STUDIES ON THE ROLE OF WATER RESOURCES IN AGRICULTURAL DEVELOPMENT OF NAGALAND

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IN

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By

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Dedicated to my
Parents, Brothers & Sisters,
and Ever Friends

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DECLARATION

I hereby state that the thesis entitled **"Studies on the Role of Water Resources in Agricultural Development of Nagaland"** submitted to the Nagaland University in November, 2016 for the partial fulfillment of the award degree of DOCTOR OF PHILOSOPHY is the original work carried out by me in the Department of Geography during 2013 – 2016 under the supervision of Dr. Y. V. Krishnaiah, Assistant Professor, Department of Geography, Nagaland University, Lumami and it has not formed the basis fully or partially for the award of any degree, diploma or any other similar titles earlier at the time of submission.

Place: Lumami, **(Mr. Rongsenchiba)**
Date: Research Scholar

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CERTIFICATE

I hereby certify that the thesis entitled **"Studies on the Role of Water Resources in Agricultural Development of Nagaland"** submitted to the Nagaland University in November, 2016 for the partial fulfillment for the award of degree of Doctor of Philosophy by Mr. Rongsenchiba (Regd. No. 549/2014, Dated: 25.11.2013), 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 any similar titles earlier at the time of submission.

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

PREFACE

Agriculture occupies a pivotal position for rural economy. It is not only an activities but most seemingly way of life for millions of people around the world that shaped the society, now and then. In a developing economy of India, it contributes about one-third of National Gross Product (GDP) and provides employment facilities to nearly two-thirds of the workforce. The interplay factors of physical and non-physical determines the success of agricultural productivity as agricultural regions are distinctively distributed. By understanding the physical parameters and incorporate of man's culture, planning for agriculture will have a better future. Differences in application and operation of agriculture, productivity varies from region to region. Low productivity is responsible to food insecurity, unemployment and poverty. Traditional and unscientific practices will ultimately affect the physical components which is unsustainable in nature.

Climatic conditions are key drivers that determine the agricultural pattern of any region. Of all the climatic factors, moisture is more important factor that decides the production. However, rainfall is unpredictable, where rainfed agriculture is constantly challenged by weather uncertainty. To analyse this phenomenon, agricultural meteorology could provide information and better inputs. The study of weekly, monthly and seasonal weather conditions will pave a way for agricultural development.

The uneven distribution of cultivable land, unscientific farming, lack of modern technologies and machineries, poor farmers, lack of financial institution, government policies, etc., are responsible in failure of agricultural production. The prevailing socio-economic condition like poverty, food insecurity, unemployment, welfare of the poor farmers, etc., are some of the global issues which threatens the World Order in this 21st Century. Unless the purchasing power of this population is relieved then the world will face a rural-urban famine catastrophe. During the World Food Summit (FAO) 1996 at Rome, all the representative members have reaffirmed the pledge the right of every individual to access to safe and nutrition food to eradicate hunger by 2015 A.D. This declaration could be achieved by way of elevating the status of farmers who directly dealt with agriculture.

Agricultural development policy, broadly to generate income, to attain food security, as employment sector and produce raw materials to allied industries needs attention for researcher, scientist, policy makers, planners and governmental agency to rescue poor and marginal farmers. Dissemination of systematic information will guide the agricultural practices more optimum so that sustainable form of agriculture will be accomplished.

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Dated (RONGSENCHIBA)

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Chapter -1

Introduction

Water is essential natural resource which supports the life on this planet, as water resources have been the most noteworthy factors in the growth of every organisms and requisite for human needs and economic development. It constitutes the largest flow of any material through the biosphere which is one of the prime natural resources for all living species. Life on earth exists since all essence of species had and has their habitats in and around water resources. The demand for water is a global phenomenon due to over population and related factors, amongst all, the human started depleting in an unplanned and unscrupulous manner by exploiting the water resources. The extent, to which water is abundant or scarce, clear or polluted, beneficial or destructive, have major influences on the quality of human life. The ever increasing demand of water on one hand and the deteriorating quality of water by pollution and mismanage by human have already created serious problems. Available water must, therefore, be optimally harnessed and used most efficiently under appropriate priorities.

Agriculture requires abundant supply of water, essential for food production which has to match the needs of growing population whose quality of life is improving. The North Eastern region of India falls under high rainfall zone and the climate ranges from sub-tropical to alpine. The region is characterized by different terrain, wide variation in slopes and altitude, land tenure systems and cultivation practices. The agriculture of the region remains backward with low productivity. The region is deficient in food productions, so most of the food and essential commodities are imported from outside. Therefore, there is an urgent need to increase the food production to make the region self-sufficient. With its diverse agro-climatic conditions, climate is one of the major factors influencing to a great extent the distribution of the water resources.

1.1 Statement of the Problem

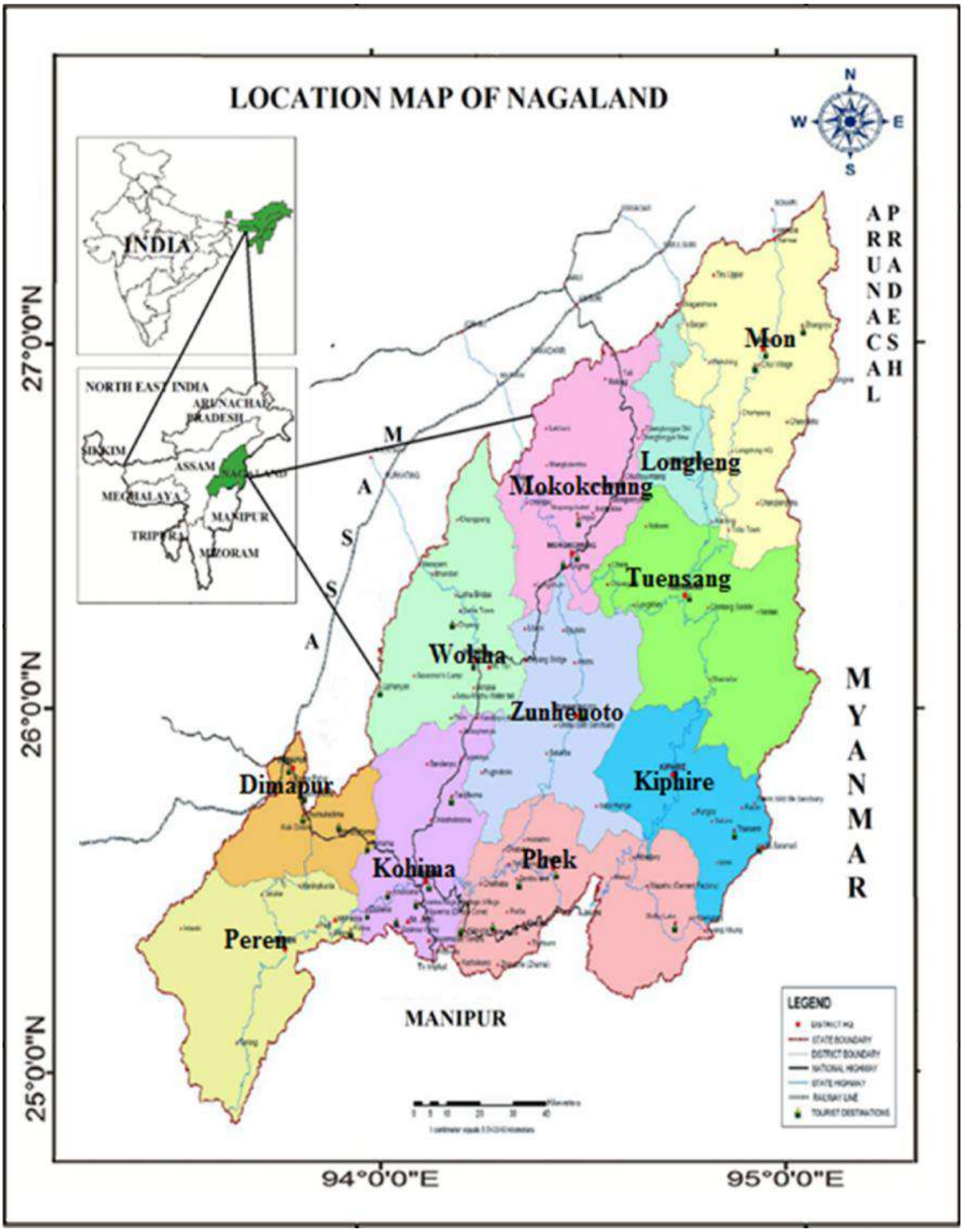
India is predominantly an agrarian economy where two-thirds of the population depends on agriculture for the sustenance. It is mostly dependent on rainfall whose variability in time and place has adverse effect on agricultural output. When rainfall fails agricultural productions are seriously affected, whereas excessive water acts as an agent of soil erosion. Agricultural development broadly based on rainfall probabilities, water balance and moisture availabilities during the growing season will be probably more relevant to development of crop adaptability strategies. Climate is the principal aspect of the physical environment affecting agriculture. Plants must derive the bulk of the water requirements through their root system, water must be available in the soil in the quantities needed by the plants. Too little water in the soil will result in the withering of the plant, whereas, excess of water will cause water-logging and diseases, or even the death of the plant.

1.2 Significance of the Study

Agriculture is a key sector in most of the developing countries. It has a key role to play in enabling farmers to accomplish developmental goals, including self-reliance, growth and equity. Nagaland is an agrarian economy, where 70 percent of the population engaged on agriculture. However, most of the farmers are subsistence in nature or in other words, marginal producers. Geographically, Nagaland has a vast area potential for agricultural product, yet threatens by food security problems now and then. By the concept of ‘optimum use of water’, types of soil, altitudinal variations, etc, adaptable forms of cultivation will be projected. The agro-climatic conditions favour agriculture, horticulture and forestry etc, yet the consumerism section depends on procured food products from other state. This vast rich-region could be developed into productive zone through research.

1.3 The Study Area

Nagaland is located in the North Eastern Region of India. The state of Nagaland shares the international border with the country of Myanmar to the east, Arunachal Pradesh state and some parts of Assam state in the north, Assam to the west and Manipur to the southern parts. It is located between 25º6' N to 27º4' N latitudes and 93º20' E to 95º15' E longitude **(Fig. 1)**. Geographically, it covers an area of 16,579 Sq. Km. Administratively, it is divided into 11 districts (Dimapur, Kiphire, Kohima, Longleng, Mokokchung, Mon, Peren, Phek, Tuensang, Wokha and Zunheboto) and have a population of 19,78,502 (2011). It is inhabited by sixteen major tribes and other sub-tribes. Nagaland has mainly a rugged hilly terrain. Its topography rises abruptly from the Brahmaputra valley eastward. The hill bordering Assam have low altitude (below 500 meters), but those bordering Myanmar attain a general height of 2000 meters. The Mount Saramati (3826 msl) located in Kiphire district, the highest peak lies on the Patkai range along the Myanmar border. The torrential monsoon rains are integral features of the state's weather. The maximum average temperature recorded in summer is 32.4 degree Celsius (June) while minimum is as low as 3 degree Celsius in winter (January). The average annual rainfall of the study area varies from 886 mm to 2206 mm. The total average annual rainfall is 1536 mm. Nagaland is drained by four chief rivers of Doyang, Jhanji, Dhansiri and Dikhu. The rivers are the tributaries of the mighty Brahmaputra River with their sources in the mountain ranges of the state. The economy is dependent on agriculture which forms the chief occupation of the tribal inhabitants. Nearly one-third of the land area is cultivated by the shifting cultivation technique. The forest regions are being cleared to practice jhum cultivation which has caused the depletion of the natural vegetation of Nagaland.



