negheriting rain-gauge station in the month of July. Finally the Negheriting rain gauge station shows highest rainfall in all the months.

The mean monthly potential evapotranspiration values are less than 110 mm in January, February and November. The mean monthly potential evapotranspiration values range from 110 mm to 210 mm in March, April, May, June, July, August, September and October months and more than 210 mm in December month. The mean actual evapotranspiration values are less than 70 mm in January, February, and November months. In October, March and April months values are found between 70 mm to 140 mm and more than 140 mm in May, June, July, August, September and October months. The average monthly water deficit values are less than 50 mm in October and December months and more than 50 mm in January, February, March, April, May, June, July, August, September, and November months. The water surplus is found in March, April, May, June, July, August, September and October months. It is less than 150 mm in two months that is March and October. The water surplus values vary from 150 to 300 mm in April, May, August and September months and more than 300 mm water surplus found in June and July months. The monthly moisture adequacy values are recorded 100% in April, May, June, July, August and September months. It is less than 100% in January, February, March, October, November and December months. The Aridity Index values exceed 40% in January, February, March, November and December months. The water shortage during these months is moderate. In the months of September and October Aridity Index values are less than 40%. During these months the water shortage in the basin is very low. In other words from April to September there is high water surplus in the basin. Climatologically the basin experiences humid and moist sub-humid type of climate in April, May, June, July, August, and September months. Dry sub-humid conditions are found in October, November, and December months. Semi-arid type of climate is prevailed in January, February and March months.

From the analysis of the water balance elements it may be concluded that April, May, June, July, August and September months are highly favorable for crop cultivation. The December, January, February, and March months are highly unfavorable for crop cultivation due to high water deficit, high potential evapotranspiration and low actual evapotranspiration.

5.2. The Seasonal analysis of Water Balance Elements

5.2.1 Winter

The mean monthly precipitation during winter season varies from 48 mm in Golaghat station to a maximum of 99 mm in Negheriting station (Table. 5.13). The average precipitation of the basin is 66.4 mm. The potential evapotranspiration during this month starts from minimum of 245 mm in Wokha station to a maximum of 285 mm in Jorhat station and remaining six rain gauge stations have 255 mm. The average potential evapotranspiration of the basin is

259.5 mm. The actual evapotranspiration values range from 115 mm in Golaghat station to a maximum of 220 mm in Jorhat station. The average actual evapotranspiration of the basin is 153.9 mm. The water deficit during this month ranges from a minimum of 65 mm in Jorhat station to a maximum of 165 mm in Golaghat station. The average water deficit of the basin is 105.6 mm.

Table 5.13 Water Balance Elements of the Kakodonga river basin (1983 2013) Winter

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	74	255	158	97	0	62	38.04	-22.82	C1
2	Golaghat	48	280	115	165	0	41	58.93	-35.36	D
3	Honowal	79	260	138	122	0	53	46.92	-28.15	C1
4	Jorhat	63	285	220	65	0	77	22.81	-13.68	C1
5	Kamarbund	63	255	125	130	0	49	50.98	-30.59	C1
6	Khumtai	51	250	153	97	0	61	38.80	-23.28	C1
7	Negheriting	99	255	185	70	0	73	27.45	-16.47	C1
8	Sycota	50	255	154	101	0	60	39.61	-23.76	C1
9	Titabor	75	255	163	92	0	64	36.08	-21.65	C1
10	Wokha	62	245	128	117	0	52	47.76	-28.65	C1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

There is no water surplus in the basin during this month in all the stations. Moisture adequacy values vary from 41.07% in Golaghat station to a maximum of 77.19% in Jorhat station. The average moisture adequacy of the basin is 59.3%. The Aridity Index value varies from 22.8% in Jorhat station to a maximum of 58.92% in Golaghat station. The average Aridity Index value of the basin in this month is 40.69%. Climatologically the Moisture Index values show dry sub humid type of climate dominated in all rain gauge stations.

5.2.2 Pre-monsoon

In the pre-monsoon season the mean monthly precipitation values vary from a minimum of 363 mm in Sycota station to a maximum of 901 mm in Negheriting station (Table 5.14). The average precipitation of the basin is 503.7 mm. The potential evapotranspiration during this month varies from a minimum of 350 mm in Wokha station to a maximum of 380 mm in Golaghat and Jorhat stations. The average potential evapotranspiration of the basin is 368.6 mm. The actual evapotranspiration values range from 280 mm in Wokha station to a maximum of 365 mm in Negheriting station. The average actual evapotranspiration of the basin is 330.2 mm. Only Sycota station is experiencing water deficiency of 60 mm. The water surplus values vary from 0 mm in Golaghat and Sycota stations to a maximum 536 mm in Negheriting station. The average water surplus of the basin is 135.1 mm. Moisture adequacy values vary

Table 5.14 Water Balance Elements of the Kakodonga river basin (1983 2013) Pre-monsoon										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	492	365	350	0	112	96	0.00	22.76	B1
2	Golaghat	411	380	343	6	0	90	1.58	-0.95	C1
3	Honowal	536	375	335	0	121	89	0.00	22.57	B1
4	Jorhat	453	380	345	0	38	91	0.00	8.39	C2
5	Kamarbund	445	376	340	0	33	90	0.00	7.42	C2
6	Khumtai	467	360	314	0	61	87	0.00	13.06	C2
7	Negheriting	901	365	365	0	536	100	0.00	59.49	B2
8	Sycota	363	370	310	60	0	84	16.22	-9.73	C1
9	Titabor	449	365	320	0	39	88	0.00	8.69	C2
10	Wokha	520	350	280	0	100	80	0.00	19.23	C2

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

from 80% in Wokha station to a maximum of 100% in Negheriting station. The average moisture adequacy of the basin is 89.58%. The Aridity Index varies from 0% in Borholla, Honowal, Jorhat, Kamarbund, Khumtai, Negheriting, Titabor and Wokha stations to a maximum of 16.21% in Sycota and 1.5% in Golaghat stations. The average Aridity Index value of the basin in this month is 10.4%. After the above analysis it may be summarized that dry sub humid type of climate prevails in two stations, moist sub-humid type of climate in five stations and humid type of climate in three stations.

5.2.3 Monsoon

The mean monthly precipitation during Monsoon season varies from 677 mm in Sycota station to a maximum of 1511 mm in Negheriting station (Table. 5.15). The average precipitation of the basin is 930 mm. Minimum potential evapotranspiration is observed in Khumtai station (405 mm) and maximum in Sycota station (470 mm). The average potential evapotranspiration of the basin is

Table 5.15 Water Balance Elements of the Kakodonga river basin (1983 2013) Monsoon

Sl. No.	Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	C C
1	Borholla	827	450	450	0	377	100	0.00	45.59	B2
2	Golaghat	730	450	450	0	280	100	0.00	38.36	B1
3	Honowal	946	460	460	0	486	100	0.00	51.37	B2
4	Jorhat	888	450	450	0	438	100	0.00	49.32	B2
5	Kamarbund	809	435	435	0	374	100	0.00	46.23	B2
6	Khumtai	913	405	405	0	508	100	0.00	55.64	B2
7	Negheriting	1511	460	460	0	1051	100	0.00	69.56	B3
8	Sycota	677	470	470	0	207	100	0.00	30.58	B1
9	Titabor	912	460	460	0	452	100	0.00	49.56	B2
10	Wokha	1088	425	425	0	663	100	0.00	60.94	B3

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist subhumid, C_1: Dry subhumid, D: Semiarid, E: Arid.

446.5 mm. The actual evapotranspiration values range from 405 mm in Khumtai station to a maximum of 470 mm in Sycota station. The average actual evapotranspiration of the basin is 446.5 mm. There is no water deficit in all stations; therefore, Aridity Index is nil. The water surplus values vary from 207 mm in Sycota station to a maximum of 1051 mm in Negheriting station. The average water surplus of the basin is 483 mm. Moisture adequacy values show 100% all the stations. In this monsoon season Moisture Index values reveal that humid type of climate exists in all the station.

5.2.4 Post-monsoon

In post-monsoon season, mean monthly precipitation values vary from a minimum of 233 mm in Sycota station to a maximum of 656 mm in Negheriting station (Table 5.16). The average precipitation value of the basin is 374 mm. The potential evapotranspiration values range from a minimum of 365 mm in Khumtai station to a maximum of 405 mm in Golaghat station. The average potential evapotranspiration value of the basin is 387 mm. The actual evapotranspiration value ranges from 320 mm in Golaghat station to a maximum of 386 mm in Negheriting station. The average actual evapotranspiration value is 350 mm. The water deficit during this season ranges from 0 mm in Khumtai and Negheriting stations to a maximum of 85 mm in Golaghat station. The average water deficit of the basin in this month is 37 mm. In post monsoon season water

Table 5.16 Water Balance Elements of the Kakodonga river basin (1983 - 2013) Post-monsoon										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	302	390	356	34	0	91	8.72	-5.23	C1
2	Golaghat	269	405	320	85	0	79	20.99	-12.59	C1
3	Honowal	403	395	360	27	0	91	6.84	-4.10	C1
4	Jorhat	350	375	350	25	0	93	6.67	-4.00	C1
5	Kamarbund	360	390	358	32	0	92	8.21	-4.92	C1
6	Khumtai	403	365	344	0	17	94	0.00	4.22	C2
7	Negheriting	656	390	386	0	262	99	0.00	39.94	B1
8	Sycota	233	395	328	67	0	83	16.96	-10.18	C1
9	Titabor	364	390	356	34	0	91	8.72	-5.23	C1
10	Wokha	402	375	340	8	0	91	2.13	-1.28	C1

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist sub humid, C_1: Dry sub humid, D: Semiarid, E: Arid.

surplus is 17 mm and 262 mm in Khumtai and Negheriting stations respectively. The moisture adequacy value varies from 79% in Golaghat station to a maximum of 99% in Negheriting station. The average moisture adequacy value of the basin is 90%. The Aridity Index value ranges from 0% in Khumtai and Negheriting stations to a maximum of 21% in Golaghat station. The average Aridity Index value of the basin is 10%. Climatologically the Moisture Index value shows that dry-sub humid type of climate present in eight stations, moist sub humid type of climate in Khumtai station and humid type of climate in Negheriting station.

The seasonal analysis of the mean rainfall depict that the basin receives the maximum mean average rainfall of 930 mm in monsoon period. In winter period the mean average rainfall is 67 mm. During pre monsoon it is 504 mm and in post monsoon period it is 374 mm. The mean potential evapotranspiration is high during monsoon and post monsoon periods. These are 447 mm and 387 mm respectively. The potential evapotranspiration value is 369 mm in pre monsoon period and 260 mm in winter period. The mean actual evapotranspiration is high during monsoon period i.e. 447 mm. and during post monsoon period it is 350 mm. In pre monsoon period it is 330 mm and in winter period the value of actual evapotranspiration is 154 mm. The high water deficit (106 mm) is found in winter period. The water deficit during monsoon period is nil and in post monsoon period it is 31 mm. The water deficit is very low during pre monsoon period i.e. 7 mm. The average water deficit is 36 mm. There is no water surplus indentified in winter period. Monsoon period experiences high water surplus i.e. 483 mm and followed by pre monsoon (104 mm) and post monsoon (28 mm) periods respectively. The average water surplus is 153 mm. The average moisture adequacy value is low in winter period. It is 59% only. The highest average moisture adequacy is found in monsoon period i.e. 100%. During post monsoon and pre monsoon period it is 90%. The average Aridity Index value is very high during winter period i.e. 41%. During post monsoon period the Aridity Index value is 8%. The lowest Aridity Index value of 2% is found in pre monsoon period. In monsoon period Aridity Index is nil. From the analysis of water balance elements it is found that monsoon and post monsoon periods receive high rainfall. The water deficit is nil and moisture adequacy values are high during monsoon period. The water shortage in monsoon season is low due to high rainfall. The crop cultivation is highly favorable during pre monsoon, monsoon, and post monsoon periods. But irrigation is essential parameter for cultivation in winter season. Climatologically the basin experiences dry sub-humid and semi-arid types of climate in winter period. The humid, moist sub-humid and sub-humid type of climate is found in pre monsoon period and the humid type of climate in monsoon period. The humid and moist sub humid type of climate is identified at Negheriting station and Khumtai station and remaining stations experience dry sub humid type climate in post monsoon period.

5.3. The Annual analysis of Water Balance Elements

The annual mean monthly precipitation varies from 1322 mm in Sycota station to a maximum of 3168 mm in Negheriting station (Table. 5.17). The average precipitation of the basin is 1875 mm. The potential evapotranspiration ranges from 365 mm in Khumtai station to a maximum of 405 mm in Golaghat station. The average potential evapotranspiration of the basin is 387 mm.

Table 5.17 Water Balance Elements of the Kakodonga river basin (1983 - 2013) Annual										
Sl. No.	**Station**	**P in mm**	**PE in mm**	**AE in mm**	**WD in mm**	**WS in mm**	**Ima in %**	**Ia in %**	**Im in %**	**C C**
1	Borholla	1697	390	356	0	1273	91	0.00	75.01	B3
2	Golaghat	1458	405	320	0	968	79	0.00	66.39	B3
3	Honowal	1964	395	360	0	1534	91	0.00	78.11	B3
4	Jorhat	1754	375	350	0	1354	93	0.00	77.19	B3
5	Kamarbund	1678	390	358	0	1256	92	0.00	74.85	B3
6	Khumtai	1835	365	344	0	1449	94	0.00	78.96	B3
7	Negheriting	3168	390	386	0	2774	99	0.00	87.56	B4
8	Sycota	1322	395	328	0	860	83	0.00	65.05	B3
9	Titabor	1799	390	356	0	1375	91	0.00	76.43	B3
10	Wokha	2072	375	340	0	1662	91	0.00	80.21	B4

Source: Water Resources Department (Rainfall)

P: Precipitation, PE: Potential Evapotranspiration, AE: Actual Evapotranspiration,WD: Water Deficit, WS: Water Surplus, Ima: Moisture adequacy Index, Ia: Aridity Index,Im: Moisture Index, CC: Climatic Classification, A: Prehumid, B_1-B_4: Humid, C_2: Moist sub humid, C_1: Dry sub humid, D: Semiarid, E: Arid.

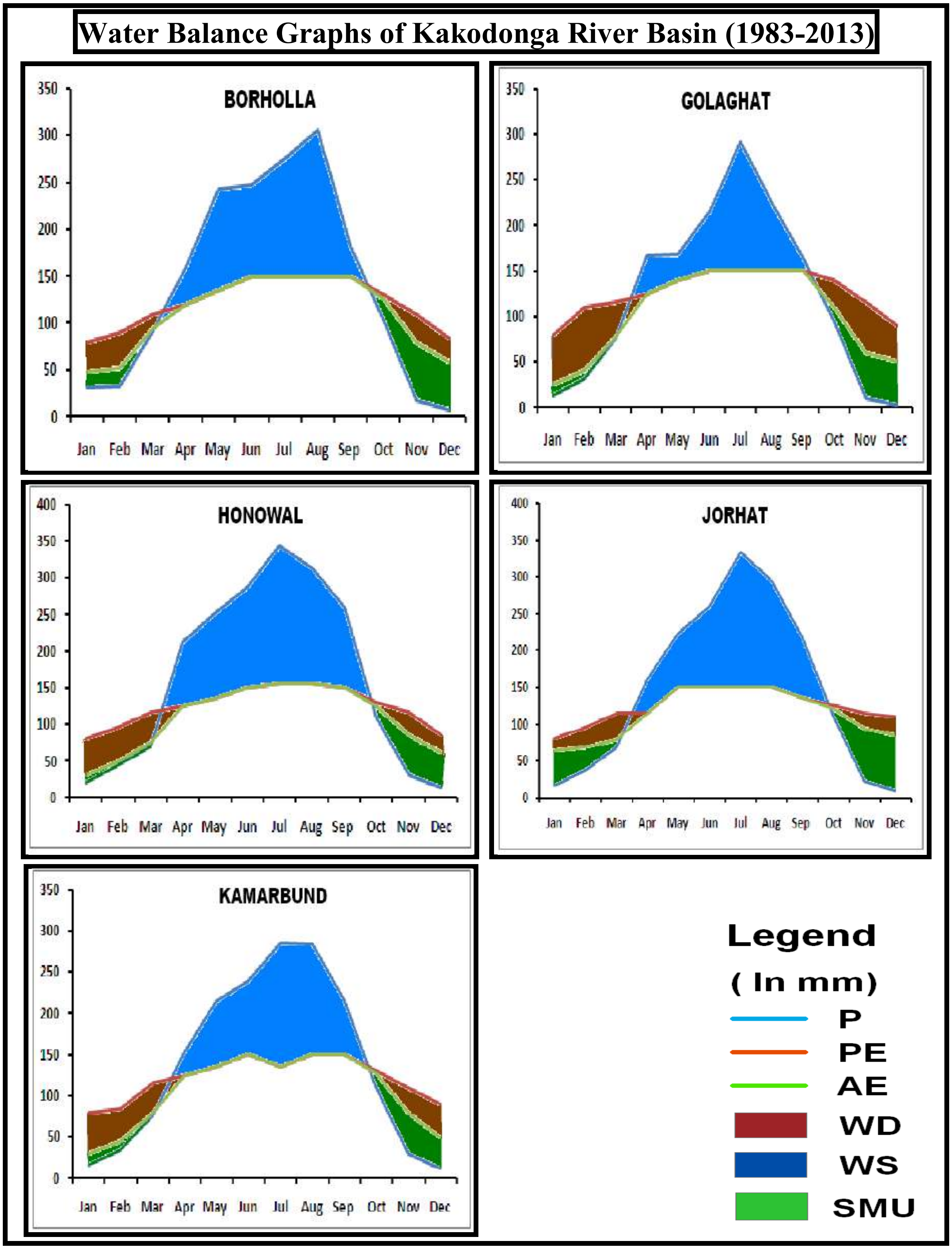
The actual evapotranspiration values range from 320 mm in Golaghat station to a maximum of 386 mm in Negheriting station. The average actual evapotranspiration of the basin is 350 mm. Water deficiency is nil in all the stations; it indicates that there is no Aridity in the study area. Water surplus exist in all the stations of the basin. The water surplus values vary from 860 mm in Sycota station to a maximum of 2774 mm in Negheriting station. The average water surplus of the basin is 1456 mm. Moisture adequacy values vary from 79%

in Golaghat station to a maximum of 99% in Negheriting station. The average moisture adequacy of the basin is 90.48%. Climatologically the Moisture Index values show that humid type of climate is found in all stations.

The annual water balance elements reveal that the basin receives average rainfall of 1875 mm. The mean annual potential evapotranspiration is 387 mm. The mean annual actual evapotranspiration of the basin is 350 mm. There is no water deficiency in the basin. The average annual water surplus is 1451 mm. The mean annual moisture adequacy value is 90.48% and there is no Aridity Index. Climatologically the basin experiences humid type of climate.

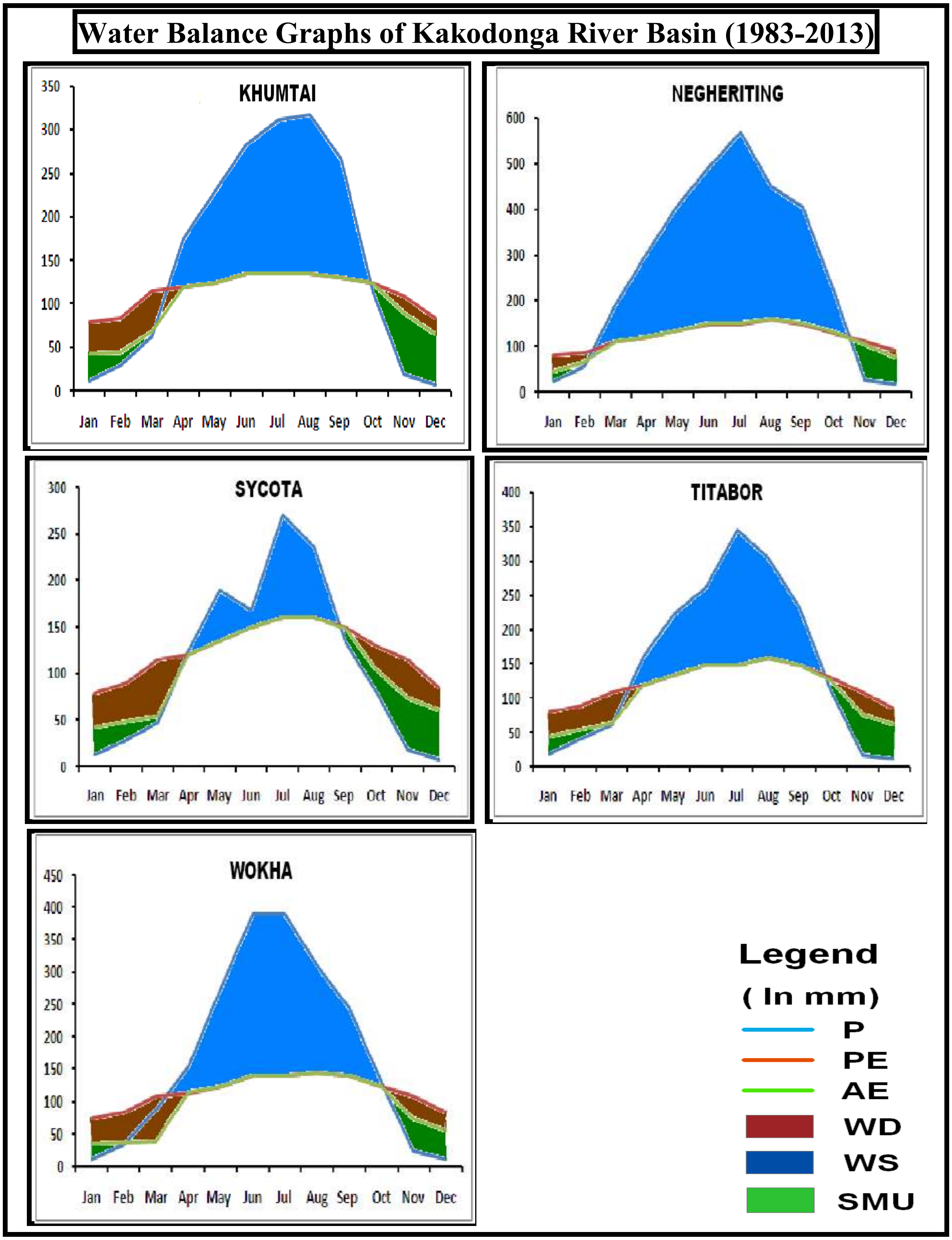
5.4. Raingauge Station wise analysis of Water Balance Elements of the Kakodonga river basin

The analyses of the water balance graphs (Fig. 5.1) reveal that Borholla, Golaghat, Honowal, Jorhat, Kamarbund, Khumtai, Negheriting, Sycota, Titabor and Wokha stations suffer water deficiency from January to March and October to December month. The water surplus is found in May, June, July, August and September months. Soil moisture utilization is found from January to March and September to December (Fig. 5.1). The water deficit ranges from 1 mm in Khumtai station to a maximum of 70 mm in Golaghat station. The average water deficit found in these six stations in the months of January, February, March, October, November and December is 15.08 mm. The water surplus ranges from 5 mm in Sycota station to a maximum of 419 mm in Negheriting station. The average water surplus is 62.91 mm in these eight stations from March to October months. In Golaghat Station water deficiency is very high particularly from January to March and October to December. The total water deficit in Golaghat station is 287 mm. In March to October months there is water surplus in Negheriting station. In Borholla, Honowal, Jorhat, Kamarbund, Khumtai, Sycota and Titabor stations (Fig. 5.1 & 5.2) water deficiency is observed from January to March and October to December months. In Golaghat and Sycota stations the water surplus is low during April to September months in compare to other stations of the basin. From the analysis of water balance graphs it may be conclude that the northern and central parts of the basin experienced water surplus in eight months. In north-eastern, western and central parts of the basin the water surplus is very low during March, April and October months and very high during May, Jun July, August and September months.



Source: Water Resource Department

Fig. 5.1



Source: Water Resource Department.

Fig. 5.2

Water Balance estimation of the Kakodonga River basin

1. Total surface of the water resources: 2,086,875,000m^3.
2. Surface water resources stored in ponds, lakes, reservoirs etc:

   8,280,000 m^3 (0.39%)
3. Surface water resources recharged to ground water:

   387,324,000m^3. (18.56%)
4. Surface run-off: 834750,000 m^3 (40%)
5. Water lost in the form of evaporation and evapotranspiration**:**

   856,662188 m^3 (41.05%)

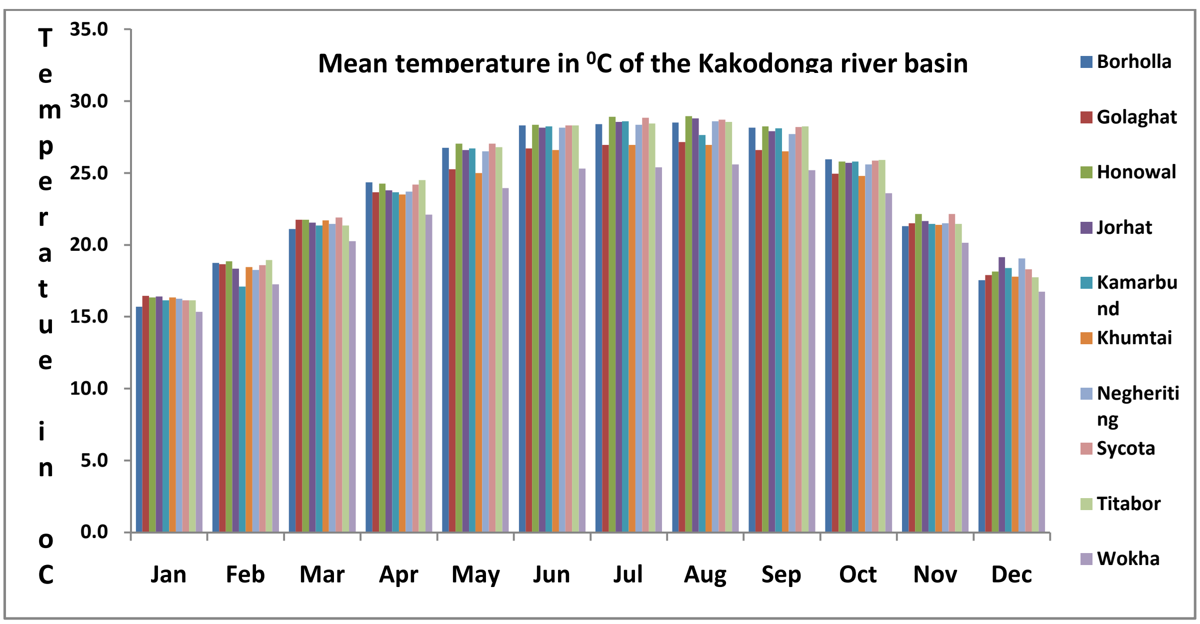
5.5. The analysis of mean monthly temperature

The average monthly temperature in Kakodonga river basin varies from a maximum of 29^0 C in August month at Honowal rain-gauge station to a minimum of 15.4^0C in January month at Wokha rain-gauge station (Table 5.18 and Fig. 5.3). The average monthly temperature is less than 20^0C in January, February, and December months. The average monthly temperature is between 20^0 to 25^0C in March, April and November months. The mean temperature is above 25^0C in May, June, July, August, September and October months.

Table: 5.18: Mean monthly minimum temperature in ^{0} C of the Kakodonga river basin (1983-2013)

Sl. No	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Borholla	15.7	18.8	21.1	24.4	26.8	28.3	28.4	28.5	28.2	26.0	21.3	17.6
2	Golaghat	16.5	18.7	21.8	23.7	25.3	26.7	27.0	27.2	26.6	25.0	21.5	17.9
3	Honowal	16.4	18.9	21.8	24.3	27.1	28.4	28.9	29.0	28.3	25.8	22.2	18.2
4	Jorhat	16.4	18.4	21.6	23.8	26.6	28.2	28.6	28.8	27.9	25.7	21.7	19.2
5	Kamarbund	16.2	17.1	21.4	23.7	26.7	28.3	28.6	27.7	28.1	25.8	21.5	18.4
6	Khumtai	16.4	18.5	21.7	23.5	25.0	26.6	27.0	27.0	26.5	24.8	21.4	17.8
7	Negheriting	16.3	18.3	21.5	23.7	26.5	28.2	28.4	28.6	27.7	25.6	21.5	19.1
8	Sycota	16.2	18.6	21.9	24.2	27.1	28.3	28.9	28.7	28.2	25.9	22.2	18.3
9	Titabor	16.2	19.0	21.4	24.5	26.8	28.3	28.5	28.6	28.3	25.9	21.5	17.8
10	Wokha	**15.4**	17.3	20.3	22.1	24.0	25.3	25.4	25.6	25.2	23.6	20.2	16.8

Source: Water Resources Department



Source: Water Resources Department

Fig. 5.3

5.6. Station wise mean annual temperature in ^{0}C of the Kakodonga River Basin:

Minimum mean annual temperature is recorded as 17.15^{0}C in Wokha station and maximum temperature as 29.80^{0}C in Honowal station. The maximum annual average temperature is highest in Titabor station i.e. 23.86^0 C and minimum is noticed in Jorhat station i.e. 17.28^{0}C.

Table: 5.19: Station wise mean annual temperature in ^{0}C of the Kakodonga river basin

S. No	Rain Gauge Station	Mean Temperature in ^{0}C		
		Min.	Max.	Average
1	Borholla	18.67	28.77	23.72
2	Golaghat	18.46	27.80	23.13
3	Honowal	18.33	29.80	24.07
4	Jorhat	18.61	29.55	17.28
5	Kamarbund	18.74	28.46	23.60
6	Khumtai	18.28	27.72	23.00
7	Negheriting	18.94	28.60	23.77
8	Sycota	18.34	29.72	24.03
9	Titabor	18.81	28.90	23.86
10	Wokha	17.15	26.33	21.74

Source: Water Resources Department

5.7 Climatic classification based on Thermal Regime

The Kakodonga river basin's climate could be estimated on the basis of Thermal Efficiency (TE). Thermal Efficiency is nothing but Potential Evapotranspiration. Thornthwaite considered PE as an index of thermal efficiency. Thornthwaite (1955) introduced modified classification table of the climates based on TE and also initiated another parameter table namely Summer Concentration of Thermal Efficiency (SCTE) in order to study complicated variation from place to place located in same latitude. It is the ratio of the sum of the thermal efficiencies for the three highest summer months to the annual total TE. Based on thermal regime, main categories and sub categories of climates of Kakodonga river basin have been calculated for present temperature situation, which comes under the climatic category of Megathermal (A) as its mean annual value of PE is 3870 mm. Summer Concentration of Thermal Efficiency (SCTE) value is 30.8 percent in all the situations of temperature and it comes under a' type climate (Megathermal). Thus, both annual and seasonal distribution of thermal efficiency suggests that Kakodonga river basin is experiencing abundant thermal potential which can support luxuriant vegetation if moisture is not a constant.

Table 5.20: Climatic Classification on Thermal Regime

Kakodonga river basin	**Thermal Regime**			
	Annual TE/ PE (mm)	**Climate Type**	**SCTE %**	**Sub Climatic Type**
Present Temperature Situation	3870	A (Megathermal)	30.8	a' (Megathermal)

Source: Water Resource Department

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Chapter-6

Land use pattern, Irrigation and Cropping pattern of the Kakodonga River Basin

6

A. LAND USE CATEGORIES OF THE KAKODONGA RIVER BASIN

Land use/ land cover studies are of fundamental significance, as the land resources play a strategic rule in the determination of man's economic, social and cultural progress (Jabeen and Ahmed, 2013). Land use describes how a parcel of land is used such as for agriculture, settlements or industry, where as land cover refers to the material such as vegetation, rocks or water bodies that are present on the earth's surface. Hence, land use refers to man's activities and various uses, which are carried on land and land cover refers to natural vegetation, water bodies, rock or soil, artificial cover and other resulting due to land transformations. The nature of land use / land cover in an area reflects not only the environmental conditions and land resource base of the area, but also it projects the level of development of the people under different physical, cultural and economic conditions. The over increasing population and decreasing man-land ratio are posing challenging problems to the planners and policy makers. Land use planning is essential for the determination of the optimum utilization of every piece of land. Land use study is very important from the point of eco-development and eco-planning. Land use classification is generally made on the basis of different land uses like agricultural, non-agricultural and ecological. A few organizations like National Atlas and Thematic Mapping Organization, All India Soil and Land use Survey, National Bureau of Soil Survey and Landuse planning (NBSS & LUP), Department of Agriculture have developed their own land use classification. Gautham and Narayan (1982) have suggested the methodology for land use and land cover mapping using remote sensing data. They have suggested six major level land uses. They are built up land, agricultural land, forest land, water body, wasteland and others. The Technical Committee on Coordination of Agricultural Statistics, Government of India has recommended standard land use classification and uniform definition of the same to be adopted all over India. They are forest cover, area put under non agricultural use, barren lands, permanent pastures and other grazing land, land under miscellaneous trees and groves, culturable waste land, current fallow land, other fallow land and net area sown. The land use data have been collected for three years (2012 – 2014) at revenue circle level to evaluate the land use concentration, net area sown, total irrigated area, intensity of irrigation, intensity of cropping pattern and land use efficiency of the basin.

The statistical method adopted by Bhatia (1965) is used for the analysis of land use pattern and above mentioned parameters.

1. To compute the land use pattern or land use concentrations (for example Bhandari circle's forest cover area)

$$= \frac{\text{(Forest area of Bhandari circle / total area of Bhandari circle)}}{\text{Total forest area of the basin (all the circles)/ total net area (land use) of the basin}}$$

2. The land use efficiency of the Kakodonga river basin has been work out using five positive variables like net sown area, total irrigated area, irrigated area more than once, intensity of irrigation and intensity of cropping pattern adopting standard deviation method.

6.1. The land use concentration of the Kakodonga river basin

6.1.1. Forest

The concentration of the forest area is medium in three circles and they are spatially distributed in southeastern and central part of the basin (Table 6.1 & Fig. 6.1). The low concentration of forest area is found in four circles which are distributed in western, northwestern and northeastern parts of the basin. Bhandari circle has the highest forest area (19,126 hect.). But Golaghat, Dergaon and Jorhat West circles don't have forest.

6.1.2. Barren and uncultivable land

The concentration of the barren and uncultivable land is high in two circles which are located in western and north-eastern parts of the basin. (Table 6.1 & Fig. 6.1). The concentration of barren and uncultivable land is medium in two circles and they are spatially distributed in southeastern part of the basin and it is low in three circles. They exist in northeastern, central and northwestern parts of the basin. Highest area of barren and uncultivable land is found in Jorhat west circle i.e. 2781 hect. This category of land is not available in Dergaon.

Tab. 6.1: Land use concentration of the Kakodonga river basin (2012-14) (In %)

S. No	Name of the Circle	Forest	Area Put to Non-Agr. Uses	Barren & Uncultivable Land	Permanent Pastures & Other Grazing Land	Land under Miscel. Trees & Groves	Culturable Waste Land	Other Fallow Land	Current Fallow Land	Net Area sown
1.	Bhandari	2.43	0.79	NA	NA	NA	2.11	3.11	1.88	0.15
2.	Changpang	2.43	0.85	NA	NA	NA	2.11	3.11	1.88	0.15
3.	Dergaon	0	0.31	0.00	2.05	2.18	0.54	0.29	1.20	1.50
4.	Golaghat	0	2.05	1.59	1.71	0.27	0.04	0.14	0.19	1.54
5.	Jorhat west	0	1.92	3.71	2.32	3.59	2.22	0.89	1.91	0.98
6.	Mariani	0.81	0.05	0.05	0.06	0.06	0.03	0.02	0.03	1.49
7.	Titabor	2.98	0.35	0.64	0.70	0.67	0.32	0.15	0.18	0.54

Source: Economic and Statistical Department.

Land use concentration of the Kakodonga river basin(2012-2014)

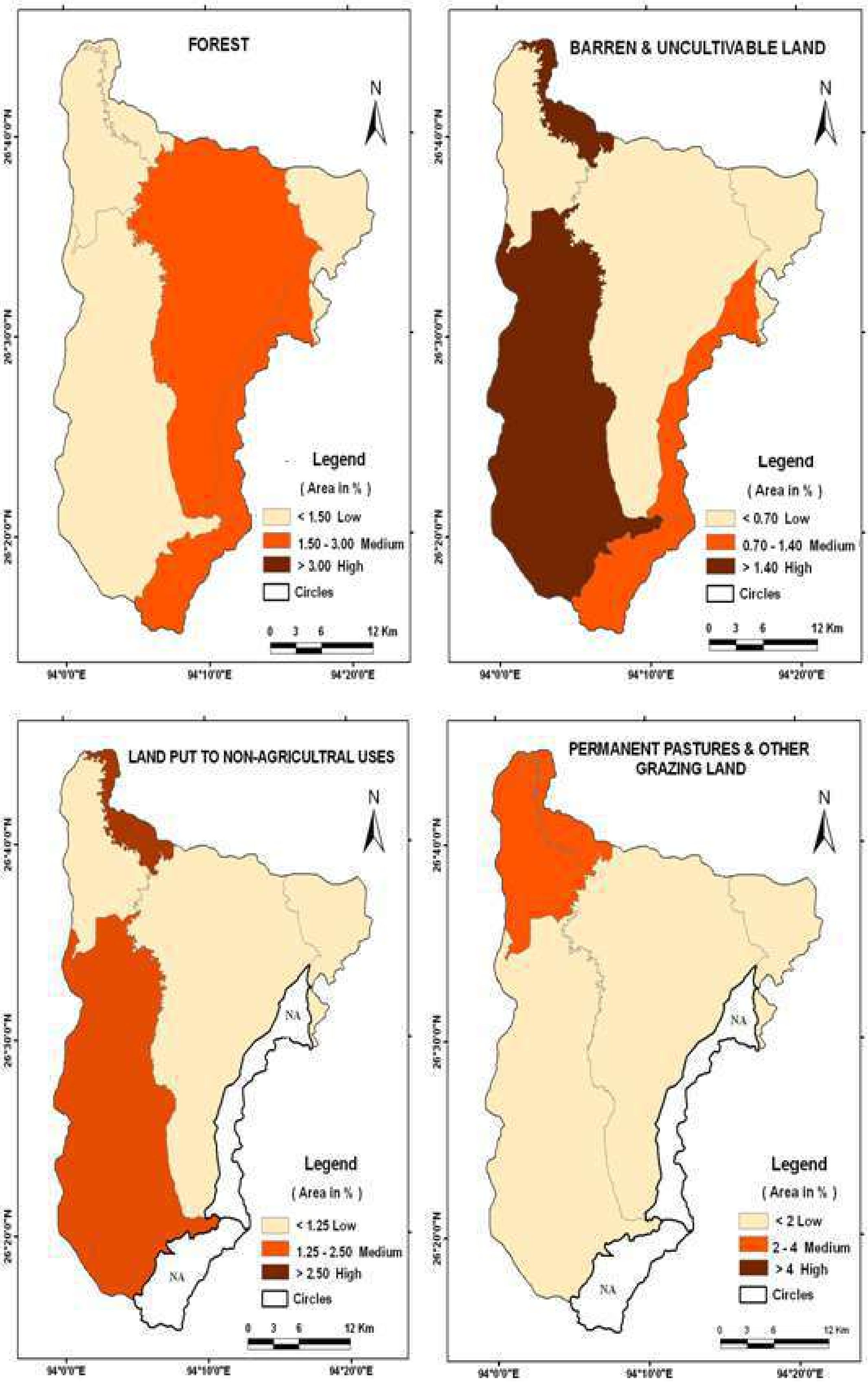


Fig. 6.1

6.1.3. Land put to non-agricultural use

The land put to non-agricultural use is high in one circle and medium in another circle. They are distributed in northwestern and western parts of the basin (Table 6.1 & Fig. 6.1). The concentration of land put to non-agricultural use is low in three circles. They are located in northern, northeastern and northwestern parts of the basin. With 3000.98 hector of non agricultural land Golaghat circle occupy 1st position followed by Jorhat west, Bhandari, Changpang, Dergaon and Mariani (65 hact.) circles.

6.1.4. Permanent pastures and other grazing land

The concentration of permanent pasture is medium in two circles. They are located in northwestern part of the basin. The permanent pasture concentration is low in three circles and they are spreading from northeastern to southwestern parts of the basin (Table 6.1 & Fig. 6.1).Maximum permanent pasture and other grazing land falls under Jorhat West circle(1468 hact) and minimum comes under Mariani circle (42 hact.).But data is not available for Changpang and Bhandari circle.

6.1.5. Miscellaneous tree, crops and grooves

High and medium concentration is found in Jorhat West and Dergaon circle respectively and they are spatially distributed in northwestern part of the basin (Tab.6.1 and Fig. 6.2). The low concentration of miscellaneous tree and grooves is found in three circles which exist in northeastern to southwestern parts of parts of the basin. Areas of miscellaneous tree, crops and groves in Jorhat West, Dergaon, Titabor, Golaghat and Mariani circles are 3265 hect, 1413 hect, 301 hect, 270 hect and 58 hect. respectively. Data is available for two circles of Nagaland.

6.1.6. Culturable wasteland

The spatial distribution shows that its concentration is high in three circles. They are located in peak of northwestern and southeastern parts of the basin. The low concentration of culturable wasteland is found in four circles. They are distributed in northeastern to southwestern parts of the basin. The medium concentration of culturable wasteland is not identified in the basin (Tab.6.1 and Fig.6.2). Highest area of culturable wasteland belongs to Jorhat West circle (2367 hect), followed by Bhandari (2141.65 hect), Changpang (1095.46), Dergaon (414.47 hect), Titabor (167 hect), Golaghat (42.88 hect) and Mariani circle (30.09 hect).

6.1.7. Other fallow land

The other fallow land's concentration is high in two circles i.e. Changpang and Bhandari circle of Nagaland. Both the circles have more than 4800 hect of other fallow land. Location of these two circles is towards southeastern part of the basin (Table 6.1 and Fig.6.2). The low concentration of other fallow land is noticed in five circles, which are spatially distributed in northern, western and central parts of the basin. Mariani circle has only 68 hect of other fallowland, which is lowest one among all the circles.

Land use concentration of the Kakodonga river basin

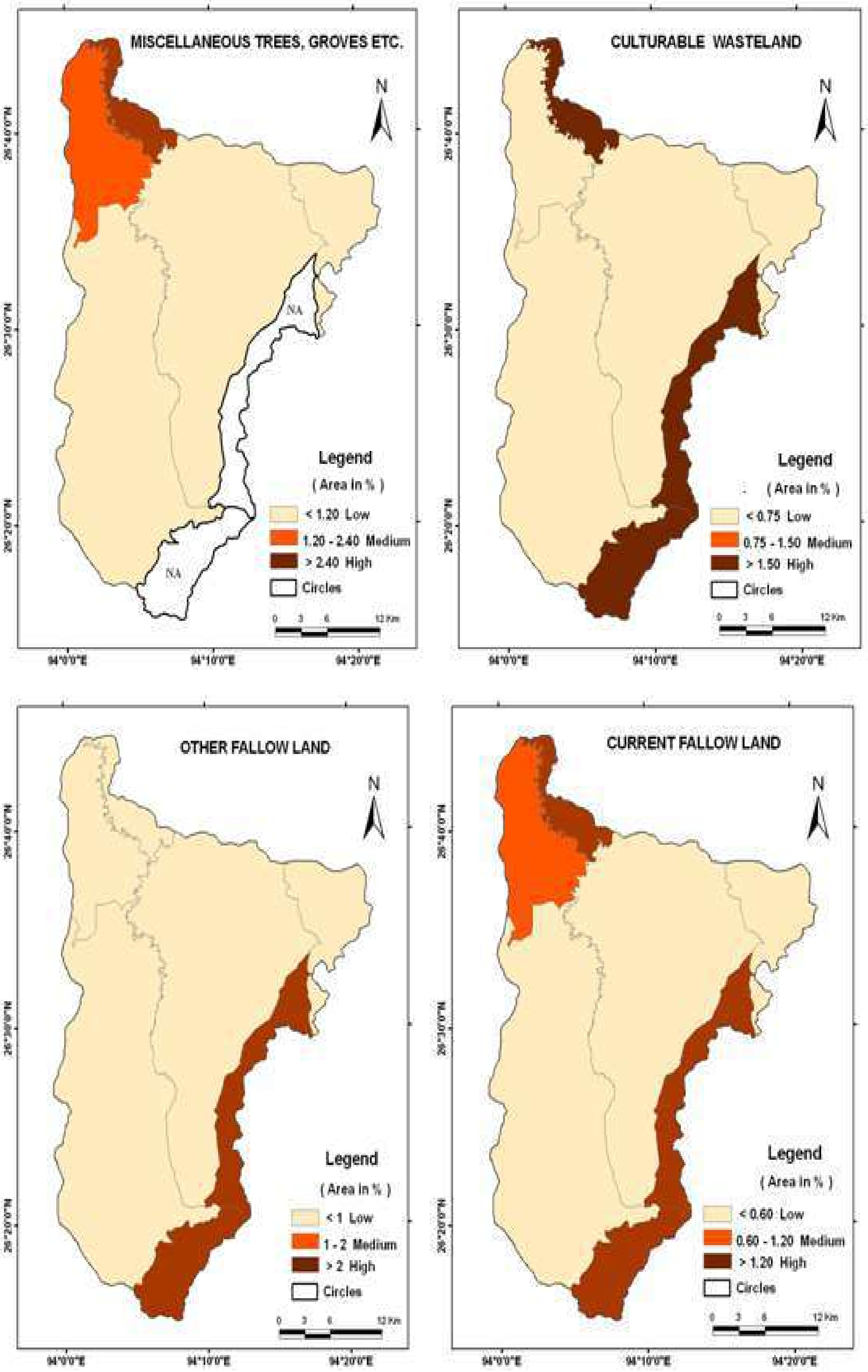


Fig. 6.2

6.1.8. Current fallow land

The high concentration of the current fallow land is found in three circles i.e. Changpang, Bhandari and Jorhat west. They are distributed in extreme northwestern and southeastern parts of the basin. Bhandari, Jorhat West and Changpang have 2718 hect, 2544 hect and 1302 hect.of current fallow respectively. One circle shows medium concentration of current fallow land and it is found in northwestern part of the basin. The low concentration of current fallow lands is noticed in three circles. They are distributed in northeastern to southwestern part of the basin (Tab.6.1 and Fig.6.2). In respect of total area of current fallow land, Mariani occupies the last position (45 hect) among the circles.

6.1.9. *Net area sown*

The spatial distribution shows that there are three circles come under high concentration of the net sown area. It is located in northwestern, western and northeastern parts of the basin. The medium concentration of net sown area is found in one circle only that is located in peak northwestern part of the basin. Three circles fall under low concentration group of net sown area, which are distributed in northern and southeastern parts of the Kakodonga river basin (Tab.6.1 & Fig 6.3).Golaghat circle has the highest net area sown i.e. 36622 hect. Second and third highest area recorded in Dergaon (24930.59 hect) and Titabor (25,955 hect) circle and lowest in Changpang circle (1549 hect).

Net Area Sown of the Kakodonga river basin

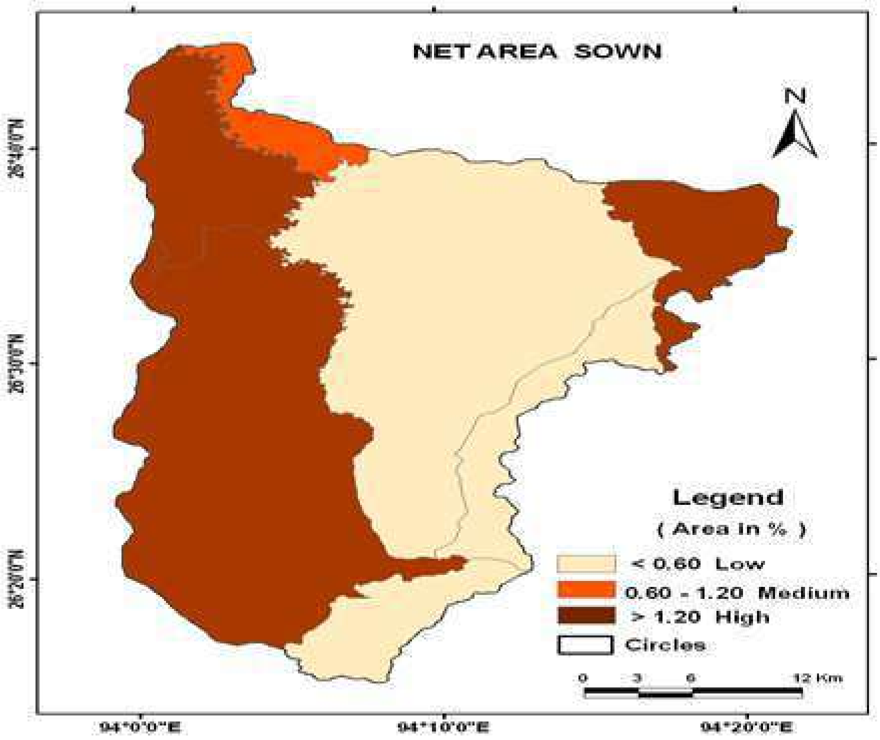


Fig. 6.3

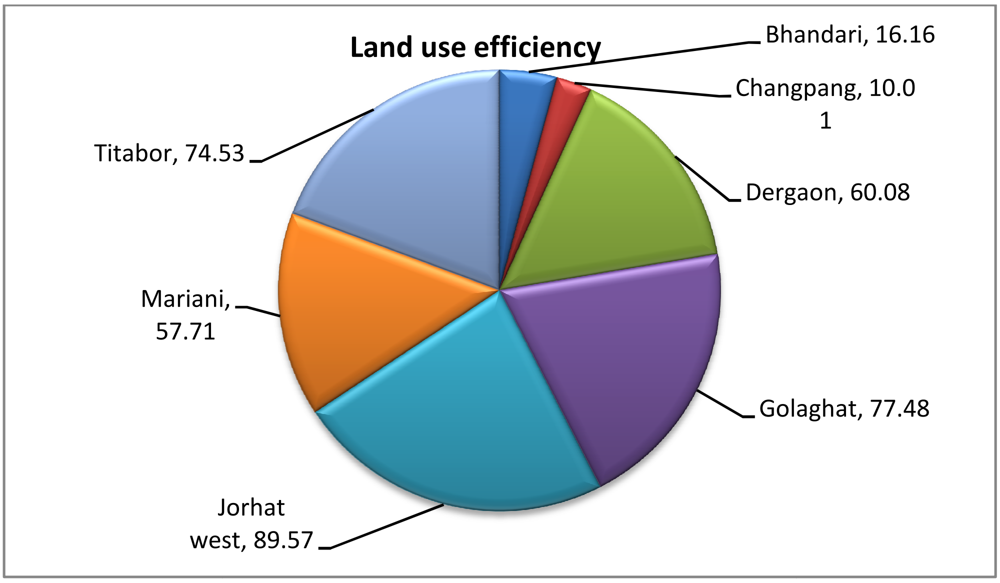
6.2. Land use efficiency

The minimum land use efficiency (10.01%) is found in Changpang circle of the basin (Tab.6.2 and Fig. 6.4). The maximum land use efficiency value (89.57%) is noticed in Jorhat west circle. The average land use efficiency of the basin is 55.08%. The land use efficiency is high in three circles which are Golaghat, Jorhat west and Titabor circles. They are located in western, northwestern and northern parts of the basin. The medium land use efficiency is found in two circles i.e. Dergaon and Mariani. They are located in northeastern and western parts of the basin. The low land use efficiency is found in two circles which are located in the southern and southeastern parts of the basin they are Bhandari and Changpang circles. From the analysis of land use efficiency we can concluded that the western and northwestern and central parts of the basin shows very high land use efficiency. The medium land use efficiency found in southern and southeastern parts of the basin and northeastern part shows low land use efficiency.