Source: Nagaland GIS Centre.

Fig. 1

1.4 The main objectives of the study area

1. To study the water resources on monthly, seasonal and annual, and groundwater recharge of Nagaland.
2. To study the water balance elements on monthly, seasonal and annual, and rain-gauge station-wise of Nagaland.
3. To analyse land utilisation and irrigation area of Nagaland.
4. To study the agricultural development of Nagaland.
5. To work out water availability and suggest crop suitability of Nagaland.

1.5 Research Questions

1. How to evaluate the water resources and groundwater recharge of the study area?
2. What is the status of water balance in the present study area?
3. What types of land-use categories exist and irrigation in the study area?
4. Is there any impact of water resources on land-use and agriculture of the study area?

1.6 Research Methodology

1. The land resources of Nagaland were mapped using Survey of India (SOI) topographic sheets and IRS P6 LISS III satellite data on scale 1:50,000. The landforms, drainage, soils, land use/ land cover, geological and hydro geological units were mapped. The monthly rainfall analysis, annual rainfall analysis, temperature and population growth (2011 census) were worked out.

2. The water resource of Nagaland was studied by analysing rainfall data over a period of 30 years (1986-2015) and worked out mean rainfall, rainfall intensity, rainfall variability and rainfall ratio on monthly, seasonal and annual basis according to Bhargava's (1977) method also used interpolation and extrapolation statistical methods to find out unknown values from the given facts. About 16 rain-gauge stations were selected within Nagaland to analyse the rainfall. On the basis of mean rainfall the groundwater recharge was also worked out according to Radhakrishna *et al.* method (1974), U.S. Geological Method (1962), Seghal's (1973) and Krishna Rao (1970) Method.
3. The water balance elements of Nagaland were studied using Thornthwaite and Mather (1955) method on monthly, seasonal and annual basis taking mean monthly temperature, mean monthly rainfall over a period of 30 years (1986-2015) from 16 rain-gauge stations. This generates information on certain parameters such as actual evaporation (AE) potential evaporation (PE), water deficit, water surplus, run-off, moisture adequacy, aridity index, climatic classification and also worked out climatic classification on thermal efficiency.
4. The data for existing land use categories, irrigation and agriculture were collected (1993-94 to 2013-14) from Directorate of Economics and Statistics, and Soil and Water Conservation Department, Nagaland. The temporal analysis of land utilisation, irrigation, crop concentration, crop diversification, crop ranking, and crop combination were worked out

adopting different statistical methods of Bhatia's (1965), Rafiullah's (1956) and Doi's (1957). Finally worked out spatial temporal analysis of cropping pattern, crop production and crop yield per hectare of Nagaland.

5. The water availability days and months were worked out using monthly actual evapotranspiration (AE) and potential evapotranspiration (PE) ratio for each rain-gauge stations using Raman and Srinivasa Murthy (1971) method. The water availability periods were categorised into dry, moderately dry, wet and humid periods. Based on water availability days and water availability months, suggest crop suitability of the study area.

1.7 Review of Literature

The availability of natural resources determines the prosperity and development of a region (Tejpal, 2013). Water is an essential condition of life on this planet, as water resources have been a decisive factor in the growth and development of human civilisation throughout history. Lakshminarayana and Krishnaiah (2013), and O'Callaghan (1996) highlighted that water is available on earth through the hydrological cycle which governs all components. Krishnaiah (2010b) and Sundaram *et al.* (2004) viewed that accurate assessment of the water resources, both surface and ground water is an essential prerequisite for proper planning to their utilisation for different purposes. Vorosmarty *et al.* (2014) stated that water acts as an important component and machinery of earth system as it connects everything. In the writings of Bairagya and Bairagya (2011), Hangaragi (2010) and Suneetha *et al.* (2009) further viewed that water is a prime priority for survival and development, hence exploitation needs sustainable approach. Iyer (2005) regarded water as ‘sacred’ as it supports life and sustains all aspect of developmental activities for unceasing civilisation. India is an agrarian economy dependent on rainfall and weather conditions or in other words dependent on monsoon rain which refers to as rainy season as large part of the agricultural produce comes during this period. However, the agricultural activities in rainfed area face many uncertainties as farmers are fully dependant on the distribution of precipitation. In fact, the arrival of monsoon rain earlier or if not delay in its distribution affects the agricultural activities, hence the livelihood of the farmers largely depends on the monsoon rains. In the concept of Merret (2002), opined fundamental agronomic fact that crop growth depends on water availability to each plant growth root zone. Thus, the survival of all plants depends on the availability of water. As such, Chopra *et al. (*2003) supplemented that supply of these key natural resources in acceptable quality, in an adequate quantity, and at the required place and time, is the outmost important. With the increasing population and decreasing per capita availability of water there is a need for careful planning and utilisation of water resources. Rai (2001) remarked, with an increase in population, the demand for water resources is increasing on account of urbanisation and modernisation. However, its largest use on global level is in agriculture, in the form of watering for the cultivation of different crops. Subbaiah and Prajapathi (2013) and, Sukumar and Sukumar (2013), outlined that the assessment of water quality is inevitable as it deem the survival and welfare of the earth, where rainfall is a primary source for agriculture. India with its diverse agro-climatic conditions, climate is one of the major factors influencing the growth, sustenance and yield of crops. In spite of the cultivation of high yielding varieties, improved cultural practices and plant protection measures, favourable weather is a must for good harvest. Agro-climatic characterisation of the rainfed ecosystem holds great importance in agricultural planning and management which occupies a very major role in Indian agriculture. Rainfed agriculture is critical to agricultural performance in India. Jakhar *et al.* (2011) noted that rainwater is the single most important potential of moisture as it determines the success of any agricultural region. According to Gopalaswamy (1994), climate of a region determines the nature of crops to be grown but the weather conditions that prevail during crop period decide the yield potential, therefore, weather and climate are the important factors determining the success or failure of agriculture. In India, Subrahmanyam (1983), pioneer worker, studied the water balance adopting Thronthwaite and Mather (1955) method. He has published on monograph in 1985, on application of water balance technique in India 'climate is the principal aspect of the physical environment affecting the agriculture'. Chand *et al.* (2011) remarked that the Indian agriculture is mainly dependent on monsoon rainfall and its distribution.

According to Mondal *et al. (*2014), agricultural practices in rainfed regions involved a lot of risk due to uncertainty of rainfall. India with its diverse agro-climatic conditions, climate is one of the major factors influencing the growth, sustenance and yield of crops. Prasad *et al*. (2013) highlighted that adequate and timely supply of water is essential for rainfed agricultural region. After Sharma and Dubey (2013), in India, nearly 65 percent of the cultivable area are under rainfed agriculture, meantime occurrence of rainfall is unpredictable; therefore, temporal study of past records is an important method for crop planning. In fact, Singh and Singh (2010) revealed that Indian agriculture is constantly challenged by weather uncertainty. Sachan *et al*. (2014) and Subhas *et al*. (2001) evaluated that the erratic rainfall pattern affects the production as its distribution of rainfall leads to meteorological drought resulting in agricultural and hydrological drought. In the words of Mondal *et al*. (2014), drought is a situation of limited rainfall, substantially below the normal value of the concern area. Narayan and Biswas (2001) noted that water stress experienced by crops aggravates unstable yield and failure of crops. Mohammad (1992) has stated that climatic limitations affect capability, the capability of soil decreases with the decrease in effective rainfall. Schneider *et al*. (2011) dealt with the related subject, expressed that climate change exposes rural and poor population to erratic water supply, extreme weather and precipitation events which acts as the biggest concern on water supply for agriculture and households.

According to Bhattarcharjee and Bora (2012), North-East India is one of the wettest regions of the world with dense network of drainage channel; however, the importance for agriculture is poorly developed. The reason behind is the significant influence of both the monsoon and highly undulating topography which makes the water management more complicated as remarked by Samuel and Satapathy (2008). Subsequently, Pachauri (1984) also supplemented that agricultural operations in tribal areas are mostly depend on rains and unpredictable nature. Moreover, lack of soil and water conservation measures, lack of exposure to and knowledge of improved agricultural technique and low investment made the tribal agricultural to remain mostly precarious and at subsistence level. Tripathi (2009) draws that rainfall variability cause crop failure and results in considerable environmental degradation particularly when combined with inappropriate management strategies. Bathusha and Saseetharam, (2010) emphasised on water as essential for all living organisms; significantly, the availability of water has determined the place of mankind settlement and its activities. However, Purandeswari (2009) and Reddy (2013) stated that in recent times, water scarcity becomes a global phenomenon where climate change is the fundamental driver that directly affects the water cycle. To mitigate the complexity of climate, the study on climatic spatio-temporal dimensions will assists to a better understanding of weather processes and seasonal forecast as opined by Rawat and Singh (2010). To understand the water regime, Kumar and Kumar (1989) outplayed that rainfall probability is the most reliable method to predict occurrence of future rainfall based on past behaviour of rainfall. Ray *et al.* (1980) reveals that weekly, monthly and seasonal pattern of rainfall and their probability is helpful in crop planning. Patel (2009) viewed that monsoon rainfall pattern vary greatly depending on the season and the region, consequently, Banerjee *et al.* (2010) mentioned that idiosyncrasies of monsoon hinders low and unstable production in rainfed areas.

Agriculture makes use of water derived from the soil moisture content, underground water table, rainfall, and surface water. Thus, plants derive their water requirements through root system. Meret (2002) observed the demand side of water that crop growth depends on water availability to each plant root zone. Chauhan (2007) also examine that different plants require varying conditions of heat, light and water which are absorb through leaves and roots. Pandey *et al.* (2013) justifies that information on water holding capacity of soil between field capacity and permanent wilting point is useful in planning irrigation schedule, land use, watersheds management, water balance simulation, etc. Meantime, as the distribution of rainfall remained unpredictable and erratic, the high demand for water leads to exploitation of groundwater resources as cited by Raju *et al.* (2012). Rai *et al*. (2012) and, Vries and Simmers (2012) opined that the groundwater is an important resources that supplies water for manifold activities. Ballukraya (2012) and, Singh and Yadav (2010) highlighted that the exploration of groundwater resources dates back to early civilisation. In the opinion of Banerjee (1958), the demand for water facilitates the assessment of groundwater. According to Jain (2009) and Krishnaiah (2010a), the potentiality of groundwater will decline unless it is harnessed scientifically and in efficient means. Rao (1970) and Sinha *et al*. (2015) also mentioned that groundwater is an alternative potential water resources but over-exploitation will lead to depletion.