Table 6.2: Land Use Efficiency of the Kakodonga River basin (2012–2014)

Sl. No.	Name of the Circle	Land Use Efficiency (In %)
1.	Bhandari	16.16
2.	Changpang	10.01
3.	Dergaon	60.08
4.	Golaghat	77.48
5.	Jorhat west	89.57
6.	Mariani	57.71
7.	Titabor	74.53

Source: Economic & Statistics Department



Source: Economic & Statistics Department

Fig. 6.4

B. IRRIGATION SOURCES OF THE KAKODONGA RIVER BASIN

Irrigation is defined as an artificial application of water to land. For assured food supply, profitable farming and economical use of land, irrigation is essential. It plays an important role and a basic ingredient in the process of transformation of agriculture. Irrigation remains the most catalytic factor in agricultural development and change. The full exploitation of agricultural potential of an area necessitates the development of water resources for irrigation. The main sources of irrigation are surface water and ground water. Irrigation means maintaining storage of water in the soil required for plant growth at times and water supply to deficient places. Irrigation not only supplements rainfall but also corrects inequalities in the rainfall distribution. The main aims of irrigation are 1. Provide the required quantities of water to the soils for the growth of plants. 2. To increase the yield and production of crops. 3. To raise the standard of living among the farmers, 4. To correct the imbalances and to increase and sustain cash crops. The Kakodonga river basin's irrigation source data have been collected from irrigation department at revenue circle level for three years (2012-2014) are used for different calculating purposes. The statistical method adopted by Bhatia (1965) is used for the analysis of irrigation concentration and intensity of irrigation.

Compute the irrigation concentration =

$$\frac{\text{(Irrigation area of Circle / Total irrigated area of circle)}}{\text{(Total irrigated of circle / Net irrigated area)}}$$

Circle wise % of irrigation

= Total irrigated area of circle / Net irrigated area of circle X 100

Intensity of irrigation =

Total irrigated area of circle / Net area sown of circle X 100

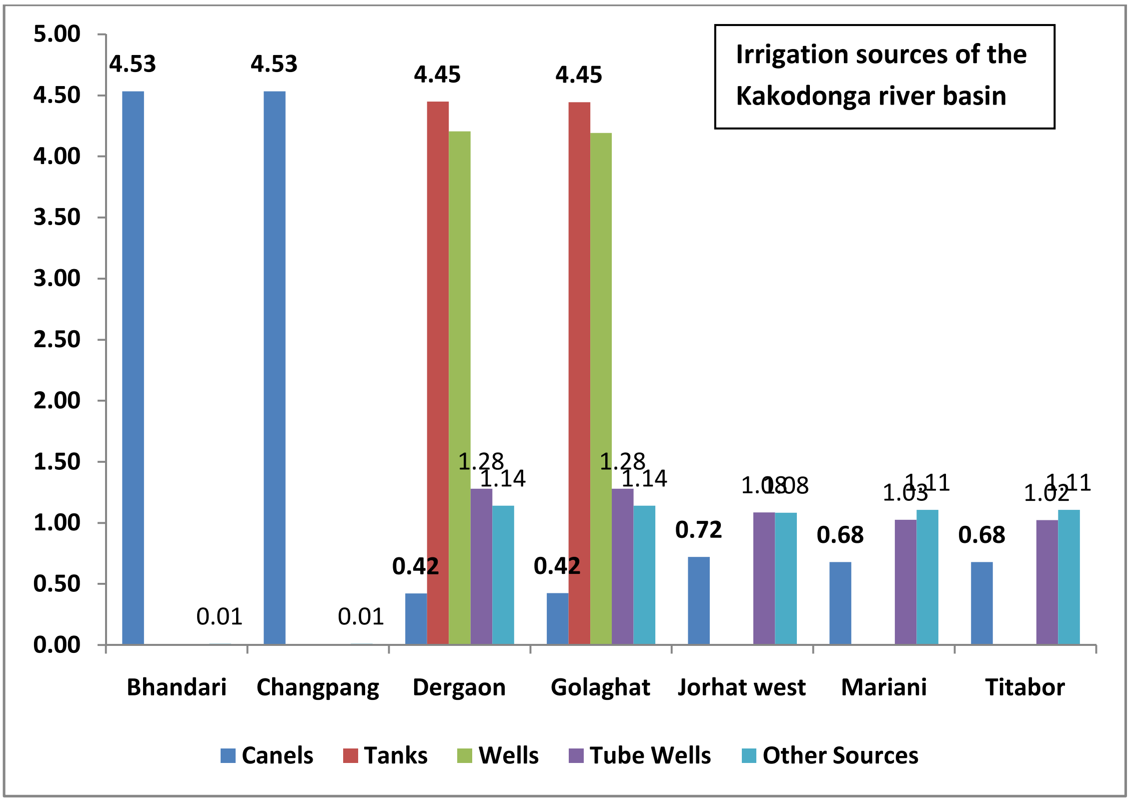
6.3. Irrigation concentration

Total irrigated area of the basin is 8184 hect. The area under canal irrigation is 1798 hectares, 12.26 hectares of land under tank irrigation, under well irrigation is 3.39 hectares, irrigation under tube well is 794 hectares and remaining 5576 hectares of land come under other sources of irrigation (Table 6.3 and Fig.6.5). The canal irrigation is found in almost all circles of the Kakodonga basin. The high concentration of canal irrigation recorded in Bhandari and Changpang circles and remaining circles have very low concentration of canal irrigation. They are located in southern and eastern parts of the basin. The tank irrigation is found in two circles that is Dergaon and Golaghat circles; they are located in western and northwestern parts of the basin. The two circles Dergaon and Golaghat only have well irrigation. The tube well irrigation found in five circles, they are Dergaon, Golaghat, Jorhat, Mariani and Titabor circles and they are situated in northern, north-eastern, northwestern, western and central parts of the basin. The other sources of irrigation concentration is found more than 1% in five circles which are Dergaon, Golaghat, Jorhat west, Mariani and Titabor circles. Other sources of irrigation are very less in Bhandari and Changpang i.e. 0.01%, these two circles located in southern and eastern parts of the basin.

Table 6.3: Various source of Irrigation concentration of the Kakodonga basin (In %) 2012-2014

Sl. No.	Name of the Circle	Canals	Tanks	Well	Tube Well	Others
1	Bhandari	4.53	0	0	0	0.01
2	Changpang	4.53	0	0	0	0.01
3	Dergaon	0.42	4.45	4.21	1.28	1.14
4	Golaghat	0.42	4.45	4.19	1.28	1.14
5	Jorhat west	0.72	0	0	1.08	1.08
6	Mariani	0.68	0	0	1.03	1.11
7	Titabor	0.68	0	0	1.02	1.11

Source: Irrigation department Assam and Nagaland



Source: Irrigation department Assam and Nagaland

Fig. 6.5

6.4. Circle-wise Percentage of Irrigation

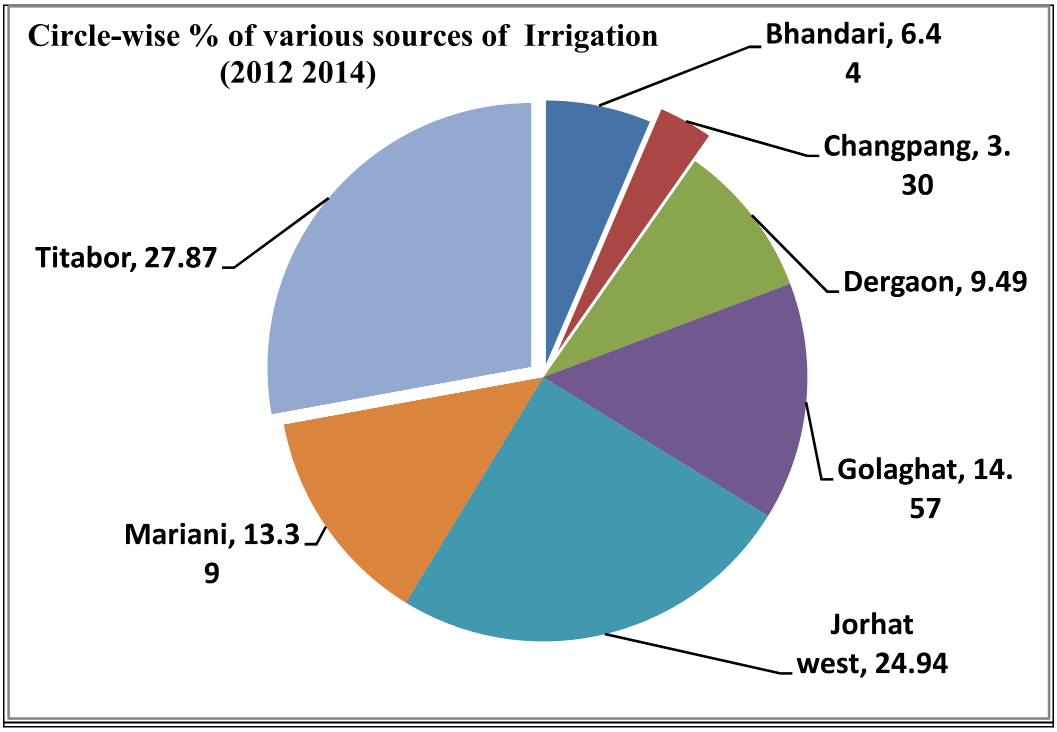
The circle wise source of irrigation varies from a minimum of 3.30% in Changpang circle to a maximum of 27.87% in Titabor circle of the basin. The average percentage of irrigation is 14.29% (Table 6.4 and Fig. 6.6). The pie chart shows that the percentage of irrigation less than 8% in two circles, they are Bhandari and Changpang, which are located in southern and eastern parts of the basin.

Table 6.4: Circle-wise Percentage of various sources of Irrigation (2012 - 2014)

Sl. No.	Name of the Circle	Circle-Wise percentage of total irrigation area
1.	Bhandari	6.44
2.	Changpang	3.30
3.	Dergaon	9.49
4.	Golaghat	14.57
5.	Jorhat west	24.94
6.	Mariani	13.39
7.	Titabor	27.87

Source: Irrigation department Assam and Nagaland

The percentage of irrigation ranges from 8% to 16% in three circles which are Dergaon, Golaghat and Mariani (Fig. 6.6). These are located in western and northwestern parts of the basin. The percentage of irrigation exceeds 16% in two circles which are Jorhat west and Titabor and located in northern and northwestern parts of the basin. The analysis of circle wise irrigation percentage reflects that most of the circles have above 10% irrigation.



Source: Irrigation department Assam and Nagaland

Fig. 6.6

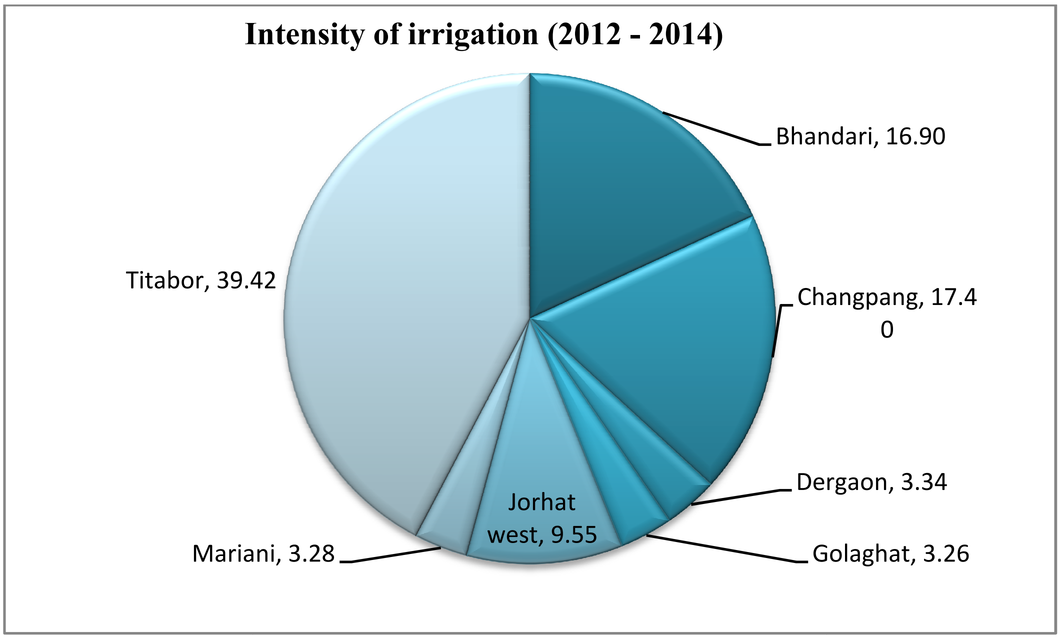
6.5. Intensity of irrigation

The intensity of irrigation ranges from a minimum of 3.26% in Golaghat circle to a maximum of 39.42% in Titabor circle (Table 6.5 & Fig. 6.7). The average intensity of irrigation of the Kakodonga river basin is 13.31%. The intensity of irrigation exceeds 15% in Bhandari, Changpang and Titabor circles. They are located in southern, eastern and northern parts of the basin. The intensity of irrigation less than 15% in Dergaon, Golaghat, Jorhat west and Mariani circles which are situated northwestern, western, northeastern parts of the basin.

Table 6.5: Intensity of Irrigation of the Kakodonga River basin (2012-2014)

Sl. No.	Name of the Circle	Intensity of Irrigation (In %)
1.	Bhandari	16.90
2.	Changpang	17.40
3.	Dergaon	3.34
4.	Golaghat	3.26
5.	Jorhat west	9.55
6.	Mariani	3.28
7.	Titabor	39.42

Source: Irrigation department Assam and Nagaland



Source: Irrigation department Assam and Nagaland

Fig. 6.7

C. ***CROPPING PATTERN OF THE KAKODONGA RIVER BASIN***

Cropping pattern is the relative acreage of various crops in an area. It represents the spatial crop sequence in a given area and it also indicates relative proportion of area under different crops at a given point of time. It reflects the diversified physical, socio-economic, technological and organizational factors of a region. It is not static. It changes as progress in technology and socio economic conditions. It gets modification under the influence of dynamic socio-economic, technological and political factors. It provides a comprehensive picture of crop geography. The National Commission on Agriculture, Government of India has evolved a suitable cropping pattern based on rainfall regimes. It has identified 160 rainfall patterns on All India basis. Soil and climatic zones of India were identified. The Committee has recommended for multiple cropping, plantations and inter cropping, intensive cropping of food crops, cultivation of root crops in sandy soils, management of water resources and preparation of crop suitability maps according to agro-climatic zones. The cropping pattern data at revenue circle level for three years (2012 – 2014) of the Kakodonga river basin has been collected and analysis is done in this respect. To compute the crop concentration, crop diversification, intensity of cropping pattern, ranking of crops and crop combination Bhatia (1967) method is adopted. Rafiullah's (1956) and Doi's (1957) methods are also used to find out crop combination.

Crop concentration =

$$\frac{(\text{Crop area of Circle / Total cropped area of circle})}{(\text{Total cropped of circles / Net cropped area})}$$

Circle wise % of total cropping area

= Total cropped area of circles / Net cropped area of circle X 100

Crop diversification = % of all sown area of all crops/ No. of crops X 100

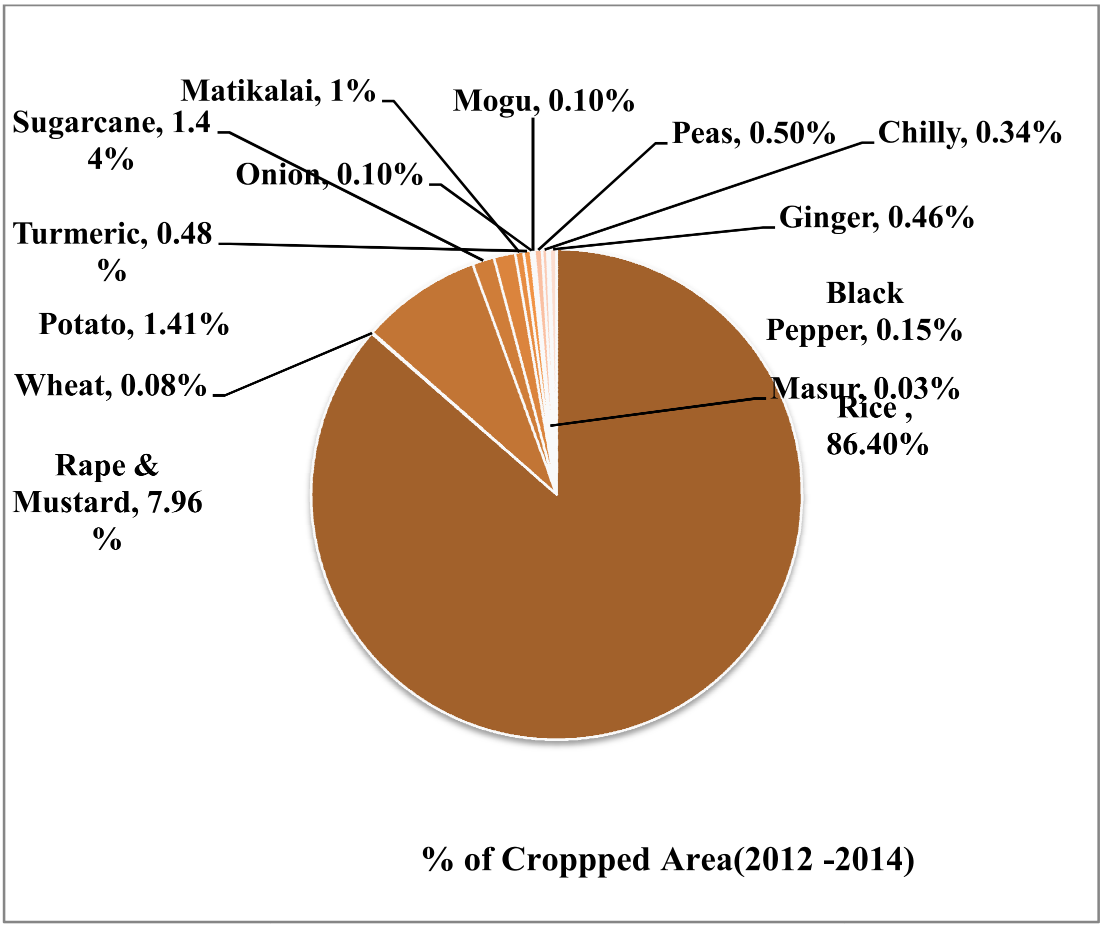
Intensity of crops= Total cropped area/ Net sown area of circle X 100

6.6. **Crop concentration**

The total cropped area of the basin is 549,000 hectares. It accounts 49.32% of the total geographical area of the basin. Data of fourteen major crops at revenue circle level are used and index of concentration is worked out adopting Bhatia (1967) Method.

6.6.1. *Rice*

The total rice cropped area of the basin is about 93,223 hectares of land. It accounts 86.40% of the total cropped area of the basin (Table 6.6 & Fig. 6.8). The spatial distribution shows that in three circles, the concentration of rice is low. They are distributed in northwestern, eastern and southeastern parts of the basin. The concentration of rice is medium in four circles. They are located in central and northeastern to southwestern parts of the basin. But unfortunately high concentration of rice is not observed. (Fig. 6.9).



Source:Economic and Statistics Department

Fig. 6.8

6.6.2. ***Wheat***

The total cropped area under wheat is about 91 hectares. It accounts 0.08% of the total cropped area of the basin. In about two circles wheat concentration is high and they are located in southeastern part of the basin. The wheat crop cultivation is found low in five circles. They are Dergaon, Golaghat, Jorhat west, Mariani and Titabor circles, which are spatially distributed in northern and western parts of the basin (Table 6.6 & Fig. 6.9).

Table 6.6: Crop concentration of the Kakodonga river basin (In %)

(2012 – 2014)

Sl. No.	Name of the Circle	Rice	Wheat	Rape & Mustard	Sugarcane	Potato	Matikalai	Turmeric	Onion	Mogu	Mansur	Peas	Chilly	Black Pepper	Ginger
1.	Bhandari	0.90	16.36	1.75	1.12	2.08	0.71	0.14	1.31	0.98	0.00	0.79	1.54	0	2.84
2.	Changpang	0.93	13.39	1.62	1.11	1.61	0.54	0.08	0.74	0.74	0.00	0.74	1.52	0	2.81
3.	Dergaon	0.71	1.05	3.66	4.32	0.78	0.77	1.92	3.02	2.09	3.10	0.59	0.68	0.28	1.52
4.	Golaghat	1.01	0	0.69	0.40	1.61	1.50	1.81	0.65	1.39	1.30	1.69	2.80	2.89	1.98
5.	Jorhat west	1.10	0.17	0.14	0.06	0.82	1.95	0.44	0.44	0.77	0.19	1.91	0.32	0.68	0.23
6.	Mariani	1.15	0	0.03	0.01	0.26	0.06	0.32	0.08	0	0	0.08	0.48	0.16	0.16
7.	Titabor	1.14	0.03	0.02	0.05	1.01	0.08	0.44	0.34	0.11	0.09	0.07	0.31	0.88	0.30

Source: Economic and Statistics Department

Crop concentration of Kakodonga River Basin(2012 -2014)

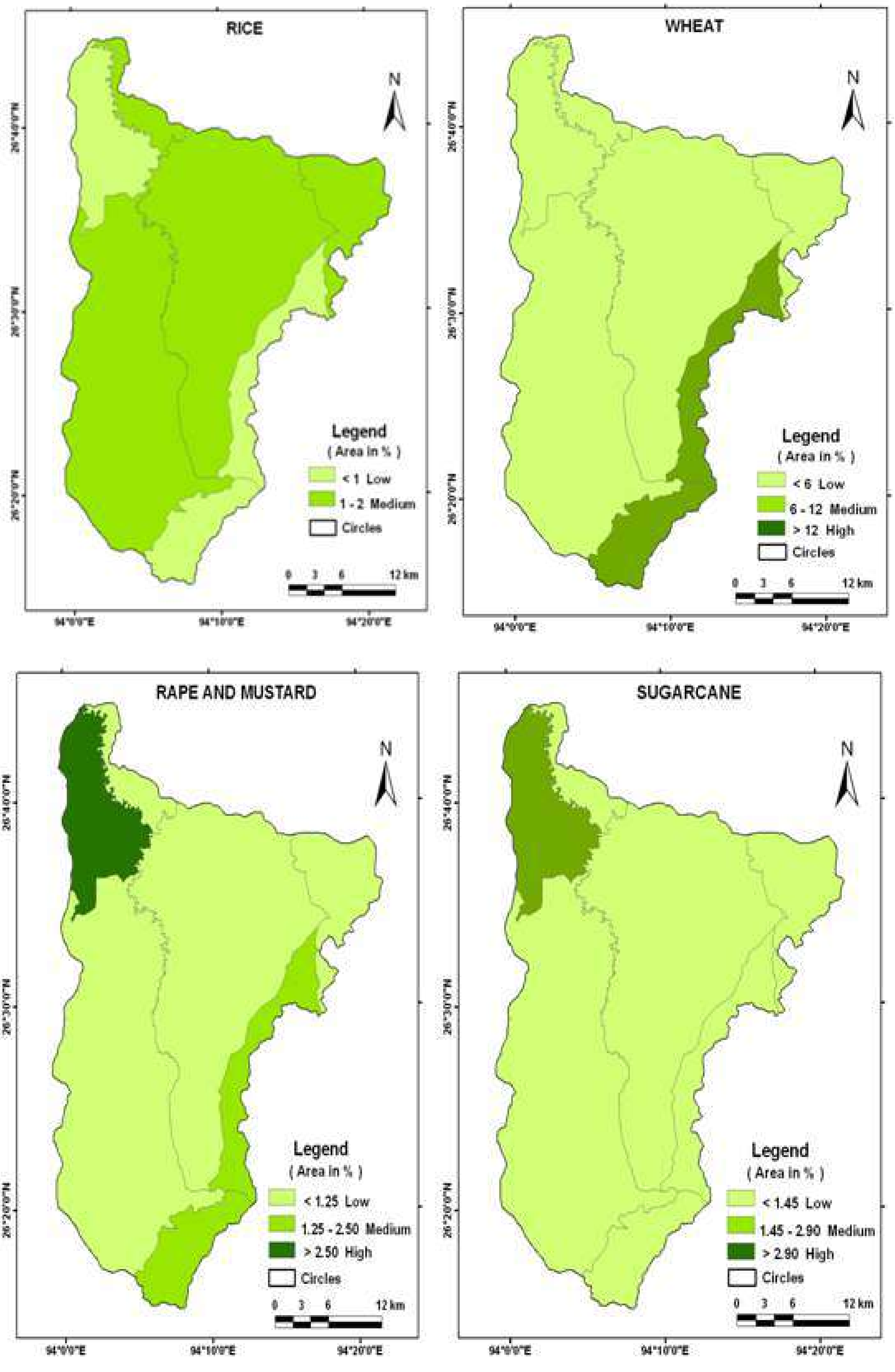


Fig. 6.9

6.6.3. ***Sugarcane***

The total area under sugarcane cultivation is about 1,557 hectares. It accounts about 1.44% of the total cropped area of the basin. The Sugarcane concentration is found high only in one circle that is Dergaon circle located in northwestern part of the basin. About six circles come under low concentration category and they are spatially distributed in northern and southern parts of the basin (Table 6.6 & Fig. 6.9).

6.6.4. ***Potato***

The total area under potato crop is about 1,520 hectares of land. It accounts 1.41% of the total cropped area of the basin. The potato concentration is high in only one circle i.e. Bhandari circle and which is situated in southeastern part of the basin. The medium concentration is found in two circles which are distributed in central and southeastern parts of the basin. Low concentration occurred in four circles which exist in northeastern, northwestern and western part of the basin (Table 6. 6 & Fig. 6. 10).

6.6.5. ***Matikalai***

The total cropped area under matikalai crop is about 593 hectares. It accounts 0.55% of the total cropped area of the basin. The high concentration of matikalai is found in two circles, spatially distributed in northwestern and southwestern parts of the basin. Medium concentration is observed in two circles, which are spreading over southeastern and northwestern parts of the basin. Eastern part of the basin exhibit low concentration of matikalai crop (Table 6.6 & Fig. 6.10).

6.6.6. *Turmeric*

The total area under turmeric cultivation is about 515 hectares of land. It accounts 0.48% of the total cropped area of the basin. The turmeric concentration is high in two circles which are located in western part of the basin. The low concentration is observed in five circles they are spatially distributed in eastern and central parts of the basin (Table 6.6 & Fig. 6.10).

6.6.7. *Onion*

The total area under onion is about 105 hectares of land. It accounts 0.10% of the total cropped area of the basin. The high concentration of onions is found in only one circle i.e. Jorhat and it is located in northwestern part of the basin (Table 6.6 & Fig. 6.10). Bhandari circle is showing medium concentration, which exist in southeastern part of the basin. The spatial distribution shows that in northern, eastern, central and western parts, onion concentration is low.

6.6.8. *Mogu*

The total cropped area under mogu crop is about 104 hectares of land. It accounts 0.10% of the total cropped area of the basin. The high concentration is observed in one circle only i.e. Dergaon circle, located in northwestern part of the basin (Table 6.6 & Fig. 6.11). The medium concentration is found in four circles, they are spreading over southeastern, western and northwestern parts of the basin. Low concentration is observed in two circles, exist in central and northeastern parts of the basin.

6.6.9. ***Masur***

The total area under masur is about 31 hectares of land i.e. 0.03% of the total cropped area of the basin. High and medium concentration of masur is found in Dergaon and Golaghat circles respectively. They are located in northwestern and western parts of the basin. Low concentration of masur is observed in northern and eastern parts of the basin (Table 6.6 & Fig. 6.11).

6.6.10.***Pea***

The total area under pea crop is about 542 hectares of land, which accounts 0.50% of the total cropped area of the basin. The pea cropped area concentration is high in two circles of the basin i.e. Jorhat West and Golaghat. They are found in northwestern and western parts of the basin. The pea concentration is medium in two circles and they are located in southeastern parts of the basin. The low concentration is found in three circles which exist in central and northwestern parts of the basin (Table 6.6 & Fig. 6.11).

6.6.11.***Chilly***

The total cropped area under chilly is about 369 hectares of land, which is 0.34% of the total cropped area of the basin. The concentration of chilly is high in Golaghat circle of the basin, exist in western part of the basin. Bhandari and Changpang circle have medium concentration is of chilly, which are located in southeastern parts of the basin. Low concentration of chilly is found in rest of the circles. They are spreading over northern and northwestern parts of the basin (Table 6.6 & Fig. 6.11).

Crop concentration of Kakodonga River Basin (2012-2014)

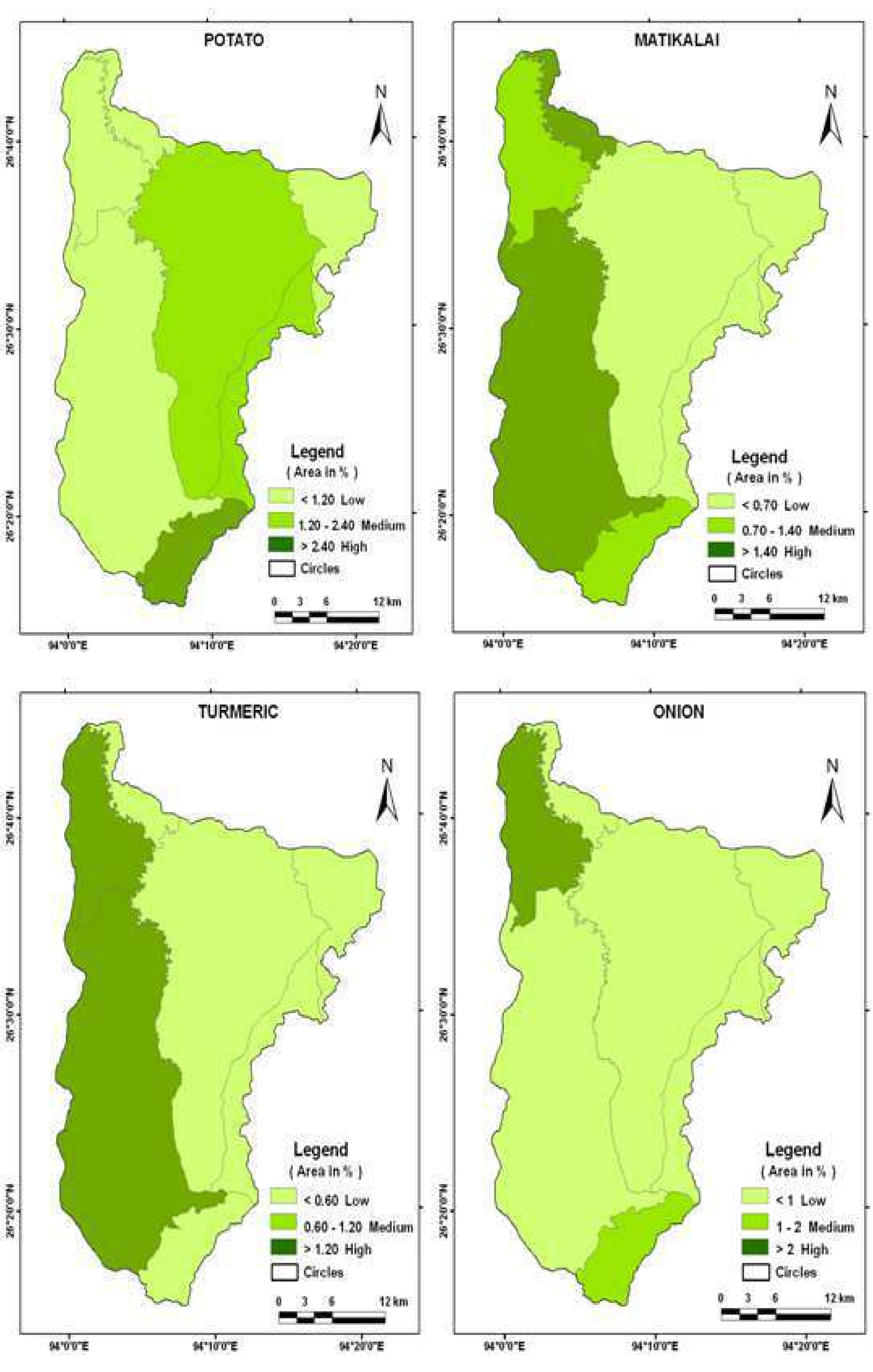


Fig. 6.10

6.6.12. ***Black Pepper***

The total cropped area under black pepper is about 164 hectares of land. It accounts 0.15% of the total cropped area of the basin. The concentration of black pepper is high in one circle i.e. Golaghat and exist in western part of the basin (Table 6.6 & Fig. 6.12). The concentration is low in six circles which are distributed in northern and southeastern parts of the basin.

6.6.13. ***Ginger***

The total cropped area under ginger is about 498 hectares of land. It accounts 0.46% of the total cropped area of the basin. Bhandar and Changpang circle have high concentration of ginger (Table 6.6 & Fig. 6.12). They are located in southeastern part of the basin. The medium concentration is observed in two circles i.e. Golaghat and Dergaon, they are located in western part of the basin. Rest of the circles has low concentration of ginger and they are spatially distributed northern and northeastern parts of the basin.

From the analysis of cropping pattern of the Kakodonga river basin, it is observed that the major and dominating crop is rice. It accounts 86.40% of the total cropped area of the basin. The rape and mustard (7.96%) falls under second ranking category of crop. The third ranking crop is sugar cane (1.44%) and potato (1.41%) is fourth ranking crop. The matikalai, pea, turmeric, ginger, chilly, black pepper, mogu, onion, wheat and masur occupy less than 1% of the total cropped area of the basin.

Crop concentration of Kakodonga River Basin (2012-2014)

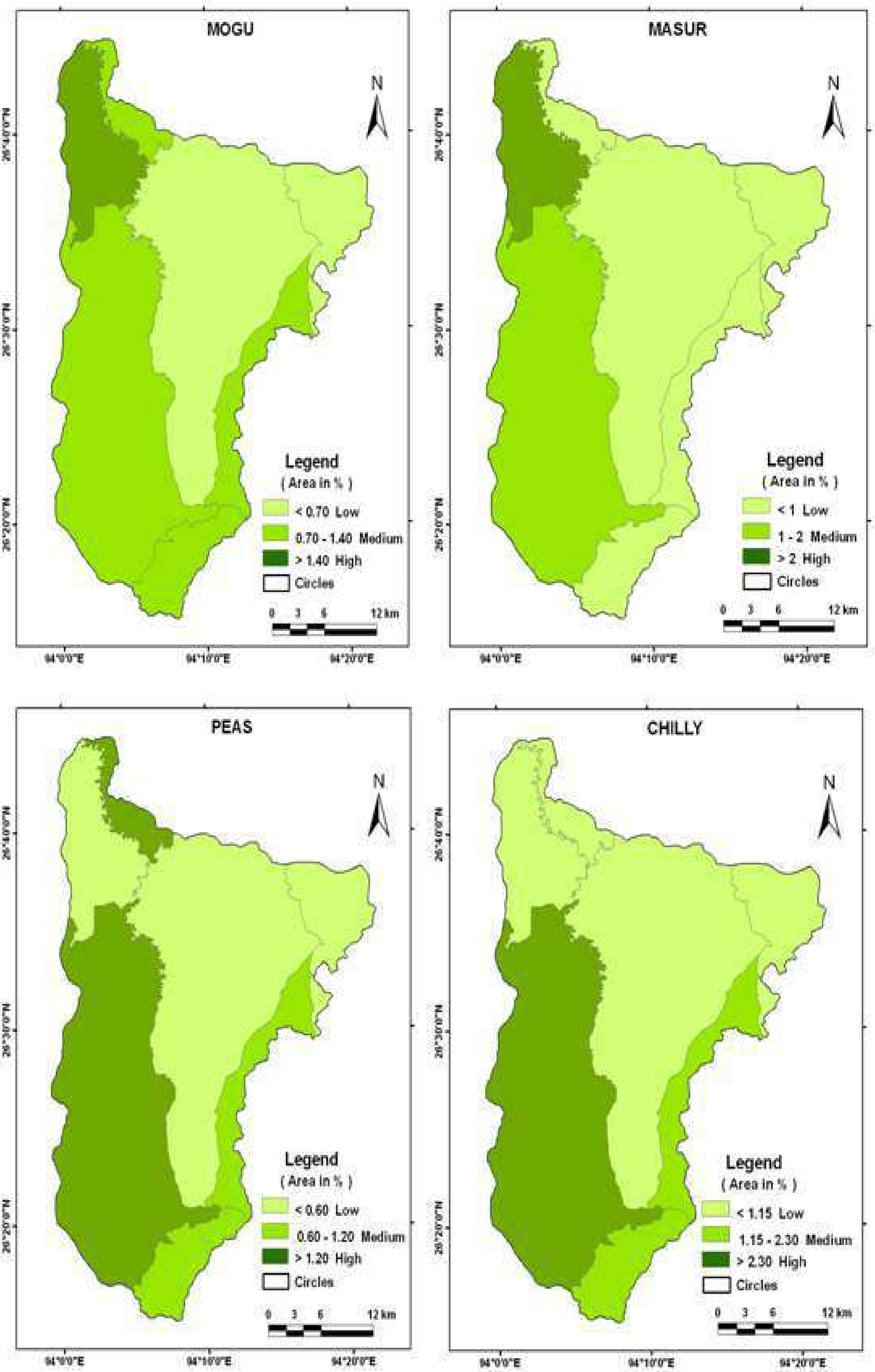


Fig. **6.11**

Crop concentration of Kakodonga River Basin(2012-2014)

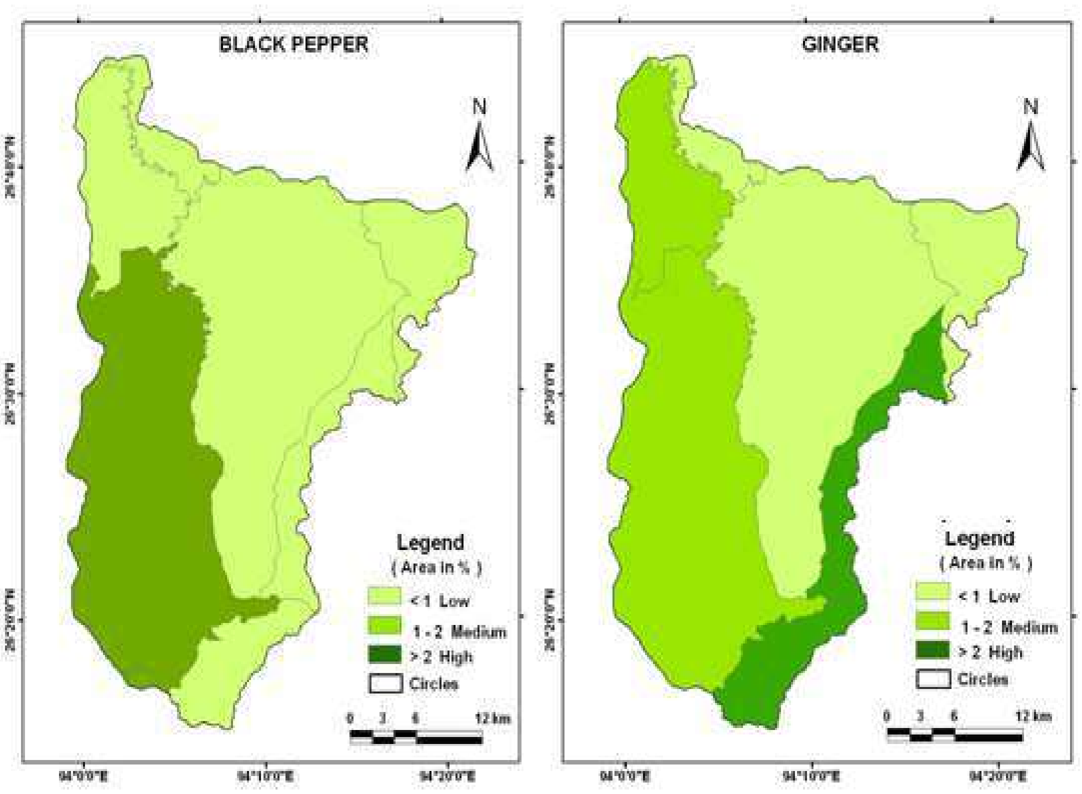


Fig. 6.12

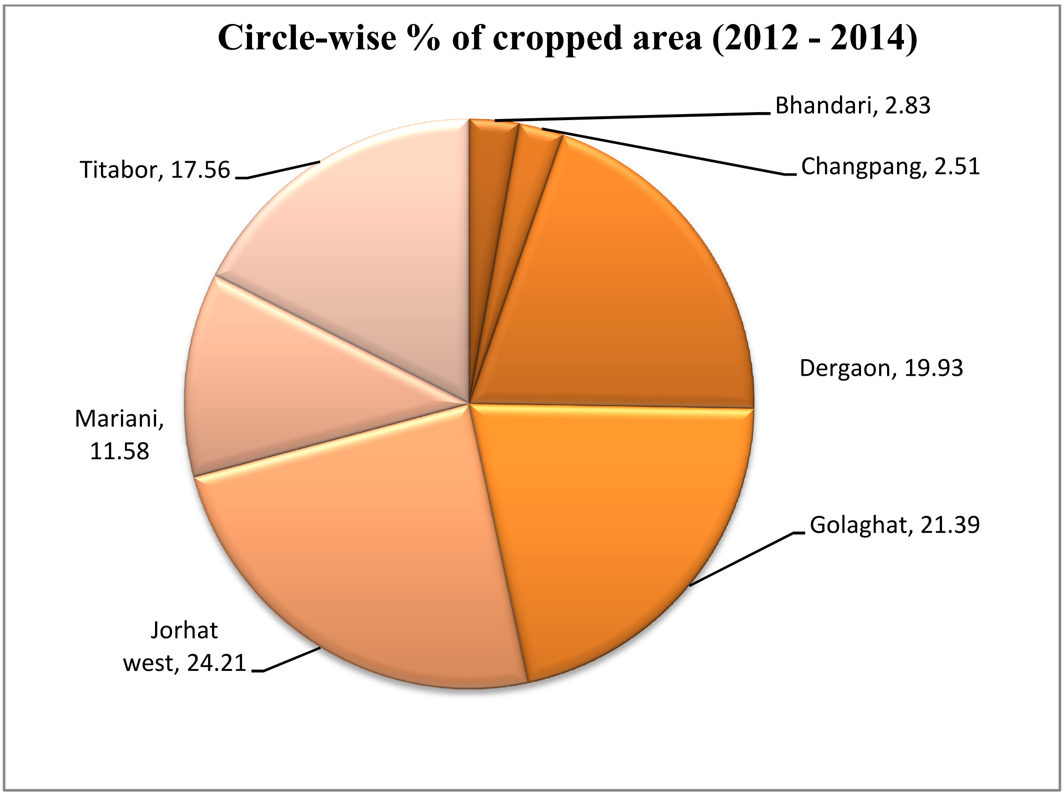
6.7. **Circle-wise percentage of total cropped area**

The circle wise percentage of total cropped area of the Kakodonga basin varies from a minimum of 2.51% in Changpang circle to a maximum of 24.21% in Jorhat west circle (Table 6.7 & Fig. 6.13). The average circle-wise percentage of crops is 14.29%. The Bhandari and Changpang circles showed very low percentage of cropping area. The medium percentage of cropping area is found in Mariani and Titabor circles of the basin. The Dergaon, Golaghat, and Jorhat west circles have maximum area under crop and these are spatially distributed in western and northwestern parts of the basin.

Table 6.7: Circle-wise Percentage of crop of the Kakodonga River basin (2012 2014)

Sl. No.	Name of the Circle	Circle-Wise percentage of total cropped area (In %)
1.	Bhandari	2.83
2.	Changpang	2.51
3.	Dergaon	19.93
4.	Golaghat	21.39
5.	Jorhat west	24.21
6.	Mariani	11.58
7.	Titabor	17.56

Source: Economic and statistics Department



Source: Economic and statistics Department

Fig. 6.13

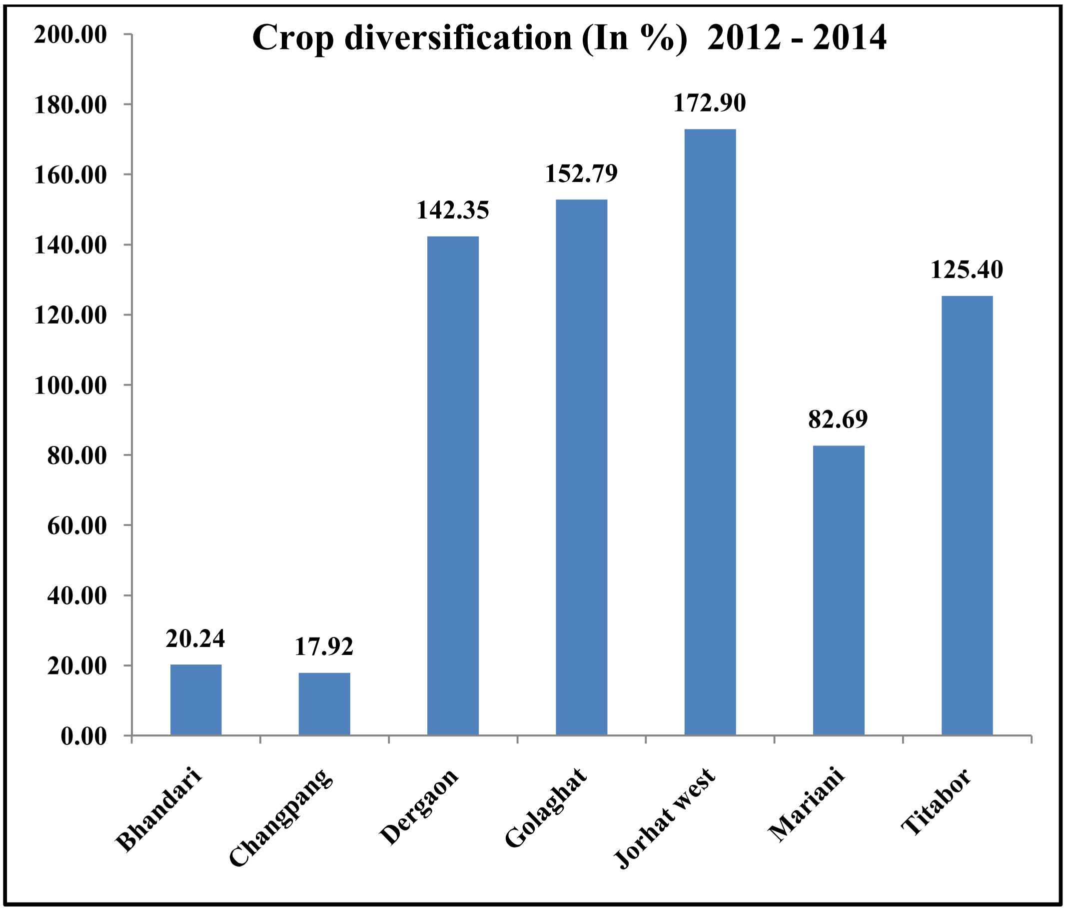
6.8. **Crop diversification**

The crop diversification index of the Kakodonga basin has been calculated adopting Bhatia (1967) Method. The crop diversification varies from a minimum of 17.92% in Changpang circle to a maximum of 172.90% in Jorhat west (Table 6.8 and Fig. 6.14). The average percentage of crop diversification is 102.04%. The crop diversification exceeds 100% in Dergaon, Golaghat, Jorhat west and Titabor circles of the basin. The crop diversification is less than 100% in Bhandari, Changpang and Mariani circles.