According to Bublaka and Begiraj (2015), Krishnaiah (2013b), Nayal (2011), Rao (1984) and Singh *et al.* (2012), the study of water balance determines the water deficit and surplus at a given point of time and space that aid in treating the problem of agriculture and water resources as very high rainfall cause severe soil erosion, landslide and other hazards, on the other hand, low rainfall cause agricultural drought. Krishnaiah (2014) and Siddiqui *et al.*

(2014) outlined the concept of water balance that this helps in finding an increasing application to the problems of water resources and agricultural development. Rao and Bhaskara (2015) observed that weather plays a decisive role in determining cropping pattern. Directorate of Agriculture Nagaland Kohima (1986) evaluated that the water-stress condition in plants occur particularly when there are dry spells of varying lengths that prevails in the monsoonal season. Also presence of meagre amount of water in the soil will result in the withering of the plant, whereas, excess of water will cause diseases or even result in death of plant. Regar *et al.* (2010) argues that crops grown in rainfed conditions are prone to water stress resulting in low water availability for root growth. Subhas (2014) offers that tillering to flower is the most crucial stage during which rice crop should not be subjected to water stress. Malini and Endris (2013) shares that moisture availability in soil determines the success of crop production, relatively Singh *et al.* (2012) asserted that quantitative estimation of the available water resources is an imperative study for a sustainable management of water. Hussain (2006) also highlighted that within wide temperature limits, moisture is more important than any other environmental factor in crop production. Nonneke (1989) emphasised on temperature as a major factor controlling the growth of plants. Further mentioned that the extreme temperature range of plant is between killing frost at 0ºC and death by heat and desiccation at 40ºC with most plants permanently immobilised at 10ºC and most plants ceasing to photosynthesis sufficiently above 30ºC. The parameters of sustainable agriculture implies to enhancement in cropping intensity which are depended on length of growing season, rainfall pattern and water holding capacity of soils as carried out by Somasundaram *et al*. (2014). Also, Giridhar and Vishwanadh (2008) and, Malhotra and Venugopal (2008) highlighted that calculating the evapotranspiration phase of hydrologic cycle and calculation of run-off are fundamental importance in all water resources development. Agricultural development broadly based on water resources during the growing season will be probably more relevant to development of crop adaptability strategies. Das (2013) and Reddy (1997) viewed that development of integrated water management of surface water which ensures the demand for water and the productive aspect of irrigation which makes it a priority issues are the vital sources of water for agricultural development.

Life on earth and water is indispensable, yet human civilisation had deteriorated the quality of water resources as noted by Kumanan (2012), Singh (2010), Singh (2014) and, Zutshi and Kumar (2013). In the concept of Chibane and Rahmani (2015), the problem inflicted by ever population growth and climatic change will consequent on water availability which will hamper economic growth and food security in future and such depletion of water quality will deteriorate environment and its living forms, therefore as cited by Chattopadhyay (2015) water management needs is technically prerequisite. Rahmani *et al*. (2016) mentioned that water resources, indeed constitutes the largest flow of natural resources but the demand for more water arises the concept of sustainable management. Bhandari (2009) is of view that water is replenishable but limited resources which need to be treated by sustainable approach. ‘Sustainable water resources management includes supply and demand aspects, policy implementation and participatory planning’. It attempts to achieve rational balance between supply and demand proportions of water resources.

Land is one of the most important asset and basic resources that represent the solid parts of the lithosphere. It is pivotal key and finite natural resources for human activities in particular. Mandal (1990) highlighted the significance of land resources as basic resources and its utilisation reciprocates the relationship between ecology and man. Singh and Singh (2013) dealt with the judicious use of land resources in a sustainable manner through proper planning of land utilisation. Land has become closely linked with the issue of sustainability and socio-economic development. As all man’s activities are based upon land, Jamir (2015) and, Khan and Khan (2012) argues that land is a scarce resource due to demographic pressure on account of productive agricultural land being converted to non-agricultural development. Contextually, population explosion and ceaseless urbanisation had engulfed land resource to a great extent. Chopra (2011) and, Taukdar and Singh (2100) notably debates that the demand for land resources, for both agricultural and other economic activities has led to decrease the per capita availability of land. They further justifies that to meet the unprecedented demand, reliable resources is a prerequisite for planning. Change in land use is a phenomenon; however, this phenomenon has attained such a debatable momentum as random land use has numerous affect on physical and biological factors. Roy (2014) rightly justifies that paradigm shift in land use is a serious concern in every region. Yadav (2014) projected that man is sole responsible for excessive land exploitation, as man being most active agent of all organisms. The most important aspect to understand land use lies in the relation of population to land.

After Farrag *et al*. (2016), Gautham and Narayan (1982) and Ramdass *et al.* (2016), land Use and Land Cover change is the main activities which burden the earth carrying capacity and acts as hindrance to sustainable development as these have impacted on unstable environment. Jaiswal and Verma (2013) and Krishnaiah (2013c) stated that mutual respect for landscape patterns, man-nature relationship are efficient principles for sustainable land management. Sardar (2011) explains that land use is the surface utilisation of all developed and vacant land which is conditioned by the interplay of physical and cultural factors. Sonwane *et al*. (2009) draws the concept of ‘land efficiency’, defined that it is the extent to which the net sown area is re-sown. He relatively stated that population factor and increase in food demand is phenomenal but there is a little scope to increase the cultural land, so it is necessary to use land intensity. Singh (1992) defined that land use functions on four variable- land, water, air and man by which each own role compose the history of life on earth, further explains that land constitutes its body, water runs through its veins life blood, air gives it oxygen and man acts as the dynamic agent. Alansi *et al*. (2009) and, Khan and Singh (1992) draws the important aspect of land uses that monitoring of land use and agriculture is highly essential as land is finite and its uses is restricted. This clearly states that under normal operation put to agricultural activities, it supply source of life to mankind. It is also evident that un-judicious utilisation of land resources is seen as diminishing return. Krishnaiah (2011a) and Majeed (1992) offers a review that land resources play a decisive factor in the development of socio-economic of all nations, since early civilisation. It is apparent that agricultural land resources nurture the largest percentage of world's population till date. Siddiqi (1992) explains the concept of general land use, highlighted that relief and drainage determines the extent of agricultural land use. This illustrate that high surface gradient with steep slope is prone to soil erosion as it absorbs low water and thereby undergoes considerable surface erosion. This will slowly turn the agricultural land to fallow and waste lands. Singh (1992) also supplemented other factors affecting soil erosion. He opined that high intensity of land use will increase the declining rate of soil fertility and land degradation. This problem emanates when plant become incapable to hold nutrient from the continuous exploitation of land. Hence, land use is an important aspect of geographical studies, subsequently; the progress of an area has to be accounted to a certain degree to understand the utilisation scale and management policy as stated by Rao (1986).

Devi *et al.* (2014) refers Land Cover as the 'physical and biological cover over the surface of the earth, whereas Land use refers to human activities on the natural environment'. Lambin (1999) notified that land use and land cover change is the main drivers that change the global environment. The supply of land is limited yet demands for economic activities are high. Kumra and Kumar (2001) viewed that consequent upon increasing population pressure there is an excessive demand of more land both for agriculture as well as non-agricultural pursuits. For judicious use of land, Kannan *et al*. (2010) suggests that the high productivity is attributed to better information on land and its uses, therefore, Singh and Singh (2013) outlines that to meet optimum requirements of the growing society, proper planning of land utilisation is essential. Meher and Sethy (2013) conveyed that systematic land use planning is the only way out which will in turn safeguard the land resources for the future generation. Jyothirmayi and Kumar (2013) stated that land is becoming a scarce commodity due to high demand for developmental activities. Hence, information on land use/ land cover change and possibilities for their optimal use for land operation are essential so that demand of land for human existence and preservation of biodiversity will be compromised.

Agriculture dominates the primary sector on which the future economy of developing economy in general and state in particular can be structured based on the crops productivity thus increase on productivity is attributed to physical and socio-economic factors. Umar and Rehman (2011) stated that agricultural productivity may be defined as ‘the ratio of total agricultural output to the total inputs in farm production’. The North Eastern region of India falls under high rainfall zone and the region are characterised by difficult terrain, steep slopes, land tenure system and cultivation practices thereby this agricultural region projects backward with low productivity. Goswami *et al.* (2002) and Mahajan (2002) draws that the deficiency in food production push the consumerism society to depend on imported food and other commodities from outside the region. Agricultural productivity is an important component as it is multidimensional concept which includes number of complex factors *viz*, physical, technological and institutional, which affects the development of a region. Agriculture is the most important constituent of man's primary occupation which marked the first vital link of man-environment interaction that paved a significant landmark in the essence of human civilisation. The chain of man's society evolved by projecting the land resources, as it forms an important resources for all agricultural performance. Land is no doubt a priceless resource factor, significantly for agrarian economy. In the concept of Mishra and Mishra (2015), agricultural related activities constitute about 50 percent labour force of the world in spite of growing technology and industrial development have heavily encroached the world's economy.

All the land available is unsuitable for cultivation as supplemented by Singh (2011); in fact, it must be used according to its capability. Gole (2009) studies reveal the close relationship between development of agriculture and carrying capacity of land. These capabilities depend on the properties of parent rocks, combination of different minerals that decides the soil fertility. However, after Singh (2004), beyond carrying capacity and excessive use there will be land degradation and loss in productivity. Das (2010) reminds that the climate acting upon parent material for pedogenic time on different types of soil and vegetation types greatly influences soil formation. Vaidya and Nannaware (2013) remarked that land is one of the important resources for the mankind; therefore, it has to use optimum usage of every acre of land. Singh (2004) defines 'The concept of optimum land use is basic to land planning which aims at balancing the competitive demand in a scientific manner for sustainable development of the economy'. Rahman and Lata (2012) stated that the ever increasing population, food insecurity and demand for more fiber highly induce land degradation. Simultaneously, Manna *et al*. (2001) is of the opinion that the indiscriminate exploitation of natural resources without considering the carrying capacity and non-judicious use of agricultural inputs has generated serious problem on sustaining agricultural productivity and soil quality. Wright (1996) justifies that the surface configuration is the chief factor in soil development and close relation exists between soil and the morphological settings. To sustain the capacity of various resources, Rao, *et al*. (1997) draws the attention that management of natural resources is the most important of all ecological problems which should be emphasised in both qualitative nature and quantitative availability. However, further argued that in rural areas, improper agricultural practices, defective methods of irrigation, and unscientific exploitation of resources adversely affects the environment. Singh *et al.* (1997), after studying the ecological problems in Himalayan region, noted that agricultural induced lands always modifies the natural environment which are responsible for environmental deterioration and degradation. Rongsen (2003) explain the relationship of man-nature relationship by stating that the Naga tribal concept of land is basically based on the wholeness of life, however, Dadhwal *et al*. (2012) opined that traditional land use that induced the environmental degradation is a worldwide problem that threatens sustainability. In the notion of Saha and Sengupta (2014) and, Wangshimenla and Jungio (2012), natural resources and livelihood of Nagas are inseparable as the bio-cultural knowledge has made them sustain their life through the ages even in this 21st century.

Agriculture is a key sector in most of the developing countries. It has a key role to play in enabling farmers to accomplish development goals, including self-reliance, growth and equity. Singh and Dhillon (1984) and, Tiwari and Sharma (2011) viewed, agriculture plays an important role in rural areas as it contributes towards economic growth and provides human and non-human resources to the other sector of the economy. It is the most important constituents of man's primary occupation and forms the first vital link of human interaction with environment. Nath (2009) highlighted that a rapid increases in agricultural productivity is essential to meet the increasing food demand and other agricultural products. However, according to Ram and Yadav (2008), 'Agricultural is not static factor but a highly dynamic one, subjected to frequent changes'. Mishra and Mishra (2015) remarked that agriculture occupies a prominent place as it contributes to the growth and development of human society and whole economy, hence, it is a way of life that shaped millions of people. Mohan and Thakur (2014) mentioned the importance of agriculture and further noted that it is the backbone to rural economy as it generates employment and thereby increases purchasing power. Also, Singh and Singh (2012) justified that poverty in rural economy can be elevated by the growth and development of agriculture. Bhalla and Singh (2001) explained that a vast sub-continent of India marked with regional diversities is likely to be characterised by uneven economic and agricultural development. This development according to Sandhu and

Kaushik (2014) viewed that agricultural development is an interlinked process between agro-climatic condition and introduction to modern inputs. These regional differences in agricultural development tend to get accentuated because of certain factors in North East India as the hills are generally characterised by undulating terrain, dense forest and difficult communication.

Kalita and Bhowmick (2008) argued that shifting cultivation is still prominently and primitively practiced in north-east India which causes serious problem in food insecurity, also Singh and Singh (2014) remarked that shifting cultivation is responsible to forest loss and land degradation. Kuba and Jha (2008) justified that traditional practice of agriculture limits the scope to meet the demand for adequate food production. However, Sachchidananda (1989) and Pareta (2013) advocates that shifting cultivation occupies a distinct place in tribal society as this act as their network of life in socio-economic development. Chaturvedi and Thakur (2012) referred to the level of any agricultural performance as a dynamic concept wherein the impacts of physical and non-physical factor affect agricultural productivity. Also, Singh (1997) explained that improper agricultural practices lead to soil erosion, causing loss of nutrients, thus affecting the crop production. Banerjee *et al.* (2010) highlights that crop planning and selection of crop according the availability of water and soil moisture will increase production. Bhaskar *et al.* (1988), Naidu *et al.* (1988) and Sehgal (1991) analysed soil-site suitability and evaluated that performance of any crop is largely influenced by soil properties in relation to physical components and management factors. In fact, soil-site suitability, soil and climatic conditions are the required elements for the plant species for its optimum growth. Prasad *et al.* (2013) analysed the methods of land capability and offers that the soil characteristics influence by texture, depth, fertility and water holding capacity are responsible to agricultural productivity. Manna *et al.* (2013) studied the soil biological health and remarked the aspect of soil suitability and limitation will sustain soil quality for ensuring sufficient food production.

Saha (2013) stated that poverty, non-mechanised farm, poor rural infrastructure, monsoon dependency, etc., are associated problems of India agriculture. Somasundaram *et al*. (2014) studies on management of stress soils shows that in rainfed areas, growing of two or more crops simultaneously in the same piece of land benefits the farmer's income. He stated 'contour cultivation, tillage practices and mulching is to be adopted for resources conservation and to increase productivity'. Furthermore, advised less responsive to production should be substituted by more sufficient crop. It is noted that crop combination and crop diversification are important indices to ascertain the productivity of a region, thereby, Roy and Barman (2014) is of the opinion that crop concentration and crop diversification are the two fundamental indices which help to know cropping pattern of a region. Wherein, Ogale (2014) and Ogale *et al.* (2012) highlighted that the study of crop combination provides an adequate understanding of an individual crop and their distribution will guide for agricultural planning. Suryawanshi and Dagu (2010) also stated that the study of crop diversification plays an important aspect in agricultural geography as it identifies cropping pattern of a given region. Kalaiselvi (2012) also stated that crop diversification is intended to give a wider choice which will reduce failure of crop production due to climatic factors. Krishnaiah (2009-10) and, Rana and Sohal (2013) dealt with the concept of cropping pattern and presents that rice-wheat dominant cropping pattern has enabled the countries of South-Asia to attain food security and provides livelihood to millions of farming families. This was possible due to development of a package of practices which include modern high yielding varieties, application of irrigation, inorganic nutrients, pesticides, government policies, etc. The concept of crop diversification viewed by Bhatia (1965), Chakraborth (2012), Kalaiselvi (2012) and, Let and Pal (2013) noted that crop diversification with enhancement of proper technologies guidance will be a good approach to sustain rural economy, *viv-à-vis*, Hashmi and Gomatee (2011) also viewed that it provide replenishment of nutrients. Dhawan (1988), Krishnaiah (2013a), Merchan *et al*. (2013) and, Rayudu and Krishnaiah (2011) study on account of role of irrigation justifying that in water stress region, irrigation plays a paramount role enhancing productivity, where irrigation implies the supply of water by man-made to regulate the plants growth, Samanta and Sengupta (2010) argued that Green Revolution technologies have failed to reach the majority of agrarian population in the country. Jha and Chawang (2013) offer a review that dissemination of agricultural information to farming community will ensure better utilisation of resources. According to the view of Murty (2008), human resources are essentially considered as important factors for economic development. It plays a significant role in deriving, to a maximum possible extent, utilities on different scales depending upon the ‘geographic potentialities’ and ‘production opportunities’.

1.8 Organisation of the thesis

The thesis is divided into eight chapters. The first chapter consists of introduction, statement of the problem, significance of the study area, main objectives of the study area, research questions, research methodology, literature review and organisation of the thesis. The second chapter deals with the physical setting of Nagaland which include physiography, population growth, geomorphology, climate, rainfall, temperature, climatic classification on thermal region, natural vegetation, relief, drainage, geology and mineral, hydrology, soils, land use and land cover etc. Third chapter discuses on the surface water resources on monthly, seasonal and annual analysis of rainfall, and groundwater recharge. The fourth chapter studied about the water balance elements on monthly, seasonal, rain-gauge station-wise. The fifth chapter presents the spatio-temporal variation of the land utilisation and irrigated area. In the sixth chapter, the agricultural development of Nagaland is highlighted. The seventh chapter depicts the water availability and crop suitability. In the last chapter, deals with summary and conclusion of the research work being carried out.

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Chapter -2

Physical Setting of Nagaland

Nagaland is located in the extreme north eastern part of India bounded by Arunachal Pradesh and parts of Assam in the north, Assam to the west, Manipur to the south and shares international border with the country of Myanmar to the entire east. It lies between 25°6' N to 27°4' N latitudes and 93°20' E to 95°15' E longitudes with the total geographical area of 16,579 Sq. Km. Nagaland became the 16th state of India on 1st December 1963. According to Census 2011, Nagaland has a population of 19,78,502 which is spatially distributed in eleven district namely Dimapur, Kiphire, Kohima, Longleng, Mokokchung, Mon, Peren, Phek, Tuensang, Wokha and Zunheboto. It is inhabited by sixteen (16) major tribes and other sub-tribes.

2.1 Physiography

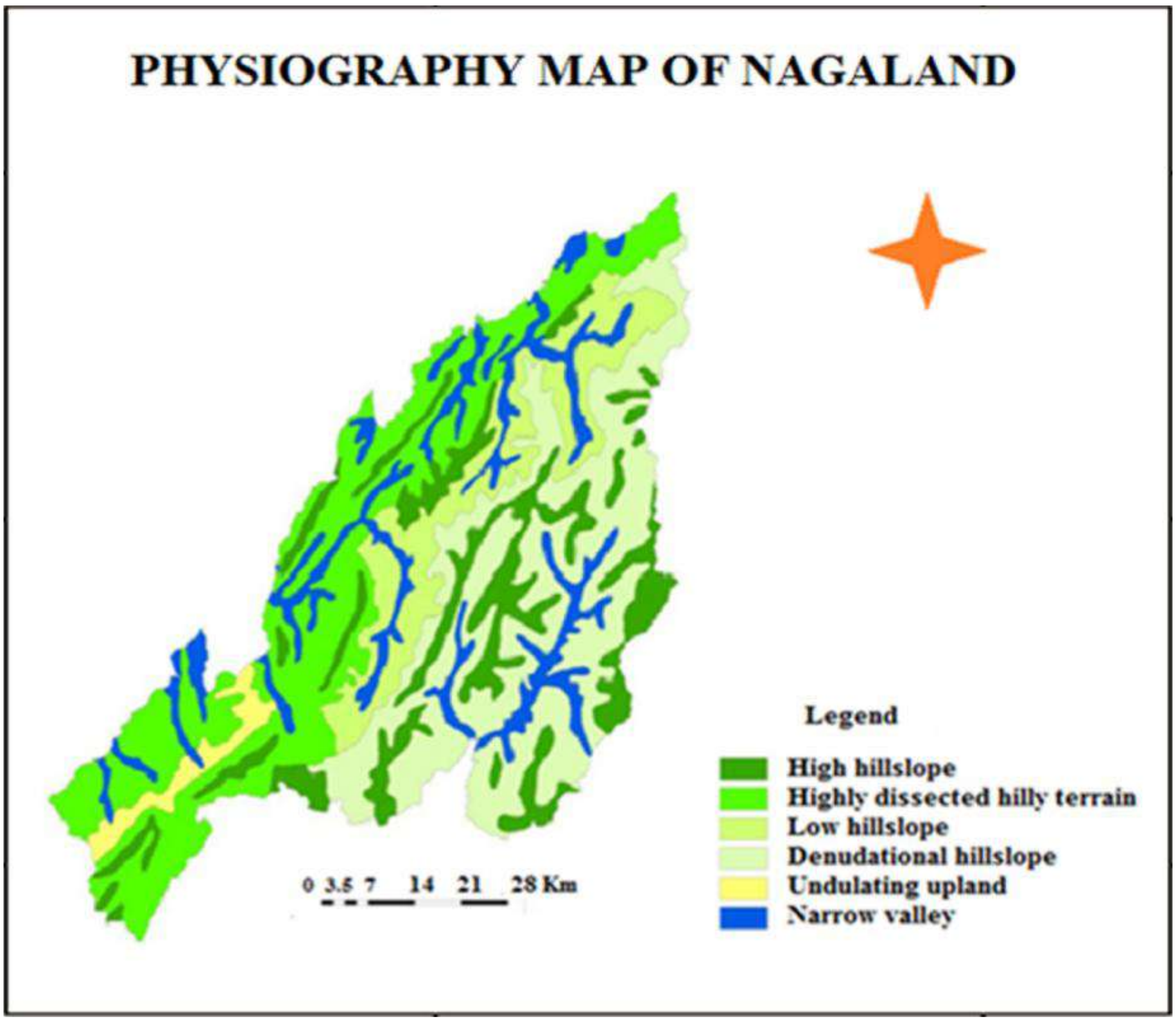
Nagaland has mainly a rugged hilly terrain. Its topography rises abruptly from the Brahmaputra valley to eastward. The hill bordering Assam has low altitude, but those bordering Myanmar attain a general height of 2000 meters. The Naga Hills are located in the northern extension of the Arakan-Yoma ranges. The general elevation of the Naga Hills increases towards the east where the highest peak Saramati (3826 meters) belong to the easternmost hill ranges of the state. After bordering Myanmar it merges with the Patkai ranges of Arakan mountain system. The Naga Hills represents hilly terrain comprising closely spaced elevated ridges with alternate ‘V’ shaped intermountain valleys. Topographically, the landscape can be categorized into three divisions namely **(Fig.2.1)**.