Table 6.8: Crop Diversification of the Kakodonga River basin (2012-2014)

Sl. No.	Name of the Circle	Crop Diversification (In %)
1.	Bhandari	20.24
2.	Changpang	17.92
3.	Dergaon	142.35
4.	Golaghat	152.79
5.	Jorhat west	172.90
6.	Mariani	82.69
7.	Titabor	125.40

Source: Economic and statistics Department



Source: Economic and statistics Department

Fig. 6.14

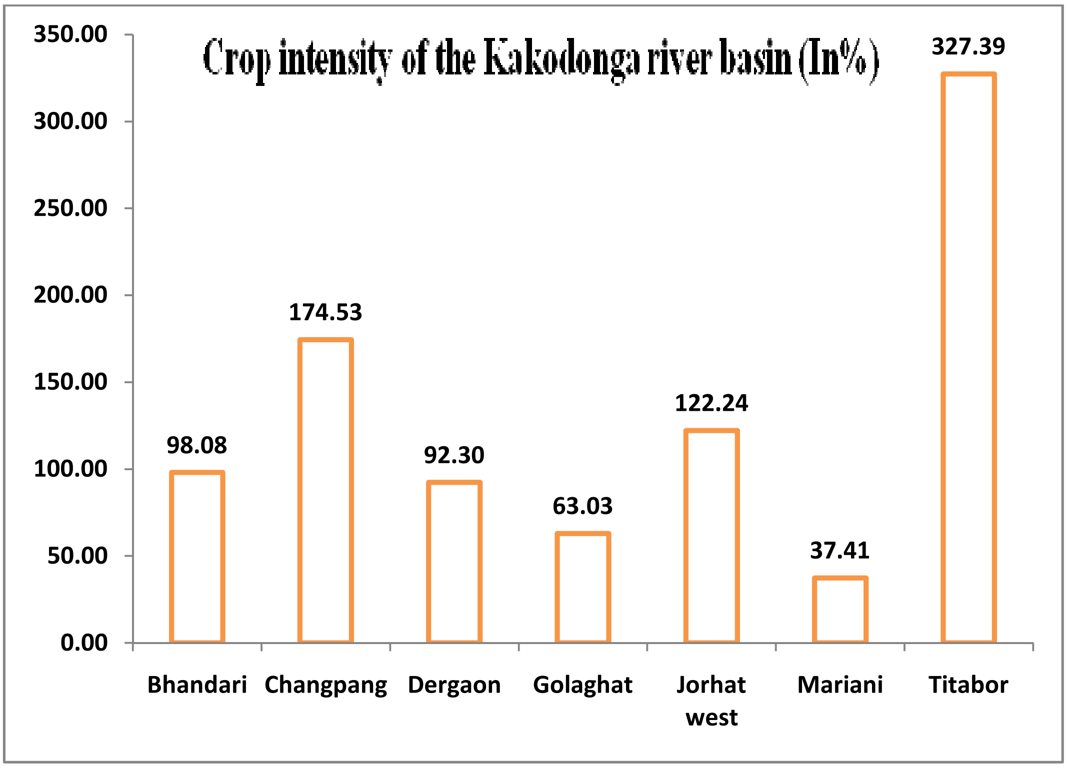
6.9. **Intensity of cropping pattern**

The intensity of cropping pattern of the Kakodonga basin varies from a minimum of 37.41% in Mariani circle to a maximum of 327.39% in Titabor circle. The average intensity of cropping pattern is 130.71%. The intensity of cropping pattern is very high in Titabor circle and it exceeds 100% in Changpang and Jorhat west circles. The Bhandari, Dergaon and Golaghat circles revel less than 100% of cropping intensity. (Table 6.9 and Fig. 6.15).

Table 6.9: Intensity of Cropping Pattern of the Kakodonga River basin (2012-2014)

Sl. No.	Name of the Circle	Intensity of Cropping Pattern (In %)
1.	Bhandari	98.08
2.	Changpang	174.53
3.	Dergaon	92.30
4.	Golaghat	63.03
5.	Jorhat west	122.24
6.	Mariani	37.41
7.	Titabor	327.39

Source: Economic and statistics Department



Source: Economic and statistics Department

Fig. 6.15

6.10. **Ranking of crops**

The r first ranking crop in Kakodonga river basin is rice. It is found in almost all revenue circles and also occupies highest percentage in Mariani circle (98.90%). The second ranking crops in the Kakodonga basin are rape and mustard and potato. Among the second ranking crops, highest percentage belongs to rape and mustard, which exhibit in Dergaon circle. Rape and mustard is concentrated in four circles and they are Bhandari, Changpang, Dergaon and Golaghat circles. Among the second ranking crops the potato is cultivated in Jorhat, Mariani and Titabor circles (Table 6.10). The third ranking crops are potato, rape and mustard, turmeric and sugarcane. The potato is found in three circles these are Bhandari, Changpang and Golaghat circles. Rape and mustard is observed in Jorhat west and Mariani circles. Turmeric and sugarcane have been noticed in Dergaon and Titabor circles .Among the third ranking crops highest percentage is occupied by sugarcane in Dergaon circle only. The fourth ranking crops in the Kakodonga basin are sugarcane, potato, chilly, matikalai and rape and mustard. The sugar cane is found in two circles which is Bhandari and Changpang circles. Chilly is cultivated in two circles that is Golaghat and Mariani circles. In Jorhat, Dergaon and Titabor rape and mustard, potato and matikalai are some of the important crop. The fifth ranking crops in the basin are ginger, turmeric, pea and wheat. The ginger crop is noticed in three circles ie. Changpang, Golaghat and Titabor. The Mariani and Dergaon circles have turmeric crop. The pea and wheat crops are practiced in Jorhat and Bhandari circle as fifth ranking crop. The crops which fall under the rank category of sixth, seventh, eighth, ninth, tenth, eleventh, twelfth, thirteenth and fourteenth occupy less than 2% of the total cropped area.

Table 6.10: Ranking of crops in Kakodonga river basin (In %) 2012-2014

Sl No	Name of the Circle	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
1.	Bhandari	77.4	13.8	2.91	1.57	1.31	1.31	0.52	0.39	0.39	0.13	0.10	0.07	0	0
2.	Changpang	79.65	12.82	2.25	1.55	1.29	1.07	0.52	0.37	0.30	0.07	0.07	0.04	0	0
3.	Dergaon	60.63	28.93	6.05	1.09	0.92	0.70	0.42	0.30	0.29	0.23	0.21	0.09	0.08	0.04
4.	Golaghat	86.65	5.46	2.25	0.95	0.91	0.87	0.84	0.82	0.56	0.43	0.14	0.06	0.04	0
5.	Jorhat west	94.98	1.15	1.09	1.07	0.96	0.21	0.11	0.11	0.10	0.08	0.08	0.04	0.01	0.01
6.	Mariani	98.90	0.37	0.22	0.16	0.15	0.07	0.04	0.03	0.02	0.02	0.01	0	0	0
7.	Titabor	97.65	1.42	0.21	0.14	0.14	0.13	0.11	0.07	0.04	0.04	0.03	0.01	0	0

Source: Economic and statistics Department

6.11. Crop Combination

The crop combination of the Kakodonga river basin has been analyzed on revenue Circle level adopting Rafiullah's (1956) and Doi's (1957) methods. **Rafiullah's (1956)** has developed a new deviation method in his work "*A new approach to the functional classification of towns*." The technique devised by Rafiullah may be expressed as follows:

$$d = \frac{\sqrt{\sum D_p^2 - D_n^2}}{N^2}$$

Where, d is deviation, D_p is the positive difference and D_n is the negative difference from the median value of the theoretical curve value of the combination, and N is the number of functions (crops) in the combination. Since it is the relative rank of the value of deviation which is needed, the under root sign may be ignored to save laborious calculations and the formula may be used in the following form:

$$d = \frac{\sum D_p^2 - D_n^2}{N^2}$$

Doi's technique is easiest for crop combination analysis. The Doi's formula expressed as:

$$(\Sigma\ d^2)$$

The combination having the lowest ($\Sigma\ d^2$) will be the crop combination. In Doi's technique, it is not required to calculate ($\Sigma\ d^2$) for each combination but the crop combination is actually established by deviation analysis table. It represents critical values for various elements at different ranks against cumulative percentage of elements at higher ranks. The use of deviation analysis table required only the summing of actual percentages under different crops instead of finding differences between actual percentage and theoretical distribution.

Crop combination put forwarded by **Rafiullah's method** shows that six circles come under mono crop and one circle under two crop combinations (Table 6.11 & Fig. 6.16). The mono crop is rice in Bhandari, Changpang, Golaghat, Jorhat west, Mariani and Titabor circles. In Dergaon circle two crops combination is noticed i.e. rice and rape and mustard. In the present study the crop combination of Rafiullah's method reveals the domination of mono crop that is rice, which is geographically distributed in northern, southern, eastern and western parts of the circles except northwestern part, which is dominated by two crops combinations.

According to **Doi's method** there are three circles dominated by mono crop that is rice. They are Jorhat west, Mariani and Titabor (Fig. 6.16). The two crops combination is found in four circles which are Bhandari, Changpang, Dergaon and Golaghat. Rice and rape and mustard are the two crops. The spatial distribution shows that dominations of mono crop combination in northern and northeastern parts of the basin that is Rice. The two crop combinations are dominated by northwestern, western and southeastern parts of the basin. The study of crop combination regions constitutes an important aspect of agricultural geography as it provides basis for agricultural regionalization.

Table 6.11: Crop Combination of the Kakodonga river basin (2012-2014)

(Rafiullah's Method)

Sl. No.	Name of the Circle	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
1.	Bhandari	754.14	656.90	390.00	250.65	174.76	128.94	98.56	77.81	62.86	51.99	43.73	37.10	32.07	27.86
2.	Changpang	878.85	709.43	418.72	267.73	186.05	136.86	104.48	82.39	66.50	54.97	46.20	39.18	33.85	29.40
3.	Dergaon	113.07	313.57	218.47	150.94	109.79	83.20	64.76	51.82	42.27	35.28	29.90	25.47	22.14	19.29
4.	Golaghat	1343.3	854.76	534.54	331.85	226.86	165.18	125.41	98.51	79.28	65.34	54.78	46.39	39.99	34.69
5.	Jorhat west	2023.60	1082.23	680.74	416.99	282.39	203.94	153.95	120.41	96.63	79.46	66.51	56.28	48.45	42.01
6.	Mariani	2391.52	1213.74	750.28	456.86	308.29	222.40	167.77	131.14	105.20	86.46	72.34	61.20	52.68	45.67
7.	Titabor	2270.6	1180.5	723.86	441.86	298.64	215.71	162.87	127.39	102.23	84.06	70.35	59.53	51.25	44.44

Source: Economic and statistics Department

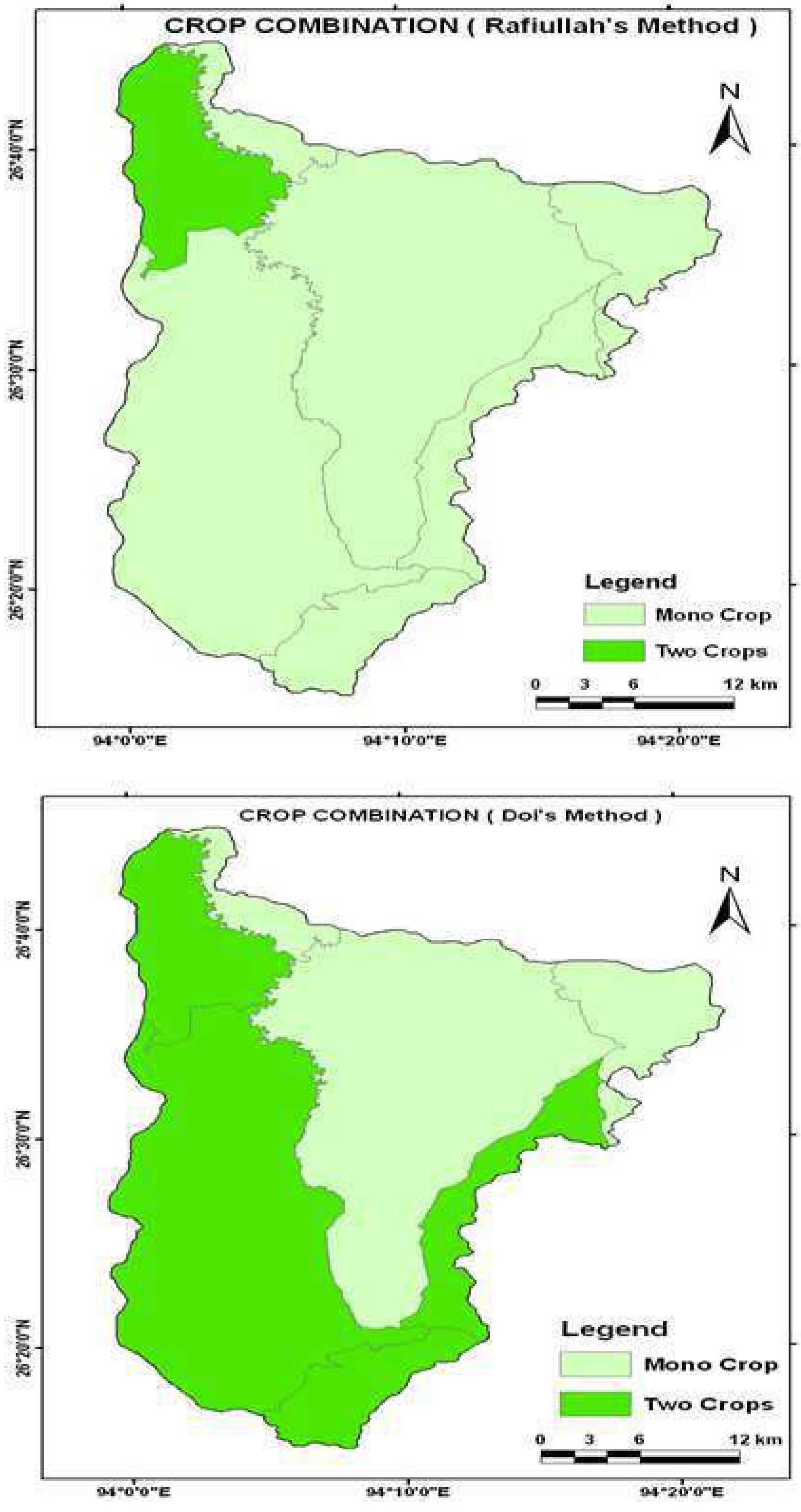

CROP COMBINATION (Rafiullah's Method)
N
Legend
Mono Crop
Two Crops
0 3 6 12 km
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E
CROP COMBINATION (Doi's Method)
N
Legend
Mono Crop
Two Crops
0 3 6 12 km
26°40'0"N
26°30'0"N
26°20'0"N
94°0'0"E
94°10'0"E
94°20'0"E

Fig. 6.16

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Chapter-7

Watershed Management of the Kakodonga River Basin

7

In India, the concept of watershed as a small unit for management and development of land and water resources was initiated by Shri (late) V.P. Bali (1974), when Ministry of Agriculture, Government of India initiated programme of soil and water conservation adopting watershed as a planning unit. The concept has gained momentum and presently watersheds form the basis of presenting natural resources for effective planning and optimum development of land and water resources. Watershed projects have been taken up under different programmes initiated by Government of India. The various programmes are the Drought Prone Area Programme (1987), Desert Development Programme (1987), Development of wasteland on a watershed basis adopted in 1989 by National Wasteland Development Board and National wasteland developmental programme in Rained areas under the Ministry of Agriculture.

The size of the watershed may vary from a few square meters to thousands of square kilometers. The size becomes important depending upon the objective of the project. The size of the watershed is also determined by afforestation, grassland development and cultivation. Many physiographical features like valley, undulating hillocks and logged hill tracks influenced the size of the watershed. The larger watersheds could be selected in plains or where afforestation and grassland development is the main objective in the hill areas of watersheds. The agricultural development is the main objective of smaller watershed. An average 5000 hectares of land is an effective unit for watershed management and 500 hectares of micro watershed is a functional watershed unit.

Watershed management is an integrated technological approach with in the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic minimum needs of the people in a sustained manner. According to Soil Conservation Society of India, watershed management means harmonious development of land and water resources within the natural boundaries of a watershed, so as to promote or produce on sustainable basis, abundance of plants and animals and these products still deliver clean and control flow of water to the down streams. According to Food and Agriculture Organization, watershed management is the process of the formulating and carrying out a course of action involving the manipulation of land and water resources in the watershed to provide goods and services without adversely affecting soils and water base.

Watershed management requires control of damage run-off, manage and utilize run-off water for useful purposes, control of erosion, moderate floods in the downstream area, enhance ground water storage where ever applicable and appropriate use of land and water resources in the watershed for development of food, fodder and forest resources.

The basic data needed for watershed management are physical data, present land use, socio-economic and cultural conditions, land tenure systems, land facets and its problems, existing stage on development and infrastructural facilities, economic development activities and technology know-how. The important factors, which affect the behavior are size and shape of the watershed, topography, soil and vegetation development. The selection of priority watershed area includes the location and determination of venerable watersheds, which are contributing high sediments and run-off in the reservoirs. The watersheds which need to be treated on the priority basis can be determined using reconnaissance surveys, soil and land use survey, sediment yield data, interpretation of aerial photographs or satellite data, interpretation of topographic sheets and weightage to the socio-economic factors. The major criteria for priority delineation of watershed are soil conservation, identification of suitable agricultural crops and contribution of more run-off and sediment yield. The various soil moisture conservation measures to be adopted in watershed are contour stone wall and contour trenching on barren hill slopes, afforestation, bench terracing for steep slopes, contour and graded bunding on agricultural land, gully protection by check dams, construction of small ponds and percolation ponds, stream bank erosion, control road side stabilization, pasture development, water spreading for ground water recharge, control of land-slides and mass wasting, insitu soil moisture conservation method and vegetative barriers along contours. Miss management and over exploitation of natural resources through over cultivation of agricultural land, over grazing of grassland and over cutting of forests have resulted in degradation of environment and drawing immediate awareness of conservation of natural resources.

About 16.2% our country is under wastelands, which are degraded lands. They include 4.3 million hectares of gullied or ravines, 3.9 million hectares of saline and alkali lands and 0.88 million hectares of water logged land. Every year about 16.55 thousands million cubic meters of soil, six millions tones of fertile soil and other plant nutrients are being lost. The progress of the country is linked with agricultural and bio mass products which depends on soil, water-plant-nutrient relationship of watershed. They are the basis for micro level planning for optimum utilization of land, water and forest resources.

Participatory Rural Appraisal in watershed programme is emphasized on the establishment of a more equitable relationship between facilitator and community. There is conscious effort made to empower of the community. The empowerment is creation of a participatory research process in which local people are viewed as active agents. The objective of participatory process is to facilitate local people doing their own analysis through own situations. Participatory Rural Appraisal is exploratory and helps in assessing needs and prioritizing problems. Planning formulation feasibility studies, monitoring and evaluation can be undertaken by using Participatory Rural Appraisal techniques in the watersheds.

The participatory development is a new economic force aiming at sustainable development at the village level in the watersheds. There is a close link between resource and community. The community has a great deal of interaction among individual user resources. Allocation of resources based on a community approach, rather than on an individualized one, adds an element of sustenance to the development process. Participatory development is a non-conventional approach. It is required to encompass the evaluation of non-market, non-government people organization, changes of system of the property rights and methods of resource allocation.

The integrated watershed development aims at sustainability, productivity and equity. It has been amply emphasized to ensure sustainability where there is majority of people below poverty line, women or landless assistance and support to immergence and establishment local institution is crucial. Watershed advisory committee is an advisory body for watershed at development programmes in extensive areas. The watershed advisory committee comprises of District Collector, Chief Executive Officer of Zilla Parishad, Director of District Rural Development Authority, all MLA's of the District, all the Project Officers and one or two members from the relevant research and training institutes in districts. The Watershed Advisory

Committee must meet regularly to advice and assist District Rural Development Area for training, community mobilization for implementation of Watershed Development Programme.

The project implementation agency shall normal be assigned 10 to 12 watersheds covering an area of about 5000 to 6000 hectares to motivate Gram Panchayat and pass necessary resolutions, to make public contribution, conduct Participatory Rural Appraisal exercises, prepare the development plans for the watersheds and undertake community organization and training for the village community. The project implementation agency should provide technical guidance and supervision of watershed development activity, inspect and authenticate project accounts, under take action research to adopt low cost technology and validate and build upon indigenous technical knowledge. The Project Implementation Agency should monitor and review the overall project implementation and setup institutional arrangements for post project operation. The Project Implementation Agency shall carry out its duties to multi disciplinary team designed as watershed development team. The Project Implementation Agency shall constitute self-help group in the watershed area with the help of watershed development team. The Project Implementation Agency shall constitute user groups in the watershed area with the help of watershed development team. Watershed Associations are formed at Village Panchayat level to implement watershed development plans, monitor and review the progress, approve the statement of accounts, formation of user groups and resolve differences of disputes between different user groups, self help groups or amongst members of user groups. Watershed committee should be nominated by watershed association with 10 to 12 members, which constitute of user groups, self-help groups, gram panchayat and watershed development team. The watershed committee shall carryout day-to-day activities of the watershed development projects.

The watershed developments are

1. Land Development including insitu soil and moisture conservation measures like contour and graded bunds fortified by plantation, bench terracing in hilly terrain, nursery raising for fodder, timber, fuel wood, horticulture and Non Timber Forest Product Species.
2. Afforestation including block plantations, agro-forestry and horticultural development, shelterbelt plantations, sand dune stabilization, etc.
3. Drainage line treatment with a combination of vegetative and engineering structures.
4. Development of small water harvesting structures such as low-cost farm ponds, nalla bunds, check-dams and percolation tanks and ground water recharge measures.
5. Renovation and augmentation of water resources, desiltation of tanks for drinking water / irrigation.
6. Pasture development either by itself or in conjunction with plantations.

7. Repair, restoration and up-gradation of existing common property assets and structures in the watershed to obtain optimum and sustained benefits from previous public investments.
8. Crop demonstrations for popularizing new crops/varieties or innovative management practices.
9. Promotion and propagation of non-conventional energy saving devices and energy conservation measures.

The Kakodonga river basin can be divided into 227 micro watersheds. Each micro watershed consists of 500 hectares of land. One macro watershed was selected in the basin to study in depth the physical characteristics using IRS P6 LISS-III imagery (23.5mt resolution) 2011, and Survey of India topographic sheets on scale 1: 50,000 (Fig. 7.1). The selected macro watershed was Bojalkata, which is located in southeastern part of the Kakodonga river basin.

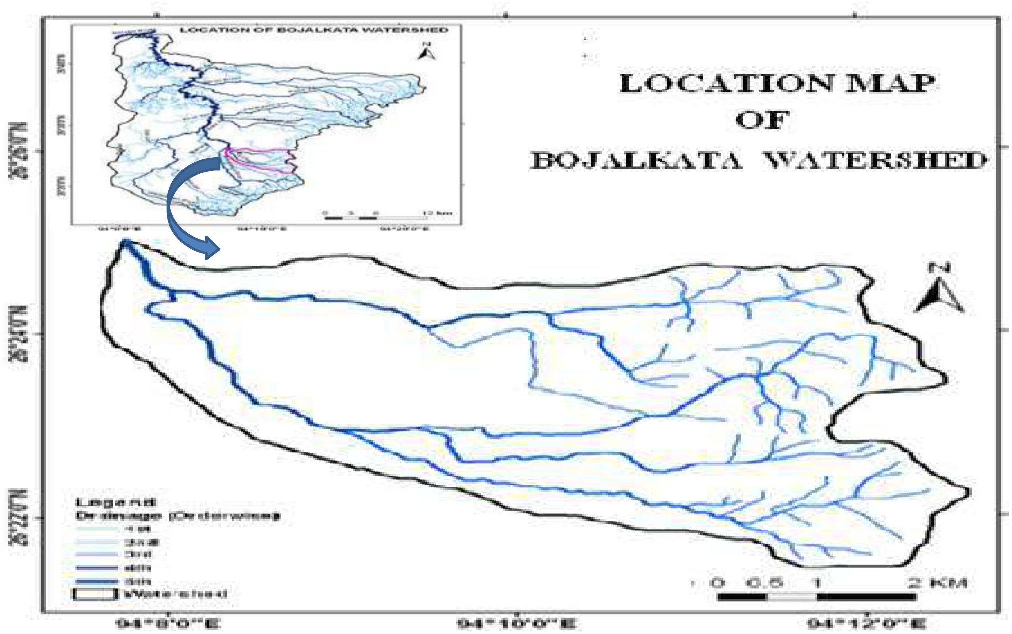

Fig. 7.1

THE BOJALKATA WATERSHED

The Bojalkata watershed covers about 3,857 hectares area. It is a macro watershed. The Bojalkata watershed encloses fourteen villages. They are Bojalkata, Borholla Grant, Halfmile Belt, Miri Gaon, Nagabat Gaon, No.1 Block, No. 1 Kakodonga Habi Gaon, No.2 Block, No.2 Kakodonga Habigaon, No.3 Block, No.4 Block, No.5 Block, Orongial Gaon, and Raidangjuri.