(a) The foothills with undulating to rolling topography below 1000m, facing the Assam plain on the northern sides.

(b) The lower ranges and the mid slopes with varying degrees of slopes with an elevation of 1000m and above.

(c) High hills and mountainous region.

The state consists of many narrow strip of hilly region running north-east to south-east. The Barail hill range in the southwest corner of the state runs in the north-eastern direction almost up to Kohima. It then merges with the hill ranges extending up to Manipur border which assumes northerly direction. Between Mao and Kohima, there are several high peaks such as Japfu. Barail and Japfu ranges of the Naga Hills and their extension in Mokokchung and Tuensang mark a prominent water divide separating Brahmaputra and Chindwin River systems. The hills of Nagaland, and the North-East India, are also known as part of the eastern Himalayas. Geomorphologically, the terrain can broadly grouped into four topographic units, they are alluvial plains (150 to 200 meters above msl), low to moderate linear hills (200 to 500 meters above msl), moderate hills (500 to 800 meters above msl) and high hills (800 meters and above).



Source: Nagaland Science and Technology Council.

Fig. 2.1

2.2 Climate

The Nagaland has humid tropical type of climate and minor variations are caused by change in Physiographic locations. Plain area experience warm and subtropical climate. The foothill areas with rolling to undulatory topography experience subtropical climate, low to moderate ranges with varying degree of slopes have submontane climate. Owing to varied topography and relief, the annual rainfall varies from 800 mm to 2200 mm at different places with an average rainfall of above 1500 mm.

2.3 The analyses of mean monthly rainfall (1986-2015)

The analyses of mean monthly rainfall of Nagaland were worked out from 30 years data (1986-2015) from sixteen rain-gauge stations. The maximum mean monthly rainfall of 454 mm was shown at Mokokchung rain-gauge station in the month of August while Tseminyu rain-gauge station recorded the minimum value of 2 mm in the month of January **(Table 2.1)**. The average mean annual rainfall for 30 years of the study area was 1536 mm. From the analysis, the highest mean monthly rainfall above 300 mm was recorded in the month of August, whereas, the month of December, January, February, March and April (five months) were shown less than 100 mm. The months of July, September and October received above 200 mm of mean rainfall.

Table 2.1: The analyses of mean monthly rainfall (1986-2015)

Sl. No	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Bhandari	12	15	35	126	152	267	326	331	222	104	13	9
2	Dimapur	4	12	24	62	105	190	176	175	138	87	8	3
3	Jalukie	6	19	38	100	146	186	230	235	164	86	31	3
4	Kiphire	9	9	21	51	102	133	181	169	109	85	14	3
5	Kohima	10	37	54	104	186	264	355	352	277	127	22	7
6	Mangkolemba	7	20	59	165	218	357	413	332	299	102	17	6
7	Meluri	10	11	18	67	118	174	220	201	160	97	19	6
8	Mokokchung	16	13	54	120	216	337	454	392	269	119	12	4
9	Mon	23	33	87	148	185	316	398	317	226	103	16	5
10	Phek	12	15	31	85	164	213	286	249	174	134	20	9
11	Sechu	10	17	44	82	129	222	284	217	196	101	10	3
12	Tseminyu	6	18	20	51	142	294	363	249	190	120	8	2
13	Tuensang	10	14	34	96	141	225	290	241	166	79	8	9
14	Wokha	27	50	77	134	268	361	409	401	299	131	39	10
15	Yisemyong	15	37	98	140	199	268	337	290	299	160	55	8
16	Zunheboto	14	7	25	106	214	282	297	292	235	82	16	3

Source: Compiled by the Scholar.

2.4 The analyses of mean annual temperature, mean annual rainfall and height of rain-gauge stations (msl)

The mean annual analyses for temperature and rainfall of Nagaland (sixteen rain-gauge stations) were calculated for 30 years (1986-2015). The maximum annual mean temperature of 25ºC was recorded at Dimapur rain-gauge station and minimum of 17ºC at Zunheboto station **(Table 2.2)**. The average annual temperature was 20.88ºC. It is evident that the station of Kohima, Mokokchung, Phek, Tuensang and Yisemyong shows less than average while Bhandari, Jalukie, Kiphire, Mangkolemba, Meluri, Mon, Sechu and Tseminyu recorded above the average. The analysis of annual mean rainfall reveals that Wokha station received maximum mean rainfall of 2206 mm whereas Kiphire station shows minimum mean rainfall of 886 mm. The total average annual rainfall was 1536 mm. From the table it is apparent that station of Dimapur, Jalukie, Meluri, Phek, Sechu, Tseminyu and Tuensang recorded below the mean annual rainfall.

Table 2.2: Mean annual temperature in ^{0} C, mean annual rainfall (mm) and height MSL, Nagaland

Sl. No	Rain gauge Station	Mean Temperature (°C)	Mean Rainfall (mm)	Height MSL
1	Bhandari	22	1612	703
2	Dimapur	25	986	160
3	Jalukie	24	1244	415
4	Kiphire	21	886	1195
5	Kohima	18	1795	1420
6	Mangkolemba	24	1995	661
7	Meluri	22	1101	1350
8	Mokokchung	20	2006	1180
9	Mon	22	1857	734
10	Phek	19	1392	1360
11	Sechu	21	1315	1094
12	Tseminyu	21	1463	1200
13	Tuensang	18	1313	1480
14	Wokha	20	2206	1360
15	Yisemyong	20	1836	1050
16	Zunheboto	17	1573	1780

Source: Directorate of Soil and Water Conservation, Nagaland.

2.5 Climatic Classification based on Thermal Regime

The thermal regime is a basic climatic parameter used to define the agro-ecological zone. The Thermal Efficiency (TE) indicates thermal potentiality of a region which measures heat received at the ground available for plant growth and development during the growing period. Thornthwaite (1955) introduced climatic classification based on TE and later initiated another parameter known as Summer Concentration of Thermal Efficiency (SCTE) which studies complicated climatic variation of different places located in same latitude. This SCTE is the ratio of sum of the thermal efficiency for three highest summer months to the annual total TE. Based on this thermal Regime, main categories and sub-categories of Nagaland were calculated. This analysis projected that present temperature is under the climatic category of Megathermal (A) as the mean value of PE is 16857 mm **(Table 2.3)**. Thus annual distribution of thermal efficiency suggests that Nagaland experienced abundant thermal potential that can support luxuriant vegetation if moisture is not at constant.

Table 2.3: Climatic Classification on Thermal Regime

Nagaland	Thermal Regime	
	Annual TE or PE (mm)	**Climate Type**
Present Temperature Situation	16857	A (Megathermal)

Source: Compiled by the Scholar.

2.6 Natural Vegetation

The mountainous slopes of the state is endowed with lush green vegetation vividly illustrates the rich and diverse nature heritage. The vegetation types of varies from tropical rain forest to Alpine type of vegetation. The forest cover of all types of vegetation accounts 52.54 percent of the total geographical area (Directorate of Agriculture, 2014), out of which the vegetative growth of evergreen tropical and sub-tropical forest occupy 8,62,930 hectares (20%). The forest type is mostly tropical semi-evergreen with evergreen in the valley and gorges to sub-tropical broadleaf and sub-alpine vegetation type above 3000 meters. Rare species of trees and plants are found in the forest of Nagaland. The variety of endangered species of animals and birds make the forest region rich in biodiversity. The forests are enveloped in a dense growth of timber, palms, cane and bamboo, rich flora and fauna, etc. The state is located in one of the 34 hotspots of the world in terms of biodiversity. A few area of the state are still pristine and harbor a wide variety of endemic species of plants, animals and micro-organisms. The forest regions are accessible to the people while the interiors are impenetrable and home to wild species. Meanwhile, the biodiversity of the state is facing serious threats due to exploitation of forest at alarming rate.

2.7 Population growth of Nagaland from 1901 to 2011

The spatial distribution of population, according to Census of 2011 shows that Nagaland has 19,78,502 population which rose from 1,01,550 in 1901 (110 years). The decadal variation revealed 46.76 percent during 1911 which drastically decreased to 6.55 percent in 1921and 6.04 percent during 1941 **(Table 2.4)**. The analysis shows that in 1961 Census, decadal variation was dramatically increased to 73.35 percent. Since then, the following variation fluctuated in descending which drastically decreased to –0.58 percent during 2011 Census. The density of population was recorded 119 persons per sq.km in Census of 2011. During the Census of 1901, it was recorded 6 persons per sq.km which doubled in 1951 by 13 persons per sq.km. In 1971, it was 31 persons per sq.km and 73 persons per sq.km during 1991 Census. The sex-ratio was recorded 973 females per 1000 males during 1901Census; however, in 1941 Census the ratio was 1021 females per 1000 male which indicated that female population was higher during this decade. The census of 1951 revealed decrease in the sex-ratio till the census of 1981 but increased slowly from 1991 to 2011 Census by 931 males per 1000 males. Nagaland has 79.55 percent literacy rate (Census 2011) which progressed constantly prior to 1951 (10.52%).

Table 2.4: Population growth of Nagaland from 1901 to 2011

Sl. No.	Year	Population	% of Decadal Variation	Density per sq.km.	Male	Female	Sex-Ratio (female per 1000 male)	Literacy Rate (%)		Literacy Rate (%)
								Male	Female	
1	1901	101550		6	50.69	49.31	973			
2	1911	149038	46.76	9	50.19	49.81	993			
3	1921	158801	6.55	10	50.21	49.79	992			
4	1931	178844	12.62	11	50.06	49.94	997			
5	1941	189641	6.04	11	49.48	50.52	1021			
6	1951	212975	12.30	13	50.03	49.97	999			10.52
7	1961	369200	73.35	22	51.74	48.26	933			21.95
8	1971	516449	39.88	31	53.46	46.54	871			33.78
9	1981	774930	50.05	47	53.67	46.33	863	50.06	39.89	42.57
10	1991	1209546	56.08	73	53.02	46.98	886	67.62	54.75	61.65
11	2001	1990036	64.53	120	52.62	47.38	900	71.77	61.92	67.11
12	2011	1978502	-0.58	119	51.79	48.21	931	82.75	76.11	79.55

Source: Statistical Handbook of Nagaland.

2.8 Relief

Nearly all of Nagaland is mountainous. In the north, the Naga Hills rise abruptly from the Brahmaputra valley to about 2,000 feet (610 metres) and then increase in elevation toward the southeast to more than 6,000 feet (1,830 metres).

The mountain merge with the Patkai range, part of the Arakan system, along the Myanmar border, reaching a maximum height of 12,552 feet (3826 metres) at Mount Saramati.

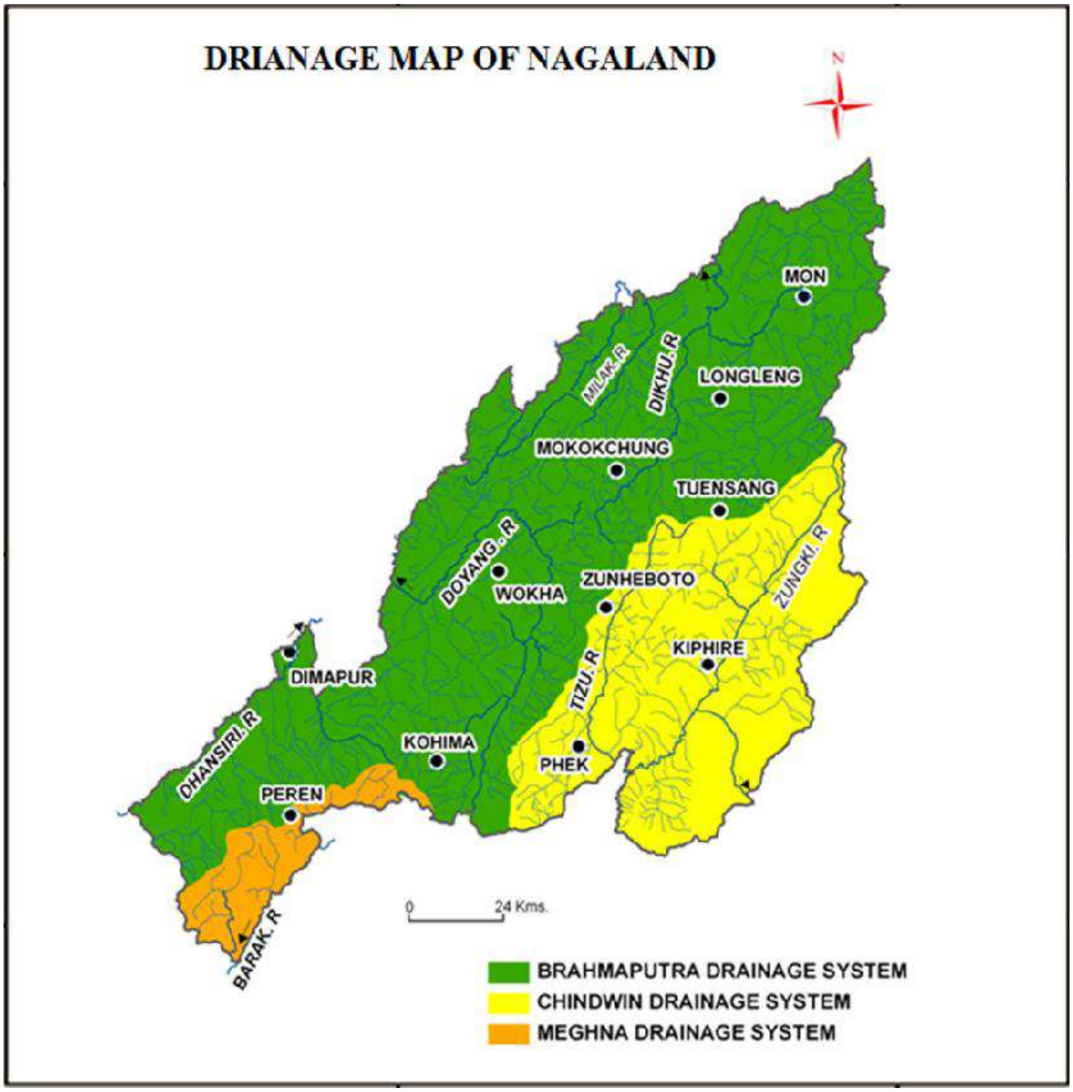
2.9 Drainage

Nagaland is dissected by number of seasonal and perennial rivers and rivulets **(Fig. 2.2)**. The major rivers of Nagaland are Doyang, Dikhu, Dhansari, Tizu, Tsurong, Nanung, Tsurang or Desai, Tsumok, Menung, Dzu, Langlong, Zunki, Likimro, Lanye, Dzuza and Manglu. Also, these rivers are dentritic in nature. Of the rivers, Dhansiri, Doyang and Dikhu flow westward into the Brahmaputra. The Tizu River, on the other hand, flows towards east and joins the Chindwin River in Myanmar (Burma).

Table 2.5: Important Rivers of Nagaland

Sl. No	**River**	**Length (Km)**	**Catchment Area (Km^2)**	**Length of river measurement point**
1	Zungki	80	2060	From Chingmei/Noklak area to Tizu confluence area.
2	Tizu	203	2760	From Helipong area to Avankhu area
3	Milak	67	845	From Aliba/Mopungchukit area to Tzudikong area
4	Doyang	167	3283	From Gariphema/Ghathashi area to Liphi
5	Dikhu	171	2996	From Phuye/Surumi area to Naginimora
6	Dhansiri	241	2262	From New Ngaolong area to Nuiland area
7	Barak	53	809	From Puilwa area to Manipur boundary

Note: Length of Rivers and catchment area calculated in GIS environment.
Source: Nagaland GIS and Remote Sensing Centre, Planning and Coordination Department, Government of Nagaland.



Source: http://nagalandws/rivers-of-nagaland/

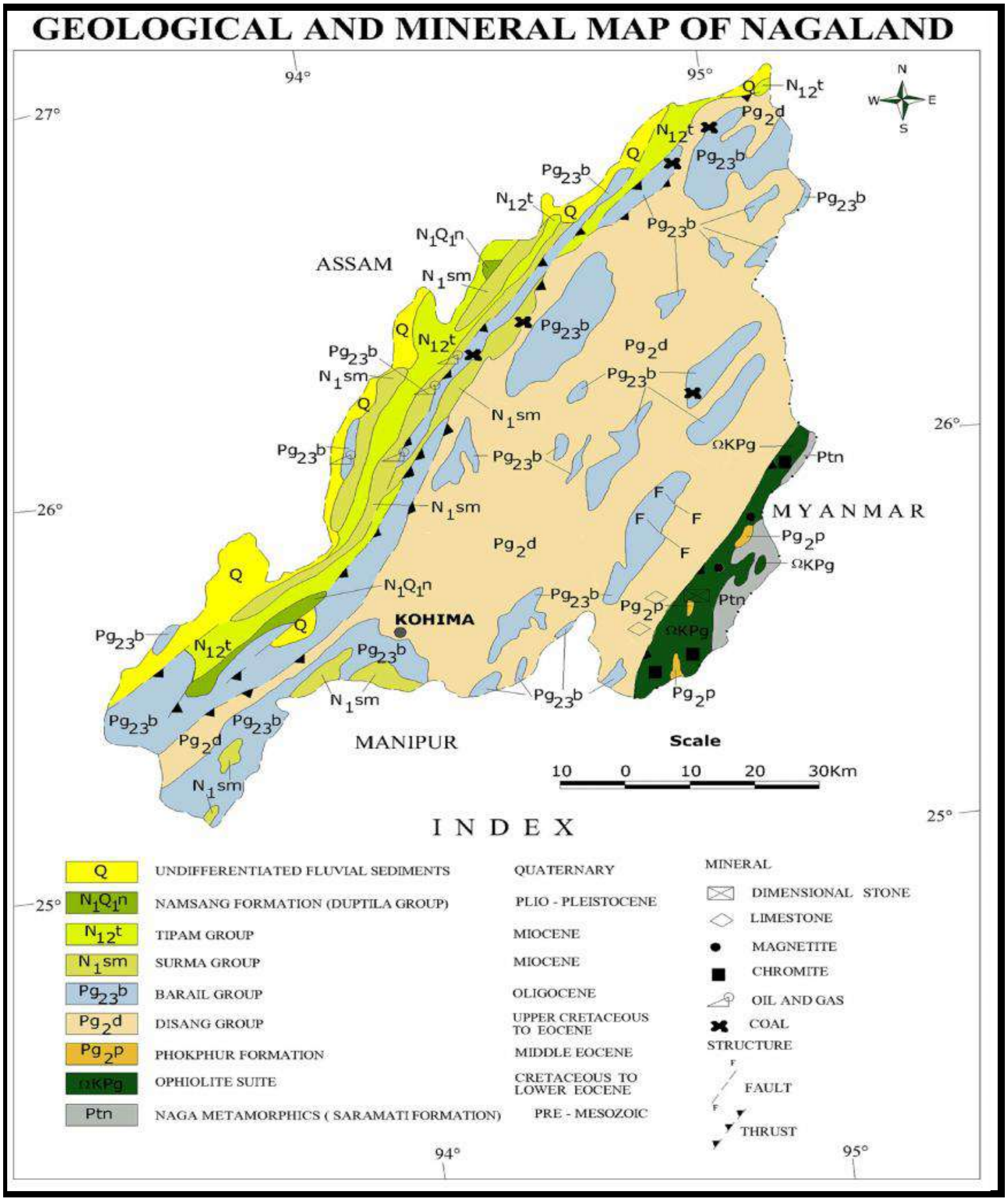
Fig. 2.2

2.10 Geology and Mineral of Nagaland

The geology of Naga Hills relates to the oblique subduction and subsequent collision between India and central-eastern Myanmar continental blocks during late Cretaceous-Eocene period. In the writings of Prof. Pandey, Department of Geology, Nagaland University, Kohima, morphotectonically, the geological of Nagaland has been divided longitudinally, from west to east into three distinct units namely the belt of Schuppen, the inner belt and the Ophiolite belt. The Geological and Mineral map shows different groups and formations such as Namsang Formation (Dupitila Group), Tipam Group, Surma Group, Barail Group, Disang Group, Phokphur Formation, Ophiolite Suite and Naga Metamorphics (Saramati formation) which provides geodynamics process involved in the evolution of the geological settings of Nagaland **(Fig. 2.3)**.