7.1. Population

Bojalkata watershed has a total population of 21,931 (2011, Census). The village wise distribution of population shows that the minimum population is found in Raidangjuri village i.e. 397 person and the maximum population is 2,767 person concentrated in Halfmile Belt village (Table 7.1). The villages which have population less than 1000 are Bojalkata and Raidangjuri. The population ranges from 1000 to 2000 in nine villages. They are Borholla Grant, Miri Gaon, Nagabat Gaon, No.1 Block, No.1 Kakodonga Habi Gaon, No. 2 Block, No. 4 Block, No.5 Block, and Orangial Gaon villages. The population exceeded 2000 person in Halfmile Belt, No.2 Kakodonga Habi Gaon and No.3 Block villages.

Table 7.1: Village wise Household and Population of Bojalkata Watershed

Sl. No.	Name of Villages	Household	Total Population	Population in %
1.	Bojalkata	136	700	3.19
2.	Borholla Grant	280	1326	6.05
3.	Halfmile Belt	551	2767	12.62
4.	Miri Gaon	351	1659	7.56
5.	Nagabat Gaon	218	1041	4.75
6.	No.1 Block	385	1810	8.25
7	No.1 Kakodonga Habi Gaon	325	1598	7.3
8.	No.2 Block	278	1312	5.98
9.	No.2 Kakodonga Habi Gaon	448	2058	9.38
10.	No.3 Block	543	2608	11.89
11.	No.4 Block	357	1684	7.68
12.	No.5 Block	359	1694	7.72
13.	Orangial Gaon	290	1277	5.82
14.	Raidangjuri	84	397	1.81

Source: Census of India (2011)

7.2. Temperature

The mean annual temperature in Bojalkata watershed has recorded as maximum of 28.77^0 C to a minimum of 18.67^0 C. The average monthly temperature is 23.72^0 C.

7.3. Land resources

The land forms, drainage, geology, relief, slope, soils, hydro-geomorphology, landuse and land cover, intensity of soil erosion and land capability classification of Bojalkata watershed have been done using Arc GIS 9.3 and ERDAS 8.5 software.

7.3.1. Drainage

Bojalkata stream is one of the right-bank tributaries of the Kakodonga river basin. It originates from Changpang circle of Wokha district, Nagaland and traverses a total distance of 13.30 km until reaching its confluence with the Kakodonga River (Fig. 7.2). The Balijan, Bekajan and Terimeri Jan are the main tributaries of Bojalkata stream. The stream enters in Assam near Bekajan and flows towards west. Terimeri Jan joints Bojalkata at Thengalgaon Village and thereafter it takes a northeastern direction. Terimeri Jan also originates from Naga Hills and length of the tributary is 4.88 km. After that Bojalkata flows towards north for a distance of about 4 km and tributary Beka Jan meets the stream from right bank. Then it turns towards northeast direction to meet river Kakodonga.

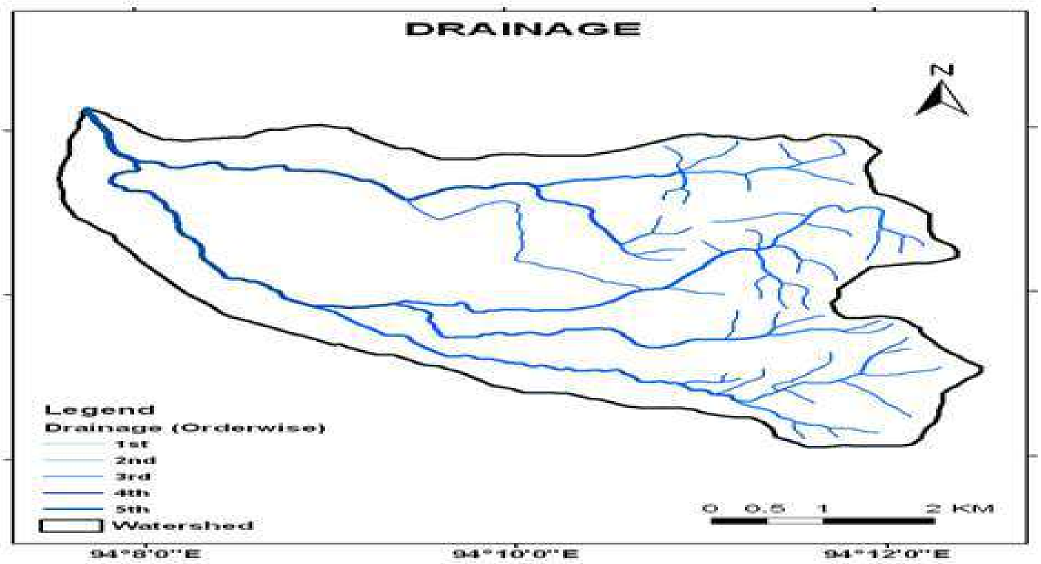

Fig. 7.2

7.3.2. Geology

The geologically the Bojalkata watershed is composed of mainly Archaen rocks consisting of granitic gneisses and schist's. The majority of the basin is covered by alluvium (56.86%), followed by undifferentiated fluvial sediments (41.77%) and narrow strip belonging to tipam group (1.37%). The alluvium has been identified in western and central parts of the watershed. Eastern parts have some undifferentiated fluvial sediments and tipam group. A very small quantity of tipam group is noticed in northern tip of the watershed (Fig. 7.3).

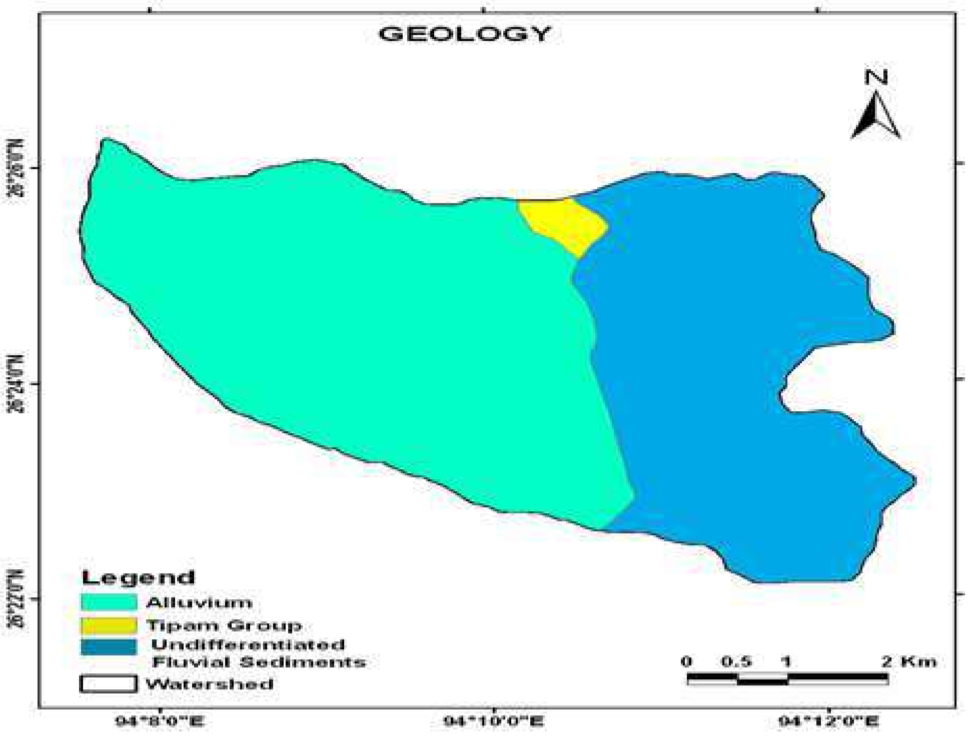

Fig. 7.3

7.3.3. Relief

The relief in the watershed varies from 99 m to 520 m above MSL. The maximum elevated portion of the watershed is near Lio Longidum village of

Wokha district, Nagaland and minimum is at Negherigaon of Jorhat district, Assam where it meets with river Kakodonga (Fig. 7.4).Below 100 meter elevation is found at Bojalkata and Orongial village and it accounts about 6.38 sq. km or 16.52% of the whole watershed. 100 meter to 200 meter altitude is identified in middle part of the watershed and it occupies maximum area i.e. 22.86 sq. km, which is 59.28 % of the whole watershed. Next elevation zone i.e. 300 meter to 400 meter is spreading from northeast to south east part of the watershed with an area of 5.84 sq. km. (15.14%). The other two altitude zones i.e. 300 meter to 400 meter and 400 meter to 500 meter are found towards eastern part of the watershed spreading from southeast to central east and are occupying 2.50 sq. km (6.48%) and 0.98 sq. km (2.55%) area of the watershed respectively. The last zone i.e. elevation above 500 meter is confined in extreme southeastern tip of the watershed having a minimum area of 0.01 sq. km, which is only 0.03% of the whole watershed.

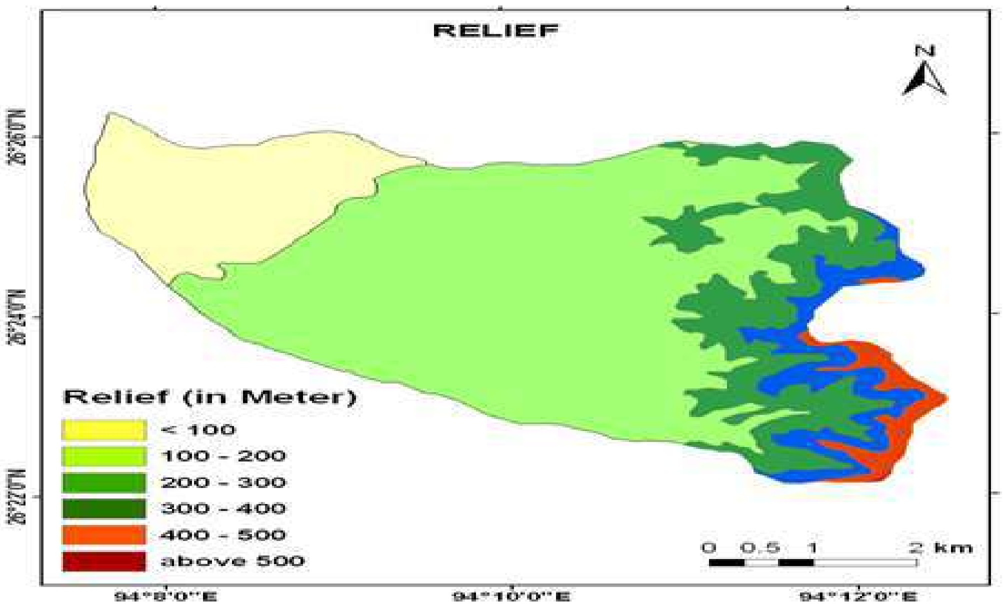

Fig. 7.4

7.3.4. Slope

The existed slope ranges from 0^0 to 40^0. The slopes of the Bojalkata watershed are classified into six categories (Fig. 7.5). The maximum portion of the watershed is under slope category of below 5^o, which is spreading mainly over the plain areas of Assam with an area of 20.63 sq. km. i.e. 53.49% of the whole watershed. The steeper slope areas i.e. above 30^o are limited in south eastern part of the basin. It is identified that the second highest slope category that is $30\,^o$ to $40\,^o$ is lying in southern part of the Changpang to Lio Longidum village of Nagaland occupying an area of 0.71 sq.km which is 1.84% of the watershed. Above 40^o slope has a very small area of 0.08 sq. km. (0.21%). Other slope categories i.e. 5^o to10^o, 10^o to $20\,^o$, 20^o to 30^o are spreading over different parts of Naga Hills. These categories occupy 5.25 sq. km (13.61%), 8.82 sq. km (22.87) and 3.08 sq. km (0.21%) area of the study area respectively.

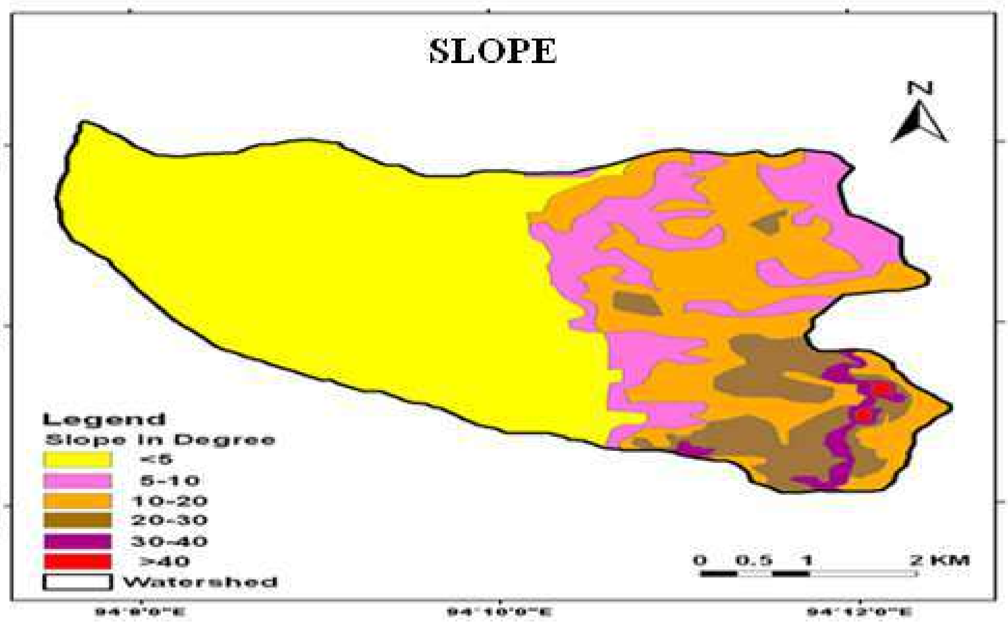

Fig. 7.5

7.3.5. Landforms

The major landforms of the Bojalkata watershed are hilly terrain, pediplains, shallow weathered pediplains, moderately weathered pediplains, wash plains and fluvial plains (Fig.7.6). The hilly terrain is found in the eastern part of the watershed. The pediplains is noticed in central and border areas of the watershed. The wash plains are lying parallel along with the main stream and western part of the watershed. The fluvial plains occurred in and around main drainage stream of the watershed.

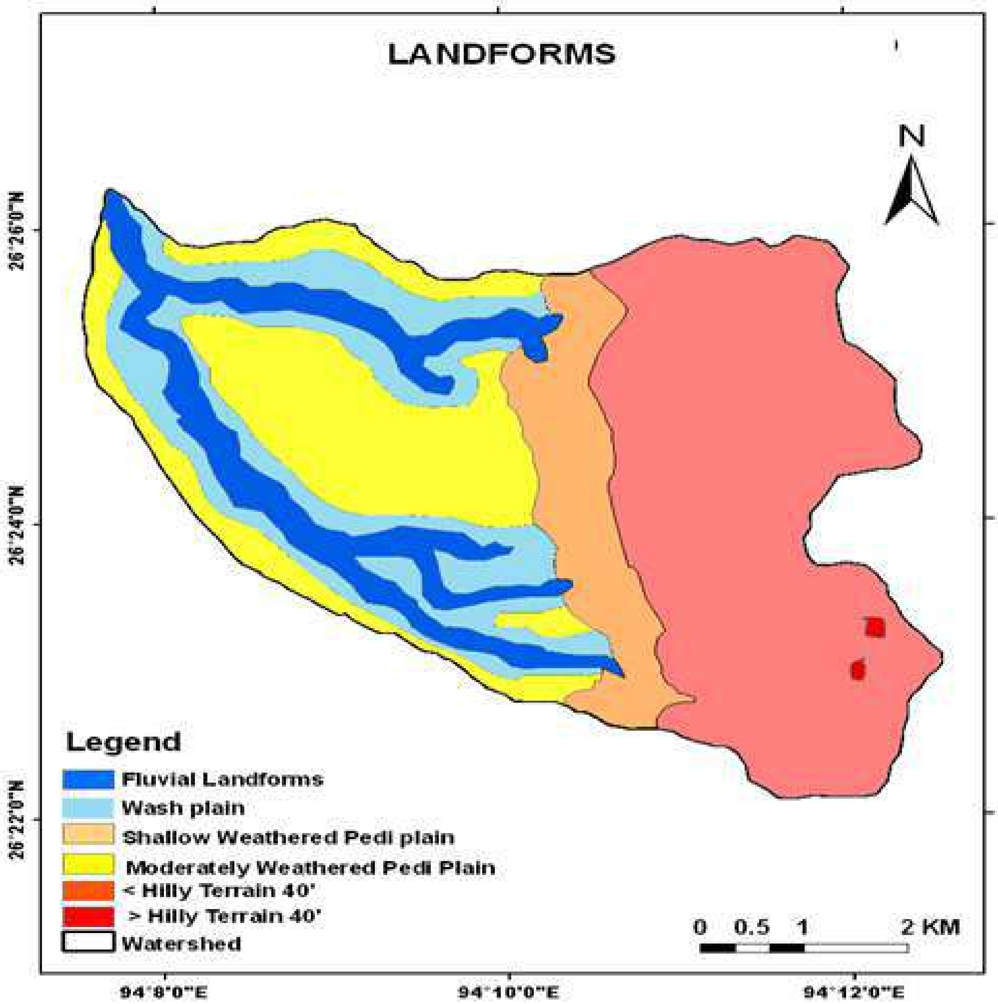

Fig. 7.6

7.3.6. Soils

In Bojalkata watershed two major types of soils existed i.e. inceptisols (22.34%) and mountain soils (16.23%). The old alluvium soils are found western to central parts and mountain soils are found in eastern part of the watershed. The inceptisols may be classified into soil sub groups like fine aquic dystric eutrochrepts, fine loamy typic dystrochrepts, and coarse loamy typic dystrochrepts etc. (Fig. 7.7 & 7.8)

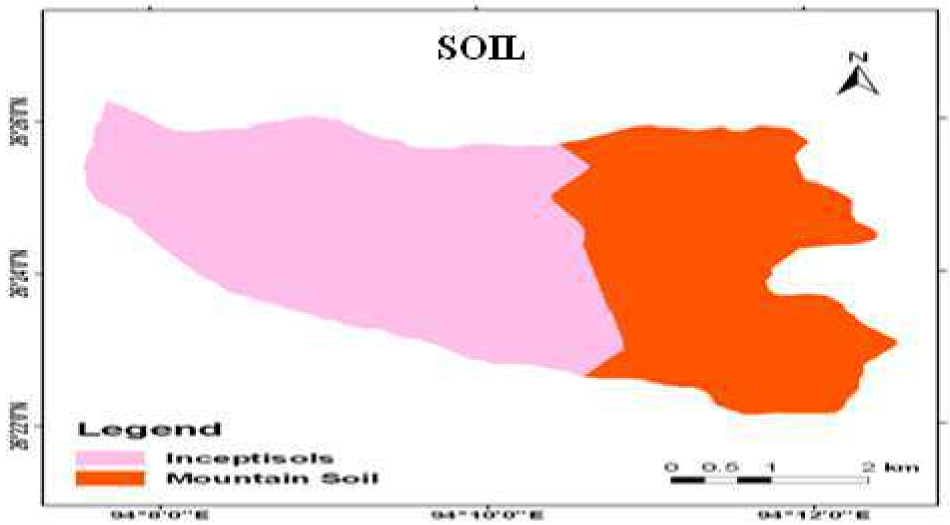

Fig. 7.7
Soil Subgroup of Bojalkata Watershed

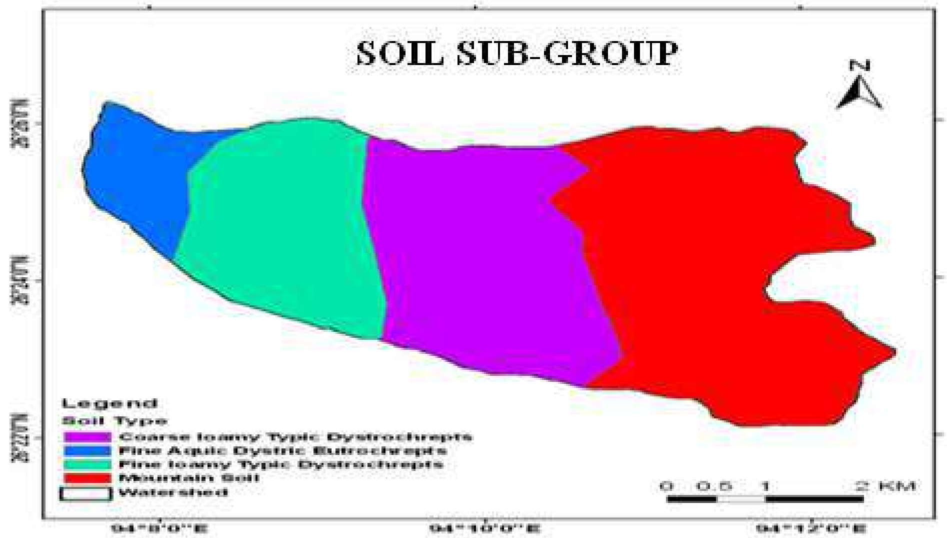

Fig. 7.8

7.3.7. Hydrogeomorphology

Hydrogeomorphologically the basin is divided into six categories (Fig. 7.9). The excellent and very good ground water resources are found in the fluvial plains and wash plains located in western and northwestern parts of the watershed. The fair ground water resources are found in the moderately pediplains. The poor ground water resources are noticed in the shallow weathered pediplains. The eastern hilly terrain is a run-off zone.

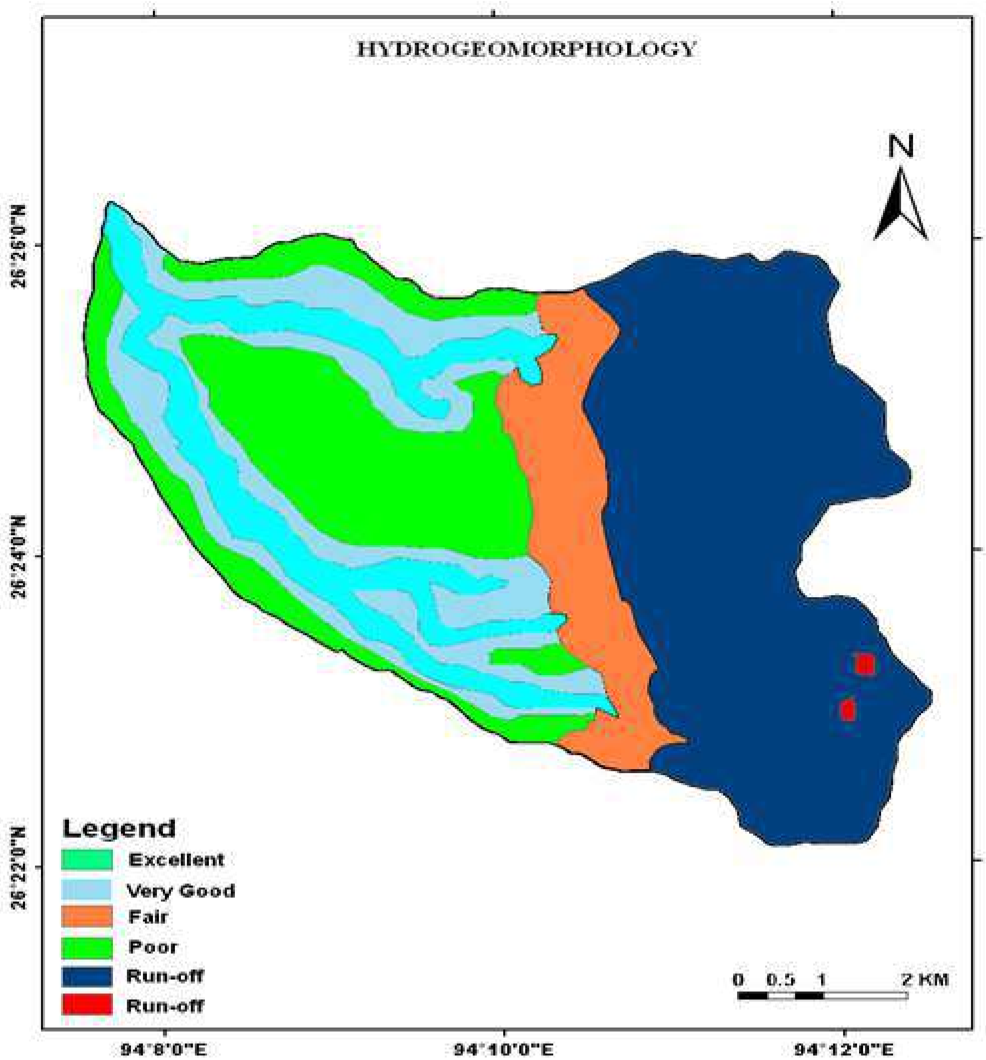

Fig. 7.9

7.3.8. Land use and land cover

The land use and land cover of the Bojalkata watershed have been studied using IRS P6 LISS-III imagery 2011 and Survey of India topographic sheets on scale 1:50,000. Land use categories identified in the study area are agricultural land (35.08%), forest (34.46%), built up land (24.73%), wastelands (5.44%) and water bodies (0.29%). The agricultural land consist of paddy and shifting cultivation fields and miscellaneous crops which are found in recent alluvial soils, fluvial plains and wash plains area and here dominated crop is paddy only. The built up land is noticed in old alluvial soils and pediplains. The tea crop is grown in pediplains and shifting cultivation is practiced in degraded forest area. The waste lands are associated with degraded forest and forest situated in eastern part of the basin particularly in hilly area (Table 7.2, Fig. 7.10 & 7.11).