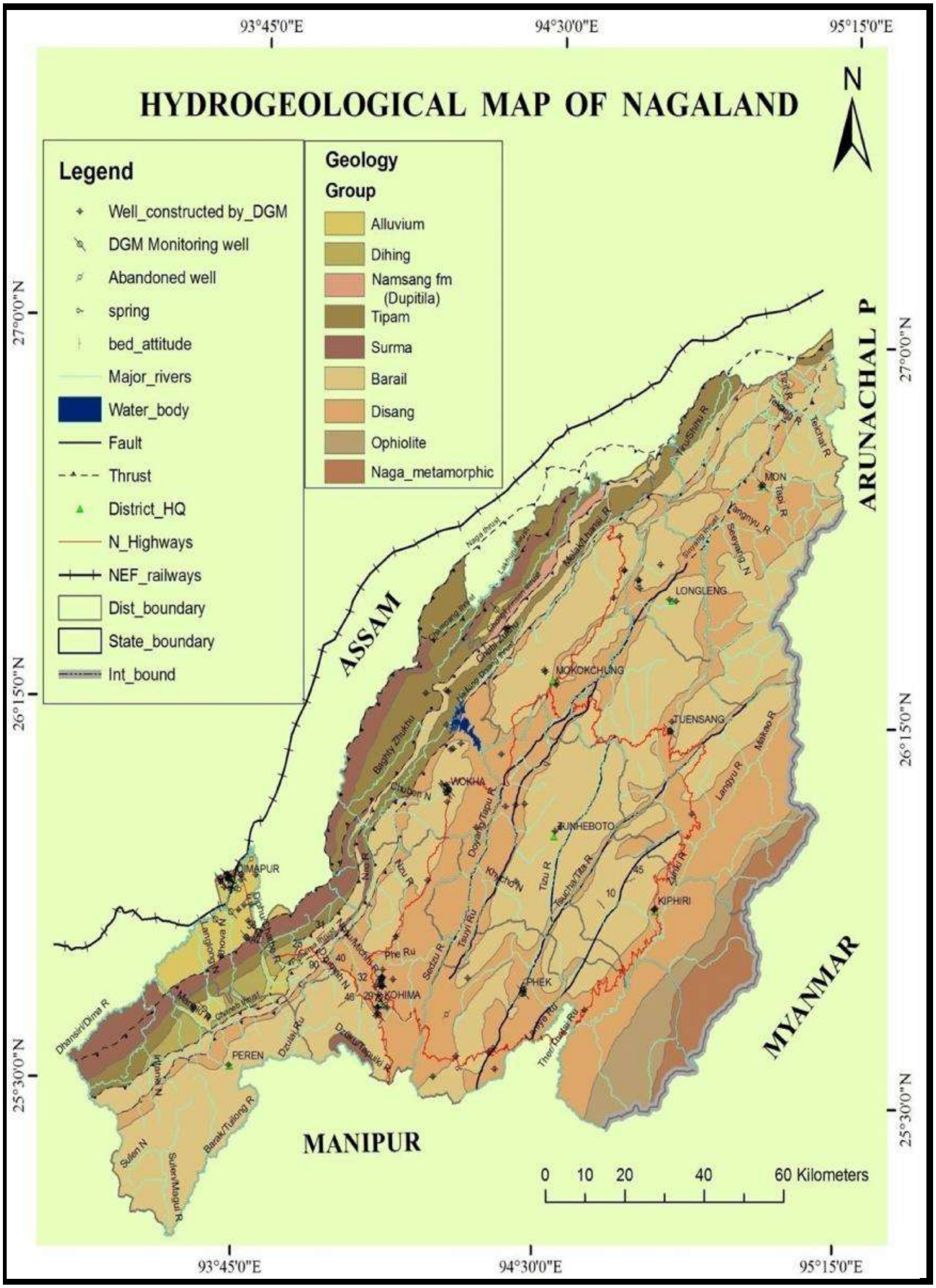
2.11 Hydro-geomorphology of Nagaland

Central Ground Water Board of India explained about hydrogeology Nagaland. The physiographically consists of narrow strip of hills running from east to south-west and facing the Assam plains to its north and north-east **(Fig. 2.4)**. The deep aquifers are thinly bedded down to 300 mm. The water table rests within 4 mbgl except in some pockets towards Naga-Patkai hills where it goes upto 12 mbgl. The yield of tube wells on the bank of Dhansiri and Diphu rivers is around 2 m^3 /hr. The low yield is because of finer nature of aquifer materials. Besides, the foothill zones, some intermontane valleys have also been observed like at Tizit, Tiru, Longtho and Baghty valleys. Yield of the wells in these areas vary from 16 to 62m^3/hr. The thickness of saturated zone is 30 to 70 m within 300 m depth on an average, the wells of 250 m depth can yield between 20-30 m^3/hr. The quality of groundwater is generally good.



Source: Geological Survey of India, 2011.

Fig. 2.3



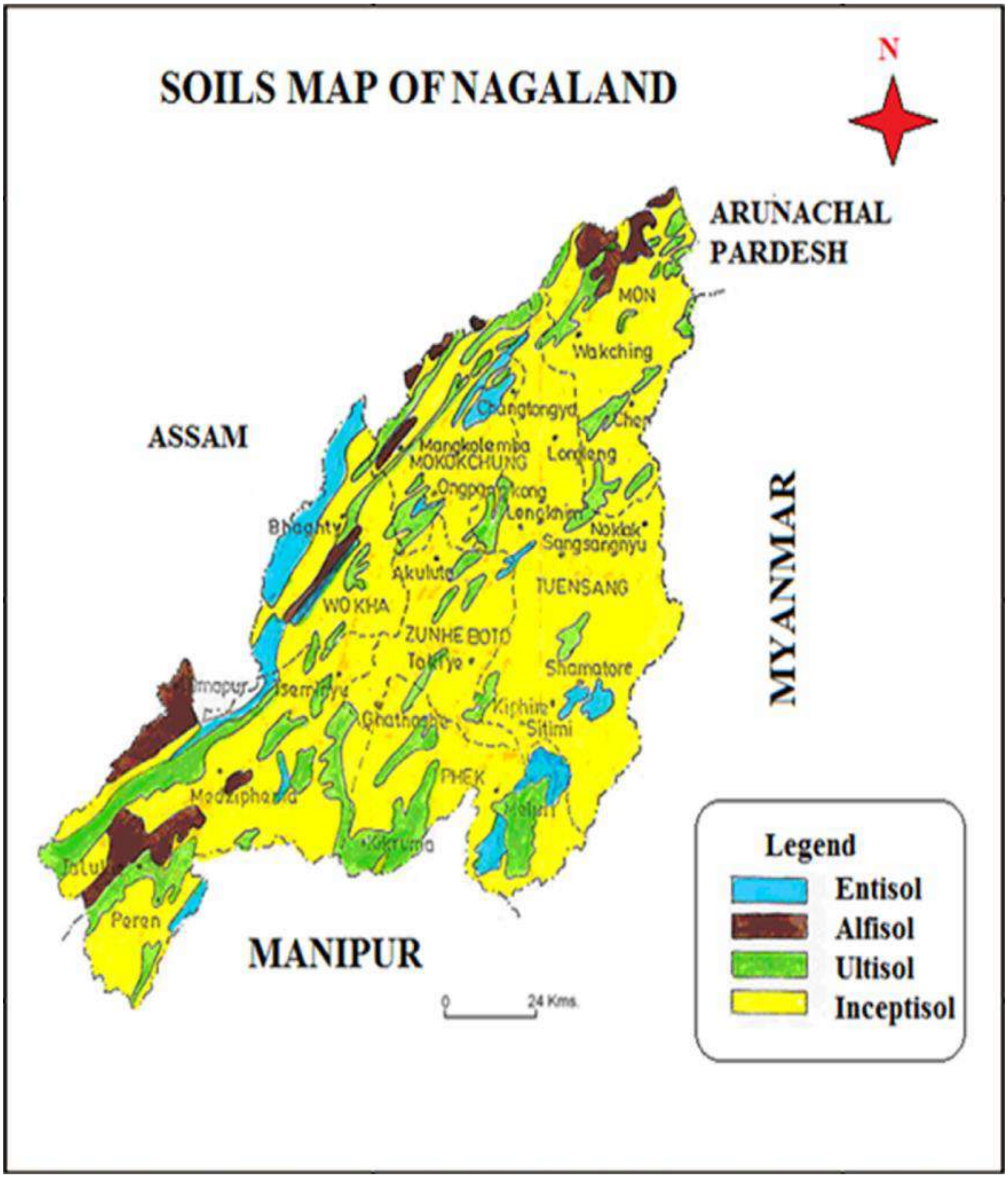
Source: Directorate of Geology and Mining, Nagaland .

Fig. 2.4

2.10 Soils of Nagaland

The soils of Nagaland belong to 4 orders, 7 sub-orders, 10 great groups, 14 sub-groups and 72 soil families. The soils of 4 orders comprise Alfisols, Entisols, Inceptisols and Utisols. Alfisols occupy 2.9 percent which are base-rich minerals soils of sub-humid and humid region. They are deep and well drained of fine to fine loamy texture. This type of soil order is found on the western corridor along the border of Assam. The Entisols (7.3%) are moderately to deep, well drained, and fine to fine loamy textured soils. This soil order is found in the western and north-western part of the state on the low hill slope and narrow valleys of river. The Inceptisols (66%) dominates the entire geographical area of Nagaland, which are often found on fairy steep slopes, young geomorphic surfaces and on resistant parent materials. Ultisols constitutes 23.8 percent which is sparely scattered in all parts of the state that have fine loam, clay loam and clayey texture. These are base-poor mineral soils of humid region developed under high rainfall and forest vegetation **(Fig.2.5)**.

In general, the soils of Nagaland are acidic. The study of soil sample shows that the pH value ranges from 4.80 to 6.50, while organic carbon is high as 3.09 percent (Directorate of Agriculture, 1986). According to the Department of Soil and Water Conservation, Government of Nagaland, it is found that approximately 70 percent of the soils are degraded (Sebu, 2013). The major factors affecting soil erosion are attributed to excessive exposure of top soil to heavy rainfall with excessive surface run-off, deforestation, and shifting cultivation.