Table 7.2: Land-Use /Land Cover Data of Bojalkata Watershed (2011)

Class	Area (in sq. km)	Area in %	Sub class	Area (in sq. km)	Area in %
1. Built-up land	9.54	24.73	1.0 Built-up land	9.54	24.73
2. Agricultural land	13.53	35.08	2.1 Paddy	12.83	33.26
			2.2 Miscellaneous Crops	0.13	0.34
			2.3 Shifting cultivation	0.57	1.48
3. Water bodies	0.11	0.29	4.1 River	0.04	0.10
			4.2 Pond	0.07	0.18
4. Wasteland	2.10	5.44	5.1 Scrubland	0.06	0.15
			5.3 Degraded Forest	2.04	5.29
5. Natural Forest	13.29	34.46	5.0 Natural Forest	13.29	34.46

Source: IRS P6 LISS III Imagery (Jan, 2011)

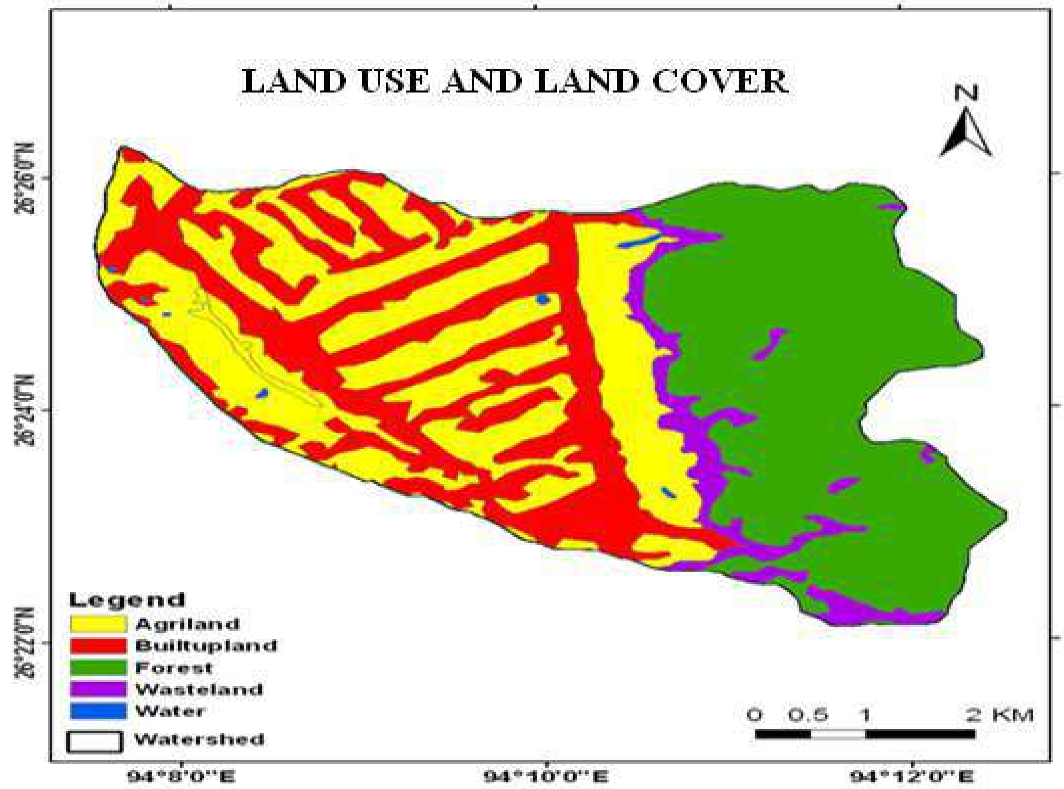

Fig. 7.10

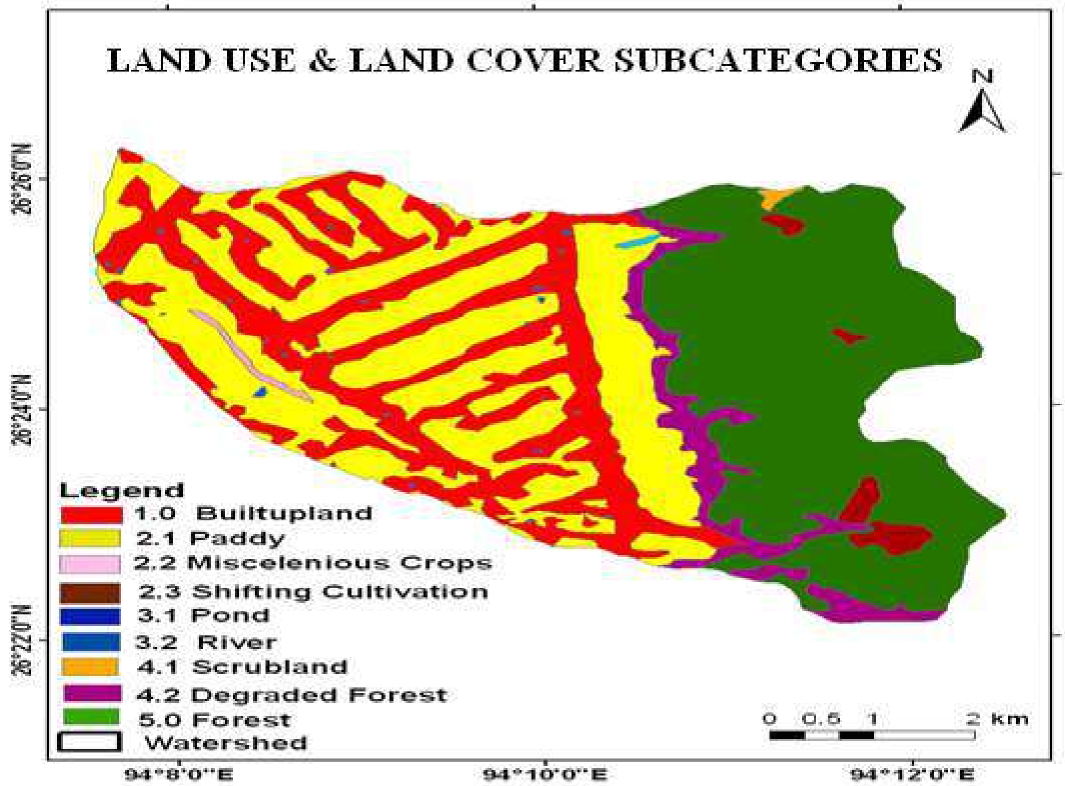

Fig. 7.11

7.3.9. Soil erosion intensity

The intensity of soil erosion is very severe and very high in hilly terrain and they are spatially distributed in the southeastern part of the watershed. The high intensity of erosion is noticed in the shallow weathered pediplains and this is located in northeastern part of the watershed. The moderate intensity of soil erosion is present in central part of the watershed; which is found in moderate weathered pediplains. The intensity of soil erosion is poor and very poor in fluvial and wash plains; they occurred at mouth of the river and western part of the watershed (Fig. 7.12).

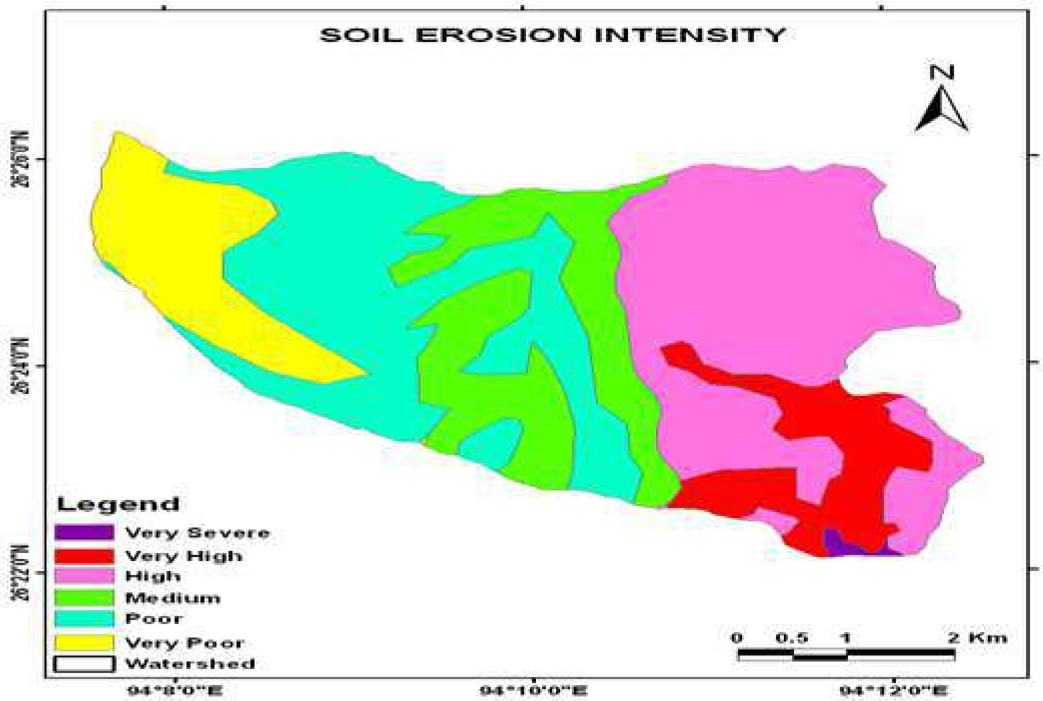

Fig. 7.12

7.3.10. Land capability Classification

Based on physical characteristics of the watershed six classes of land have been identified (Tab. 7.3 & Fig. 7.13). They are the class - I land consist of fluvial plains. The slope is less than 5^0. The soils fertility and ground water potentiality is good. The erosion susceptibility is poor. Here, the present land use is cultivated land under wet condition. The crops cultivated are rice, rape and mustard. The land development activities that could be taken up are land levelling and land mulching. The class - II land consists of wash plains. The slope is less than 5^0. The soil fertility is moderate. The ground potentiality is very fair. The erosion susceptibility is low. The present land use is cultivated land under wet and dry conditions. The crops cultivated are rice, rape and mustard and sugarcane. The land development activities that could be taken up are land levelling and land mulching. The class – III lands are moderate pediplains. The slope varies from 5^0 to 10^0. The soil fertility is moderate. The ground water potentiality is fair and erosion susceptibility is moderate. The present land use is cultivated land under wet and dry conditions. The crops cultivated are rice, matikalai, mogu, masur and black pepper. The land development activities that could be taken up are land levelling, land mulching, land bunding. The class – IV land consists of shallow weathered pediplains. The slope varies from 10^0 to 30^0. The soil fertility is moderate and ground water potentiality is poor. The erosion susceptibility is high. The present land use is cultivated land under dry condition. The crops cultivated are rice, tea, potato, onion, and black pepper. The land development activities that could be taken up are land levelling, land mulching and land bunding. The class – V land consists of hilly terrain with less than 40^0 slopes. The soil fertility is poor. It is a run-off zone. Therefore erosion susceptibility is very high. The present land use comes under forest with scrubs and degraded forest. The crops cultivated under terrace cultivation are chilly, ginger and paddy under jhum cultivation. The land development activities that could be implement are terrace bunding, rock fill dams and afforestation. Class – VI land consists of hilly terrain with more than 40^0 slopes. The soils fertility is poor. It is a run-off zone and the erosion susceptibility is very severe. The present land use is forest along with scrubs, degraded forest areas. The land development activities that could be taken up are terrace bunding and afforestation.

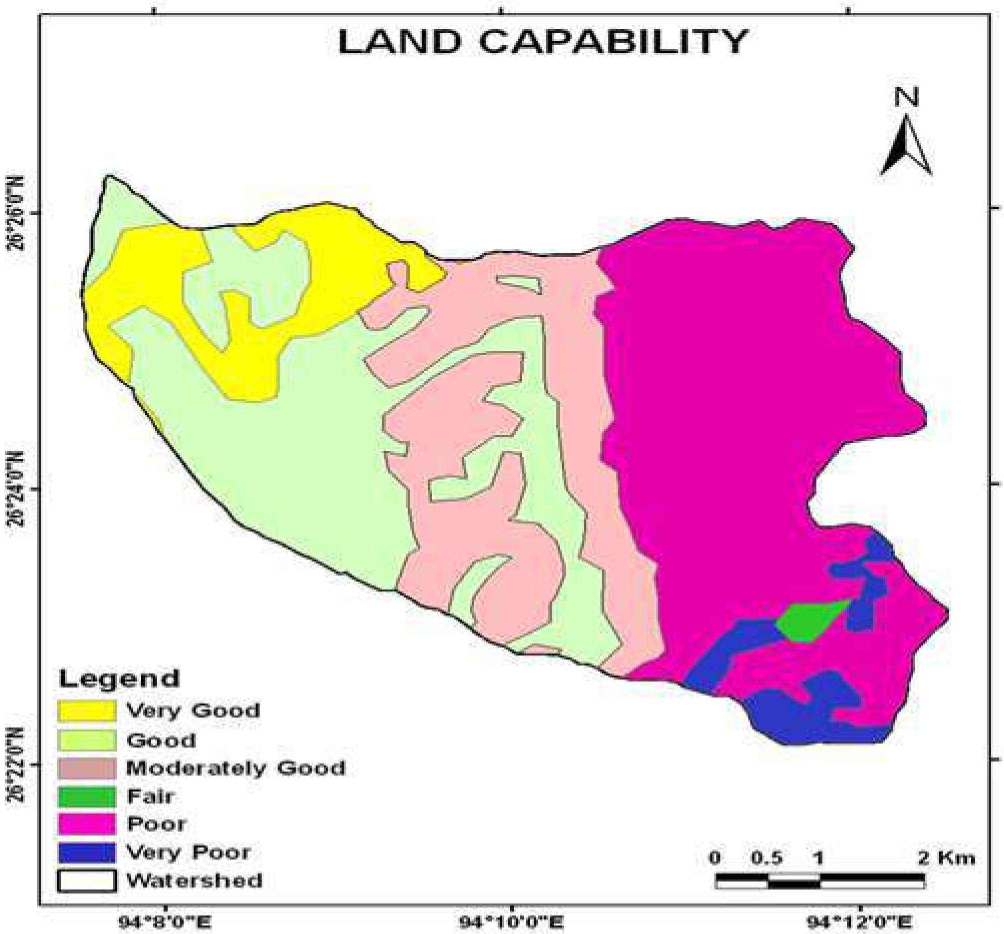

Fig.7.13

Table 7.3: Land capability classification of the Bojalkata watershed

Sl. No.	Class	Land Units	Slope	Soils Fertility	Ground Water Potential	Present Land Use	Soil Erosion Susceptibility	Land Development Activity
1.	I	Fluvial Plains	$<5^0$	Good	Good	Cultivated (wet) Rice, rape and mustard	Poor	Land mulching and Land levelling
2.	II	Wash Plains	$<5^0$	Moderate	Very fair	Cultivated (wet & dry) Rice, rape and mustard and sugarcane,	Poor	Land levelling and Land mulching
3.	III	Moderately Pediplains	5^0 to 10^0	Moderate	Fair	Cultivated land (dry) Rice, matikalai, mogu, masur, black pepper	Moderate	Land levelling and Land mulching
4.	IV	Shallow Weathered Pediplains	10^0-20^0 & 20^0-30^0	Moderate	Poor	Cultivated (dry) Rice, tea gardens, potato, onion, black pepper	High	Land levelling, Land mulching, Land grading and Land bunding.
5.	V	Hilly terrain less than 40^0	<40	Poor	Run-off	Chilly, ginger, jhum cultivation, degraded forest and forest with scrubs	Very high	Afforestation, Terrace bunding, Rock fill dams, Contour bunding, Land terracing and Stone terracing.
6.	VI	Hilly terrain more than 40^0	$> 40^0$	Poor	Run-off	Forest	Very severe	Land terracing, Contour bunding, Terrace bunding and Rock fill dams

Source: Compiled data

7.4. Morphometric analysis of Bojalkata watershed

7.4.1. Linear aspects of the drainage

The Bojalkata watershed is a fifth order drainage (Table 7.4) and total 64 no. of streams have been identified in the whole watershed. Out of which

Table 7.4: Linear aspects of the drainage system

River Basin	Drainage Order	No. of Stream (Nu)	Stream Length (in km) (Lu)	Mean stream length		Bifurcation Ratio (Rb)	Mean Bifurcation Ratio	Log Nu	Log Lu
				(Lu/Nu)	Avg. Length (km)				
Bojalkata	1st order	43	26.54	0.62		3.31		1.63	1.42
	2nd order	13	10.09	0.78		2.6		1.11	1.00
	3rd order	5	16.55	3.31		2.5		0.70	1.22
	4th order	2	9.26	4.63	0.99	2	2.60	0.30	0.97
	5Th order	1	1.30	1.30		0		0	0.11
	Total	64	63.74						

Source: SOI Toposheets, 1974

Where, Lu = Total Stream length of all orders.

Nu = Total number of streams of all orders

N1 = Total number of 1st order streams.

Π = 3.14

Rb = Nu/Nu+1

43 streams belongs to 1st order, 13 streams in 2nd order, five streams in 3rd order, two streams in 2nd order and one stream in 1st order. Length of streams is highest in 1st order streams i.e. 26.54 km, 2nd highest in 3rd order streams

(16.55 km) and it decreases from 2nd order streams to 5th order streams. Here only exception is 3rd order stream. Average length of the streams is 0.99 km. The bifurcation ratio of the basin varies from 2 to 3.31 and average is 2.60. It means less structural complexity in the watershed and also has higher potentiality of discharge after sudden heavy rain.

7.4.2. Areal aspects of drainage system

Drainage density (Dd) of the watershed is 1.65 km / sq. km. which is comparatively low (Nag, 1998), it indicates presence of high permeable subsoil in the watershed. Stream frequency is found as 1.66; it indicates positive correlation with increasing stream population and drainage density.

Table 7.5: Areal aspects of the drainage system

Morphometric parameters	Symbol/Formulas	Calculated Value
Area of the study area(In sq. KM)	(A)	38.57
Perimeter of the study area (In KM)	(P)	29.19
Drainage Density	Dd = Lu/A	1.65
Stream Frequency	Fs = Nu/A	1.66
Texture ratio	Rt = N1/P	1.47
Basin Length(In km)	Lb	13.65
Elongation Ratio	$Re = \frac{2\sqrt{A/\pi}}{Lb}$	0.51
Circularity ratio	$Rc = \frac{4\pi A}{P^2}$	0.57
Form Factor Ratio	$Rf = \frac{A}{Lb^2}$	0.21
Constant of channel maintenance	$C = \frac{1}{Dd}$	0.61
Length of overland flow	Lg = 1/2Dd	0.30

Source: SOI Toposheets, 1974

Texture ratio of Bojalkata is 1.47, which is not so high and it reveals moderate value of lithology, infiltration capacity and relief. Circularity ratio (Rc) of the watershed is comparatively high i.e. 0.57, it indicates probability of high flood hazard at peak time. Elongation ratio of Bojalkata watershed is 0.51 and it means the watershed is neither so much elongated nor circular. Form factor ratio (Rf) and constant of Channel maintenance (C) value is 0.21 and 0.61 respectively. Form factor ratio (Rf) of Bojalkata is comparatively low and it reveals that the watershed is near to elongated shape and flood of this type of watershed is easier to manage. Constant of channel maintenance indicates moderate constant of channel maintenance. Length of overland flow (Lg) 0.30 reveals comparatively moderate overland flow.

7.4.3. Relief aspects of the drainage system

Basin relief (H), Relief Ratio (Rh) and Ruggedness Number (Rn) of the basin are 0.42 km, 0.03 and 0.69 respectively. These relief parameters indicate that watershed has slightly strong relief and slope as well as moderate runoff speed. Over all soil erosion of the watershed is also moderate.

Table 7.6: Relief aspects of the drainage system

Morphometric parameters	Symbol/Formulas	Calculated Value
Maximum Elevation in the area (In meter)		520
Minimum Elevation in the area (In meter)		99
Basin Relief (mt)	H=Max. Elevation - Min. Elevation	421mt = 0.42 km
Relief ratio (Rh)	Rh= H/Lb	0.03
Ruggedness no.	Rn = H* Dd	0.69

Source: SOI Toposheets, 1974

7.5. The water balance elements of the Bojalkata watershed

The water balance elements of the Bojalkata watershed denote that the monthly precipitation varies from 8 mm to 305 mm. The watershed receives an average rainfall of more than 100 mm in April, May, June, July August, September and October months. The average rainfall ranges from 50 mm to 100 mm in March month only. The average monthly rainfall is less than 50 mm in January, February, November and December months. The average rainfall recharge of the basin is 315 mm.

The average potential evapotranspiration ranges from 65 mm to 176 mm. It is 150 mm or more than 150 mm in June, July, August and September months. The average potential evapotranspiration ranges from 100 mm to 150 mm in March, April, May, October and November months. But it is less than 100 mm in January, February, and December months.

The average actual evapotranspiration is 150 mm in June, July, August and September months and more than 100 mm in April and October months. The average actual evapotranspiration values vary from 50 mm to 100 mm in February, March, November and December months. In January month it is less than 50 mm.

The average water deficit in the watershed varies from 0 mm to 38 mm. There is no water deficit from April to September months.

The water surplus is found in April, May, June, July, August, and September months. The average water surplus ranges from 31 mm to 155 mm. It is less than 50 mm in April and September months. The water surplus ranges from 50 mm to 100 mm in June only and more than 100 mm water surplus is observed in May, July and August months. In January, February, March, October, November and December month water surplus is nil.

The average monthly moisture adequacy value varies from 58% to 100%. The moisture adequacy is 100% in April, May, June, July, August, and September months. The moisture adequacy values vary from 50% to 99% in January, February, March, October, November and December months.

Table 7.7: Water balance Elements of the Bojalkata Watershed

Elements	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
P in mm	32	34	91	159	243	247	275	305	181	103	19	8
PE in mm	80	90	110	120	135	150	150	150	150	130	80	255
AE in mm	48	52	95	120	135	150	150	150	150	126	50	158
WD in mm	32	38	15	0	0	0	0	0	0	4	30	27
WS in mm	0	0	0	39	108	97	125	155	31	0	0	0
Ima in %	60	58	86	100	100	100	100	100	100	97	73	68
Ia in %	40	42.2	13.6	0	0	0	0	0	0	3.08	27.27	31.8
Im in %	-24	-25.3	-8.9	24.5	44.4	39	45	51	17.1	-1.9	-16.4	-19
CC	C1	C1	C1	B1	B2	B1	B2	B2	C2	C1	C1	C1

Source: Water resource Department, Jorhat (Rainfall data)

The average Aridity Index values vary from 0% to 42.2%. The 0% is noticed in April, May, June, July, August and September months. The Aridity Index more than 50% does not exist. Less than 50% Aridity Index is observed in January, February, October, November and December months.

Climatologically the watershed experiences humid type of climate in April to August months and moist sub humid type of climate in September month. Dry sub humid type of climate prevails in January, February, March, October, November and December months.

The annual analysis of water balance elements

The average annual water balance elements depict that the average annual precipitation of the Bojalkata watershed is 141 mm. The average annual potential evapotranspiration value is 122 mm. The average annual actual evapotranspiration is 110 mm. The average annual water deficit is 13 mm. The maximum water surplus is occurred in monsoon period only. The average annual moisture adequacy is 87%. The average annual Aridity Index is 13%. Climatologically the watershed experiences dry sub-humid type climate in six month, moist subhumid type climate in one month, and humid type of climate in remaining five months.

Water balance of Bojalkata watershed

1. Total surface water resource of the Bojalkata watershed:

   5,438,370 m^3

2. Water resources stored in surface tanks: 4,351 m^3 (0.08%)
3. Water resources recharged to ground water resources:

   1,009,361m^3 (18.56%)

4. Water resources lost in the form of surface run-off:

   2,175,348 m3 (40%)

5. Water resources lost in the form of evaporation and evapotranspiration:

2,249,310 m^3 (41.36%)

From the analysis of water balance of the Bojalkata watershed it may be summarized that out of the total surface water resources of 5,438,370 m^3, about 0.08% is stored in surface lakes, ponds, beels etc., 18.56% is recharged to the ground water, 40% is lost in the form of surface run-off and 41.36% in lost in the form of evaporation and evapotranspiration. The water lost in the form of surface run-off has to be stored adopting watershed management programmes by rock fill dams, constructing check dams, percolation ponds and water harvesting structures.

7.6. Socio-economic profile of the Bojalkata watershed

Data about socio-economic conditions of the inhabitants of Bojalkata watershed were collected through questionnaire. Socio-economic data base were designed so as to have adequate information on income, occupation, education, agricultural area and production, resources use and their management, infrastructure etc. The survey was conducted through a questionnaire for 232 selected households of the watershed using random stratified sampling method in a view to cover all the villages and represent all category of household. Total household in Bojalkata watershed is 4605. One sample represents almost 20 populations (household), for example Borholla Grant has 280 households (Table 7.1) , out of this14 samples has been selected to represent all the household of the village considering all the categories.

Necessary secondary sources of data were collected on different aspects. The detail analysis of data has culminated with the objective to propose suitable watershed management plans to achieve sustainable watershed development goal of the Bojalkata watershed in particular and Kakodonga river basin in general. The population of Bojalkata watershed during 2011 census (Table: 7.8) was 21,931. Out of this about 11,248 were males (51.29%) and 10,683 were females (48.71%). The literacy rate is 75.62%, which is slightly above the national level (74.04).Male and female literacy rate were 80.34% and 70.64%.Female literacy rate is almost 10% lower than male literacy. The ST and SC population were 25.04% and 12.49% respectively. Male (30.45%) and female (24.70%) come under working group.

From the analysis of the responding of the questionnaire, it can be remark that almost 83% people are engaged in agriculture; 9% in business and 8% in service sector. It means agriculture is the backbone of the watershed. Here predominant crop is rice and 53.5% of the farmers cultivated rice in their agricultural field, followed by rice and vegetables by 39% and other crops by 7.5% farmers. The size of agriculture land (in bigha) belongs to the people in the watershed area is classified into four categories i.e. above 10 bighas ,5 to 10 bighas, below 5 bighas and landless people.Table 7.9 shows that only 22% farmers have agricultural land above 10 bigha,72.50% farmers have below 10 bigha and 5.5% are landless people. In the study area 71% of the farmers use machineries for cultivation and only 29% of them are still using traditional methods. Still 62% of the farmers are willing to use chemical fertilizers and

38% farmers prefer bio-fertilizers in their agricultural field if it is made available for them. In Bojalkata macro watershed 70.5% farmers don't have irrigation facilities, only 29.5% of them are availing this facilities. Basically they use pump sets to flow the water from ponds, streams and tube wells. Annual income of the inhabitant of the watershed area has divided into three categories viz., below Rs. 50,000, Rs. 50,000 to 1,50,000, and above Rs.1,50,000. Maximum people's (51%) annual income is below 50,000, 37.5% is in between50, 000 to 1, 50,000 and only 11.5% people have annual income above 1, 50,000. They are mainly govt. employees. The agricultural productivity (per bigha) in case of rice is shown in the table 7.9. Farmer producing more than 500kg rice/bigha is only 31.50%, the figure is 47.5% and 21% for the next categories respectively. It reveals that productivity is far below in compare to other developed parts of India.

Table 7.8: Socio economic profile of Bojalkata watershed (a)

	Categories	**Categories (in %)**	**Out of Total (In %)**
Population	Male	51.29	100
	Female	48.71	
Literacy Rate	Male	80.34	75.62
	Female	70.64	
Caste	ST	25.04	37.53
	SC	12.49	
Workers	Male Workers	30.45	55.15
	Female Workers	24.70	

Source: Census of India, 2011

Table 7.9: Socio economic profile of Bojalkata watershed (b)

Occupation	Agriculture	83
	Service	8
	Business	9
Crops Cultivated	Only rice	53.50
	Both rice & Vegetables	39
	Others	7.50
Size of Agricultural land (In Bigha)	Above 10	22
	5 - 10	53
	Below 5	19.50
	Landless	5.50
use machinery in Agricultural field	Yes	71
	No	29
Type of fertilizer like to Use	Chemical-fertilizer	62
	Bio-fertilizer	38
Availability of Irrigation facility	Yes	70.50
	No	29.50
Annual income	Below 50,000	51
	50,000 – 1,50,000	37.50
	Above 1,50,000	11.50
Agricultural production (per bigha) (1 bigha= 0.16 hectares) especially rice	Below 400 kg	21
	400kg to 500 kg	47.50
	Above 500 kg.	31.50

Source: Field Survey, 2014

Watershed Management of Bojalkata Watershed

A proper emphasis should be laid on land and water resources management to control soil erosion and conserve water resources. The soil erosion could be controlled by contour cultivation, contour bunding, graded bunding, bench terracing, grass waterways, diversion of drains and land grading. The soil erosion in the hills and hillocks of the Bojalkata watershed could be controlled by contour trenching, gully control measures through vegetative barriers, diversion channels and ditches, rock fill dams, stone fill dams, check dams, brushwood check dams, boulder walls, drop fill ways, embankments, spill way inlets, spill way conduits, spill way outlets, drop spill ways, spill ways and drop inlet spill ways. The gullies could be reclaimed through construction of contour graded bunds, peripheral bunds, gully plugging, stabilization of peripheral bunds through grasses or vegetative cover, construction of composite check dams and construction of sediment retention structures.

The watershed could be managed ecologically by large-scale plantation. The first step is to find out the preferences of beneficiaries in the watershed area. Information should be gathered regarding community plantation site, user groups, self-help groups, indigenous management systems, nursery location, nursery establishment, land use management and plantation operations. For successful development of plantation the measures should be taken are soil and water conservation, water harvesting structures, strip cultivation and weeding, seed selection, seed storage, seed treatment, nursery, use of fertilizers and irrigation. The management of grasslands in the upper reaches of watershed is important as constant and enriching biomass. It would help conserving soil and moisture and create environment for the advanced tree species to regenerate. In watershed management the grasslands supply fodder and forage. Afforestation is a sustainable land use system, which evolves to intement and interacting association of agriculture and horticulture crops and woody perennials (trees, scrubs, plants and bamboos). The main objectives of agro forestry are biomass production, soil conservation, soil improvement, promotion of agro based industry, herbal drugs, poultry, piggery, dairy, honey bee keeping, sericulture and mushroom cultivation.

The Joint Forest Management and Participatory Forest Management are alienated for the development of forest by local community groups from the different natural resources on which they have depended for generation. The local community gets increase access and rights over the degraded forest. Increasing biotic pressure, encroachments and development of forest based industries, scarcity of agriculture land, transfer of development activity and uncontrolled grazing has grossly depleted the natural resources of watersheds. The Joint Forest Management System and Participatory Forest Management System played a pivotal role in development of watersheds areas comprising of degraded forests. The Joint Forest Management and Participatory Forest Management are decentralized participatory and local need based forest management in the watersheds.

Common Property Resources Management is formed for amalgamation of land, forest, water, soil and other natural resources. Common Property Resources Management contributes for agriculture production, livestock management, non-farm activities and rural industry development.

Management of Common Property Resources Management is an important priority sector in watershed development. The grasslands, the degraded forest, wastelands, water conservation and harvesting management are sources of the important arenas of Common Property Resources Management. The above said watershed management activities could be implemented in Kakodonga watershed with the financial support from Central and State Governments.

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Chapter-8

Summary & Conclusions’

8

The present study area of the basin is about 1113 sq.km **T**he analysis of land resources based on physical aspects using Survey of India topographic sheets on scale 1:50,000 and IRS P6 LISS-III imagery (23.5 mt resolution) 2011. The whole basin could be divided into six major classes. They are class – I (fluvial plains), class – II (wash plains and valley fills), class – III (moderately weathered pediplains), class – IV (shallow weathered pediplains), class – V (hilly terrain with slope less than 40^0) and class – VI (hilly terrain with slope more than 40^0). Among the six classes, the class –I and class – II lands are highly productive lands. These could be used for cultivation of paddy, rape and mustard, sugar cane, fruits and vegetables. The class – III lands is moderately productive and the class – IV land is fairly productive. The crops that could be grown are paddy, matikalai, mogu, potato, tea and masur. The class – V land is less productive. It is used for cultivation of chilly, ginger, wheat, paddy (Jhum cultivation) etc. The vegetables and fruit could be practiced adopting soil conservation practices. The class – VI land should be used for growth of natural forests.

The morphometric parameters of Kakodonga river basin reveal many important factors regarding drainage characteristic and landforms of the basin. The basin has six drainage orders and overall drainage network shows dendritic pattern. Eastern tributaries are the major tributaries of the river, they also reveal linear pattern. But some western tributaries have rectangular pattern. Morphometric analysis also indicates that the basin is having low relief and in between elongated and circular in shape. In other words the basin is neither so much elongated nor circular. The fingertips tributaries have high concentration in a small part of upstream i.e. in Naga Hills area. Very low concentration of other tributaries has been noticed in plain area of the basin. The linear pattern of the graphical representation indicates the weathering and erosional characteristics of the study area.

Drainage network was digitized in GIS environment to estimate morphometric characteristics like linear, areal and relief. Stream order, number of stream, stream length, bifurcation ratio etc. are some important linear parameters. The stream length variation is occurred in the basin due to geological structure and slope. Estimated bifurcation ratio is 4.06, it means do not exceed the range. The Stream number coefficient of correlation is 0.967

and the percentage variance is 93.4. The Stream length as coefficient of correlation and the percentage variance are 0.926 and 85.8 respectively. The drainage density, circulatory ratio, stream frequency and elongation ratio are described under areal aspects. The drainage density value is 1.33, it shows positive correlation, and it is highlighting the increased drainage population with respect to increase in drainage density. The Circulatory ratio 0.42 indicates that the basin has strongly elongated shape, high flood potentiality and less population of drainage. Elongation ratio value is 0.30 reflects the flatter surface of the basin and high flood flow in rainy season. Further research is necessary for identification of features like flood zones, run-off and gully erosion etc. To harness the flood construction of the nalla bunds, small ponds, percolation ponds, stone wall, contour trenching, check dams, plantation and afforestation are very urgent in the basin. Use of high resolution latest CARTOSAT data may help the researchers to find out changes taking place in every inch and implement proper planning and management programmes. The research is necessary for identification of feature like floods zones, run-off and gully erosion in rainy season.

Monthwise analysis of water resources of Kakodonga river basin reflect that Golaghat rain gauge station receives very less rainfall in the month of December (3 mm) and maximum mean rainfall recorded at Negheriting rain gauge station (569 mm) in the month of July. The basin receives less than 100 mm rainfall in the months of November, December, January, February and March, but in March Negheriting rain gauge station obtains more than 100 mm rainfall. The maximum mean rainfall in the months of April, May and October varies from 100mm to 250 mm, but Negheriting rain gauge station obtains more than 250 mm rainfall in the above mentioned months. In the June, July, August and September more than 250 mm rainfall is recorded. The analysis of seasonal mean rainfall point out that the basin receives maximum rainfall of 930 mm in monsoon period, 504 mm in pre-monsoon period, 374 mm in post-monsoon period and 72 mm in winter period. The average annual precipitation of the basin is 1875 mm. The average ground water recharge of the basin is 348 mm. The total groundwater resources of the basin have been estimated to be 387,324,000 m^3. The data may be used for sustainable management and optimum utilization of resources and it is also useful for sustainable development and other hydrological studies in future. Present study is helpful to estimate the future flood and to suggest some measures like construction of nalla bunds, small ponds, percolation ponds, stone wall, contour trenching, check dams, plantation and afforestation etc. to mitigate the flood.

Analysis of the water balance elements depict that April May, June, July, August and September months are highly favorable for crop cultivation. The December, January, February, and March months are highly unfavorable for crop cultivation due to high water deficit, high potential evapotranspiration and low actual evapotranspiration. Maximum rainfall received in monsoon and pre monsoon periods. Therefore, water deficiency is nil and moisture adequacy values are high during these two seasons. There is no water shortage due to high rainfall. The crop cultivation is highly favorable during monsoon and pre monsoon periods. Climatologically the basin experiences dry sub humid and semi arid types of climate in winter period. Humid type climate prevails in monsoon period, mixed type of climate experienced in pre monsoon and post monsoon periods. The annual water balance elements show that the basin receives the average rainfall of 1875 mm. The mean annual potential evapotranspiration is 387 mm. The mean annual actual evapotranspiration of the basin is 350 mm. Water deficiency is not observed in the basin. The average annual water surplus is 1451 mm. The mean annual moisture adequacy value is 90.48% and there is no aridity. The basin experiences humid type of climate.

Water Balance estimation of the Kakodonga River basin

1. Total surface of the water resources: 2,086,875,000 m^3.
2. Surface water resources stored in ponds, lakes, reservoirs etc

   : 8, 280, 000 m^3.
3. Surface water resources recharged to ground water: 387,324,000 m^3.
4. Surface run-off: 834,750,000 m^3.
5. Water lost in the form of evaporation and evapotranspiration**:**

From the analysis of water balance of the Kakodonga basin, it could be summarized that out of the total surface water resources of 2,086,875,000 m^3, about 0.39% is stored in surface lakes, ponds, beels etc., 18.56% is recharged to the ground water, 40% is lost in the form of surface run-off and 41.05% in lost in the form of evaporation and evapotranspiration. The water lost in the form of surface run-off has to be stored adopting micro watershed management programmes in the basin by constructing check dams, percolation ponds and water harvesting structures.

The annual average temperatures of the Kakodonga river basin varies from a maximum of 23.86^0 C in Titabor rain-gauge station to a minimum of 17.28^0 C in Jorhat rain-gauge station. The average temperature is $22.82\ ^0$ C Thermal efficiency suggests that Kakodonga river basin is experiencing abundant thermal potential which can support luxuriant vegetation if moisture is not a constant.

The total forest area of the Kakodonga basin is about 48,094 hectares of land. It accounts only 21.09% of the total geographical area of all circles. The total area under barren and uncultivable land of the basin is about 4.375 hectares. It accounts 1.92% of the total geographical area of the circles. The total land put to non-agricultural use is about 7,972 hectares (3.50%). The total area under permanent pasture and other grazing lands is about 3,843 hectares. (1.69%).The total area under miscellaneous tree crops and grooves is about 5,309 hectares of land i.e. 2.33% of the total geographical area of the basin. The total land under culturable wasteland is about 6,260 hectares (2.75%). The other fallow land is about 18,818 hectares. It is 8.25% of the total geographical area of the basin. The land under current fallow is about 8,244 hectares. It accounts 3.61% of the total geographical area of the basin. The land under net sown area is about 125,126 hectares. It accounts 54.87% of the total geographical area of the basin. The analysis of the land use efficiency of the

Kakodonga river basin reveals that efficiency is high in Jorhat west circle and next is Golaghat circle.

The total irrigated area of the basin is 8184 hectares. Out of this 21.97% (1798 hect) is under canal irrigation, 0.15% (12.26 hect) is under tank irrigation, 0.040% (3.39 hect) is under well irrigation, 9.70% (794 hect) is under tube well irrigation and 68.14% (5576 hect) is under other sources of irrigation. The intensity of irrigation is high in Titabor and Changpang circles.

The total cropped area of the basin is 549,000 hectares. It accounts 49.32% of the total geographical area of the basin. Data of fourteen crops at circle level have been collected. The rice is cultivated in 93,223 hectares of land and wheat is grown in 91.03 hectares of land. The rape and mustard crop is cultivated in 8591 hectares of land, sugarcane in 1557 hectares and potato is in 1520 hectares of land. The land under matikalai crop is about 593 hectares; under turmeric about 515 hectares. The total area under onion is about 105 hectares and under mogu crop is about 104 hectares. Masur occupies about 31 hectares of land and pea and chilly are cultivated in 542 hectares and 16,534 hectares of land respectively. The ginger and black pepper have been cultivated in 498 hectares and 164 hectares of land respectively. From the analysis of cropping pattern it is found that the rice is the major crop in the basin followed by rape and mustard, sugarcane, potato, matikalai, peas, turmeric, ginger, chilly, black pepper, mogu, onion, wheat and masur. The peas, turmeric, ginger, chilly, black pepper, mogu, onion, wheat and masur occupy less than 1% of the total cropped area of the basin. The circle wise crop percentage is high in Jorhat west circle and followed by Golaghat circle. The intensity of cropping pattern is very high in Titabor circle. The crop diversification is very high in Jorhat west circle and followed by Golaghat circle of the basin. The crop combination studies adopting Rafiullah's method reveals that there are six circles under mono crop and one circle in two crop combinations. The mono crop is rice and two crop combinations are rice and rape and mustard. The Doi's crop combinations method reveals that three circles falls under mono crop (rice), four circles under two crop combinations (rice, and rape and mustard).

The Kakodonga river basin may be divided into 227 micro watersheds. Each micro watershed consists of 500 hectares of land. One macro watershed was selected in the basin to study in depth about the physical characteristics using IRS P6 LISS-III imagery (23.5mt resolution) 2011, and Survey of India topographic sheets on scale 1: 50,000. The selected macro watershed is Bojalkata, which is located in southeastern part of the basin. The Bojalkata watershed covers an area about 3,857 hectares of land. It is a macro watershed. The Bojalkata watershed encompasses fourteen villages. The population of Bojalkata watershed was 21,931(2011 census). The mean annual temperature of the watershed is recorded as maximum of 28.77^0 C to a minimum of 18.67^0 C. The average monthly temperature is 23.72^0 C. Based on physical characteristics, the watershed is classified into six classes. They are the class - I land consist of fluvial plains. The class - II land consists of wash plains. The class – III lands are moderately pediplains. The class – IV land consists of shallow weathered pediplains. The class – V land consists of hilly terrain with less than 40^0 slopes. Class – VI land consists of hilly terrain with more than 40^0 slopes. The total surface water resources of the Bojalkata watershed is 5,438,370 m^3, out of the total about 0.08% is stored in surface lakes, ponds, beels etc., 18.56% is recharged as the ground water, 40% is lost in the form of surface run-off and 41.36% in lost in the form of evaporation and evapotranspiration.

Tributaries of Bajalkata have to bear heavy load of silt especially sand and rock particles due to deforestation and shifting cultivation in upper part of the river mainly in the portion located in Nagaland. Therefore depth of the river is decreasing at an alarming rate, which result heavy and sudden occurrence of floods in downstream area particularly in monsoon season. At present Teri-Meri Jan a tributary of Bojalkata don't have definite river course. The river bed is increased in such a way that one could not differentiate river bed and bank of the river. In this situation clear the sand dunes and restore the streams of the watershed are the most essential task. The gullies could be reclaimed through construction of contour graded bunds, peripheral bunds, gully plugging, stabilization of peripheral bunds through grasses or vegetative cover, construction of composite check dams and construction of sediment retention structures. High intensity of soil erosion is observed in Kakodonga river basin especially during rainy season. The soil erosion in the hills and hillocks of the Bojalkata watershed could be controlled by contour trenching, gully control measures through vegetative barriers, diversion channels and ditches, rock fill dams, stone fill dams, check dams, brushwood check dams, boulder walls, drop fill ways, embankments, spill way inlets, spill way conduits, spill way outlets, drop spill ways, spill ways and drop inlet spill ways.

Most of the people (83%) of Bojalkata watershed depend on agriculture. Economic backwardness, low income, limited resource etc. are some commonly identified problems of the study area. In addition to traditional farming system, commercial farming of diary, poultry and piggery may improve the standard of life of the farmers. Extensive training should be given to them on land, water, crop, greenery and livestock management for fruitful outcome. Wasteland should be reclaimed by implementing activities like afforestation and horticulture in large scale. It will enhance economic as well as environment condition of the watershed. An action plan should be prepared to enhance the socio-economic condition. For this information should be gathered regarding community plantation site, user groups, self-help groups, indigenous management systems, nursery location, nursery establishment, land use management and plantation operations etc. Above mentioned measure are relevant for the Bojalkata watershed in particular and for whole Kakodonga river basin in general.

During winter, pre-monsoon and post-monsoon seasons the study area obtains less rainfall. Techniques of soil and water conservation, rainwater harvesting etc. need to popularize in grass-root level by organizing different training camp.

Agro forestry is another important aspect of watershed management. The main objectives of agro forestry are biomass production, soil conservation, soil improvement, promotion of agro based industry, herbal drugs, poultry, piggery, dairy, honey bee keeping, sericulture and mushroom cultivation. These objectives should popularize among the people of the watershed.

Large scale plantation is one of the important activities of watershed management. For successful development of plantation, the measures should be taken are soil and water conservation, rainwater harvesting structures, strip cultivation and weeding, seed selection, seed storage, seed treatment, nursery, irrigation and minimum use of fertilizers etc. The management of grasslands in the upper part of the watershed is important for enriching biomass. It would help in conserving soil and moisture and create environment for the advanced tree species to regenerate. In watershed the grasslands supply fodder and forage.

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Natural reservoirs like beel, lake, marshland, pond etc. can hold a sufficient amount of water, which ultimately helps in reducing flood intensity. They also work as a filter reducing debris to the river course. Unplanned growth of township, human settlement, agriculture activity in Kakodonga river basin is squeezing these reservoirs. It should be minimize with proper plan. Above these there should be good cooperation between people of upstream and downstream area. Since the watershed area is lying over the territories of Nagaland and Assam, Govt. of both the states should work together for the development of Kakodonga river basin. Finally the optimum utilization of land

and water resources could be carried out by adopting micro watershed management programmes in Kakodonga River basin. Central and State Governments should release some funds for such watershed management programmes.

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Appendices

Questionnaire

1) Name	:	
2) Sex	: Male/Female	
3) Age	:	
4) Religion	:	
5) Marital Status	:	
6) Head of the family	: Father/Mother/Any other	
7) Education	: Illiterate /Primary /Up to HS/Graduate / Above	
8) Occupation	:	

9) If Agriculture, size of your Agri.-land :

10) What type of Crops are you cultivated in your field? :

11) Location of your agri.-land (I.e. name of village) :

12) Do you like to use machine in the field (If, yes what type of machine? :

13) Do you like to use any type of fertilizer? (If yes, what type of fertilizer do you use in your field ?) :

14) Do you use irrigation system in your field? (Mention the type of irrigation):

15) Is there any effect of flood and draught on your agri.-land ? :

16) Do you think that deforestation in the upstream area is increasing flood? :

17) Any other factor which is responsible
for occurrence of flood ? :

18) Is there any programme implemented
by Govt. and other organization to
minimize the flood problem? :

19) What is your annual income :

20) What is your annual income from
agricultural sector ? :

21) What are your average
Production / 1 bigha? :

22) Do you think that with the help of
stable water supply you will be able to
increase the production of crop :

23) Any Watershed Management
Programme is implemented in your :
area or not?

24) Particulars regarding family members :

Sl. No.	Relationship With respondent	Sex	Age	Education	Occupation	Place of Work	Income (Annual)

Field Photographs

Plate 1: Kakodonga River at National Highway 37 crossing point

Plate 2: Water level measuring station of Kakodonga River at National Highway 37 crossing point

Plate 3: Paddy fields are inundated by excess water of Kakodonga River during rainy season at Barichua Village, Golaghat, Assam

Plate 4: Confluence of Kakodonga River with Gelabil River at Darikamari, Jorhat, Assam.

Plate 5: A beel near Darikamari village, Jorhat, Assam.

Plate 6: A Pond at Rajabahar Village, Titabor, Jorhat, Assam

Plate 7: A shallow weathered paddy field at Bojalkata Village, Jorhat, Assam

Plate 8: Rice cultivated at Sorukachari Village, Golaghat, Assam

Plate 9: Potato, cultivated at Bekajan Village, Jorhat, Assam

Plate 10: Onion cultivated in Balijan area, Jorhat, Assam

Plate 11: Sugarcane cultivated at Dhekial, Golaghat, Assam

Plate 12: A Tea Garden at Borholla, Jorhat, Assam

Plate 13: Soil sample collection from Bojalkata Village, Jorhat, Assam

Plate 14: A view of rock structure in Changpang area, Nagaland

Plate 15: Hill slope is cleared for jhum cultivation in Changpang area, Nagaland

Plate 16: People are carrying fuel wood from hill areas at Paninora Village, Jorhat

Plate 17: Assam Nagaland Boarder area at Kulajan, in Bojalkata watershed

Plate 18: Degraded forest near Bhandari, Nagaland

Plate 19: Water supply structure at Puranimati village, Titabor, Assam

Plate 20: Irrigation by pump at Bojalkata village, Titabor, Assam

Plate 21: Water harvesting structure at Ranibheta, Titabor, Assam

Plate 22: A view of canal irrigation system looking dry in winter season near Jalukani, Titabor, Assam