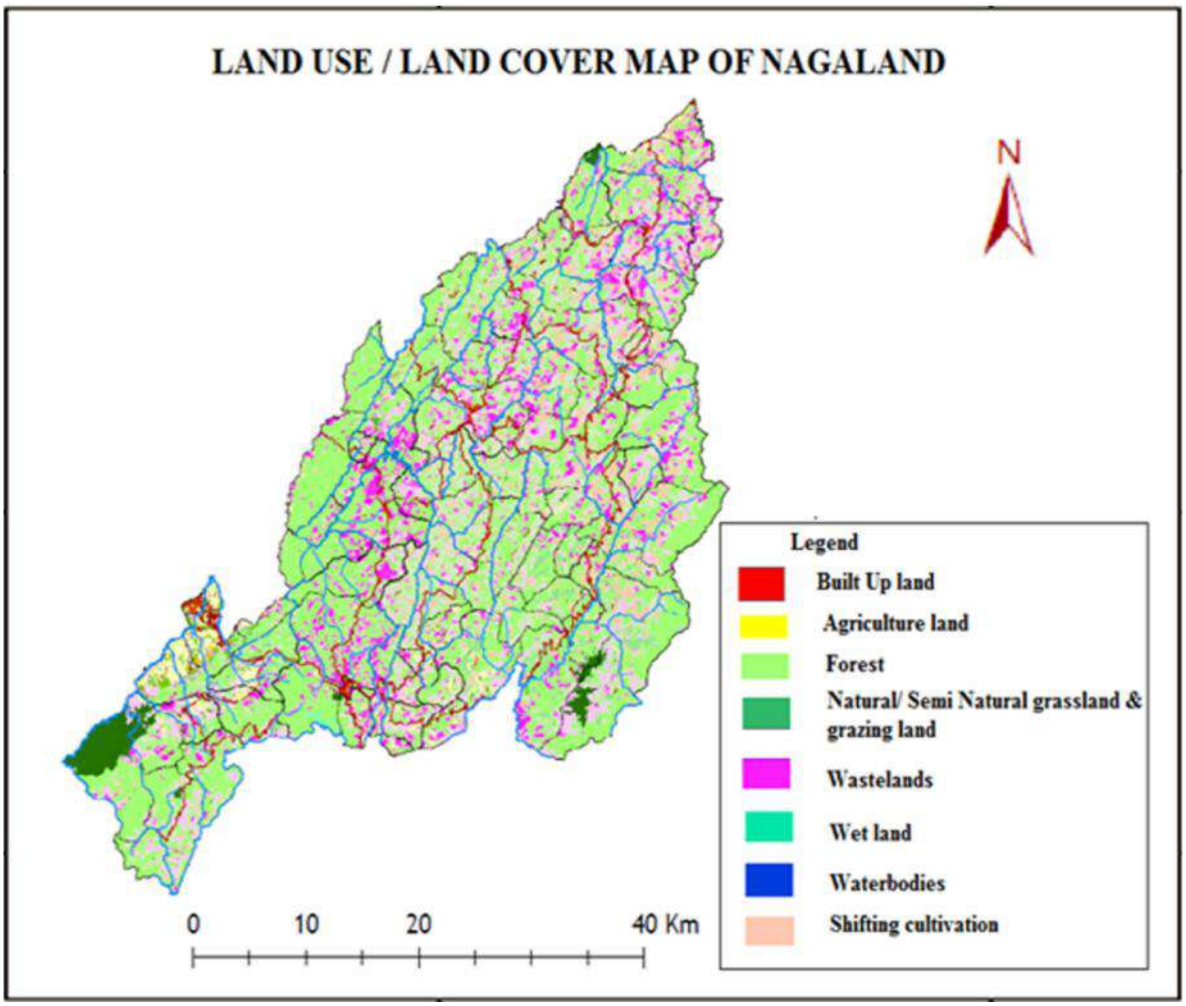


Source: ICAR Research Complex for NEH Region, Nagaland Centre.

Fig. 2.5

2.11 Land use / Land cover of Nagaland

The Nagaland Remote Sensing Application Center, IRS P6 LISS-III satellite data of November 2011, and February, March and May 2012 on 1:50000 scale classified Land Use/Land Cover into eight major categories. These are built up land, agricultural land, forest, natural/semi natural grassland & grazing land, wastelands, wet land, water bodies and shifting cultivation **(Fig. 2.6)**.



Source: Remote Sensing Application Centre, Nagaland.

Fig. 2.6

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Chapter-3

Water Resources of Nagaland

Water is indispensable natural resources for sound functioning of biosphere, essential for well-being and for smooth economic development. Tremendous civilisation in recent years has increased the demand for water, while it can be neither developed nor managed rationally without an assessment of the quantity and quality of water available. Water in its natural hydrological cycle is tapped for different activities from both surface and groundwater segments, in which the ultimate source for all water is precipitation. Hence, change in water cycles will threaten the very survival of fragile ecosystems and consequently endanger all water related activities. The non-irrigated or rainfed agriculture wholly depends on rainfall. In an agricultural economy like India, it depends on monsoon rain during which the water is readily available but briefly after the monsoon, the availability dwindles and often remains under dry spell. This form of agriculture prospers where rainfall distribution ensures favorable amount of precipitation, thereby required soil moisture is being maintained during growing periods of crops.

In crop agriculture, water as an important climatic factor affects or determines plant growth and development. Plants require water continuously during growing period which profoundly influences photosynthesis, respiration, absorption, translocation and utilisation of nutrient minerals, cell division and other processes. Limitations in water availability are frequently a restrictive factor as the growth and development of plants require water within reach of their roots in adequate quality, in appropriate quantity and at right time. Crops have specific water requirements for production and most of it is provided directly through rainfall. Besides, weather and climate influence the distribution of precipitation, however, local climatic condition controls the pattern of precipitation. This condition determines the process of plant growth-development and yield of crops, subsequently; agricultural planning and every form of operations are affected by weather phenomenon. The assessment of precipitation, solar radiation, air temperature, wind, humidity, etc, influence the crop growing season, hence suitability of these parameters determine the success of crop production. Meantime, of all the parameters, rainfall is fundamental and most important inputs which maintain the physiological and chemical process within the plant, acting as an energy exchanger and carrier agent of nutrients food supply in solution. Thus in any agricultural study rainfall is of fundamental aspects. The limitations and process of hydrological cycle is studied by analysing the precipitation in its spatial distribution, seasonal, number of rainy days and periodic pattern, etc.

To study the water resources of Nagaland, the rainfall data over a period of 30 years (1986-2015) were collected from sixteen (16) rain-gauge stations (Bhandari, Dimapur, Jalukie, Kiphire, Kohima, Mangkolemba, Meluri, Mokokchung, Mon, Phek, Sechu, Tseminyu, Tuensang, Wokha, Yisemyong and Zunheboto). The surface water resources of the study area (on monthly, seasonal and annual basis) were calculated by the statistical method of Bhargava's (1977) to analyse mean rainfall, rainfall intensity, rainfall variability (coefficient of variability) and rainfall ratio.

Formula:

$$\textbf{Rainfall Intensity} = \frac{\text{Mean Rainfall}}{\text{Mean number of rainy days}}$$

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

$$\textbf{S.D.} = \sqrt{\frac{\Sigma d^2}{N}}$$

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

The groundwater recharge were calculated adopting following four methods, that according to Radhakrishna *et al.* (1974) Method, the annual groundwater recharge of the study area is 10 percent of the annual mean rainfall and by U. S. Geological Method (1962) the annual groundwater recharge is 15 percent of the annual mean rainfall. According to Seghal's (1973), the formula for groundwater recharge is $G = 2.5\ (P-16)^{0.5}$ where precipitation is in inches and by the method of Krishna Rao (1970), the annual recharge is R = 0.20 (P-400) when precipitation is between 400 mm and 600 mm, R = 0.25 (P-400) when precipitation is 600 to 1000 mm, and R = 0.35 (P-600) when precipitation is 1000 mm and above. Finally, the surface water resources and the total groundwater resources of the study area have been estimated.

3.1 Monthly Mean Rainfall

3.1.1 January

The minimum mean precipitation recorded 4 mm at Dimapur rain-gauge station and maximum at Wokha by 27 mm. The average mean precipitation in the month of January was 12 mm. The precipitation below average was recorded at Jalukie, Kiphire, Kohima, Mangkolemba, Meluri, Sechu, Tseminyu and Tuensang rain-gauge stations **(Table 3.1)**. The spatial distribution shows that to the west, southern and east the value ranges from 10 mm to 15 mm. In the south-west the mean precipitation was low with 5 mm and in the north recorded 20 mm. The highest value was recorded in the central by above 25 mm. The rainfall intensity varies from 4 mm/ a rainy day at Dimapur, Mangkolemba and Phek stations to a maximum of 9 mm/ a rainy day at Wokha station. The average rainfall intensity of the month was 6 mm/ a rainy day. The spatial distribution of rainfall intensity shows lowest value to the south and southwestern by 4 mm/ a rainy day. In the western and eastern parts, the rainfall intensity reveals 6 mm/ a rainy day while the central and northern parts recorded maximum value of 8 mm/ a rainy day. The rainfall variability during this month ranges from 107 percent at Zunheboto station to a maximum of 170 percent at Sechu station and the average monthly rainfall variability was 127 percent. The stations of Jalukie, Mangkolemba, Mokokchung, Mon and Tseminyu were shown above the average. The distribution of rainfall variability was spatially distributed across the study area. In the east and western, it was recorded with lowest value by 100 percent and, in the central by 120 percent and 140 percent in the north. The maximum value 120 percent to 160 percent was recorded in the south-western part. The rainfall ratio ranges from 285 percent at Zunheboto station to a maximum of 662 percent at Mon station. The average rainfall ratio of the January month was 421 percent. The spatial distribution shows less than 300 percent to the east and western parts, above 300 percent in the southern and more than 400 percent along the central to northern parts of the study area **(Fig. 3.1)**

Table 3.1: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(January)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	12	6	108	338
2	Dimapur	4	4	125	380
3	Jalukie	6	6	133	463
4	Kiphire	9	5	111	371
5	Kohima	10	5	110	438
6	Mangkolemba	7	4	129	374
7	Meluri	10	5	120	422
8	Mokokchung	16	8	138	468
9	Mon	23	8	148	662
10	Phek	12	4	117	350
11	Sechu	10	5	170	340
12	Tseminyu	6	6	150	427
13	Tuensang	10	5	120	380
14	Wokha	27	9	126	541
15	Yisemyong	15	8	113	500
16	Zunheboto	14	5	107	285

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (JANUARY)

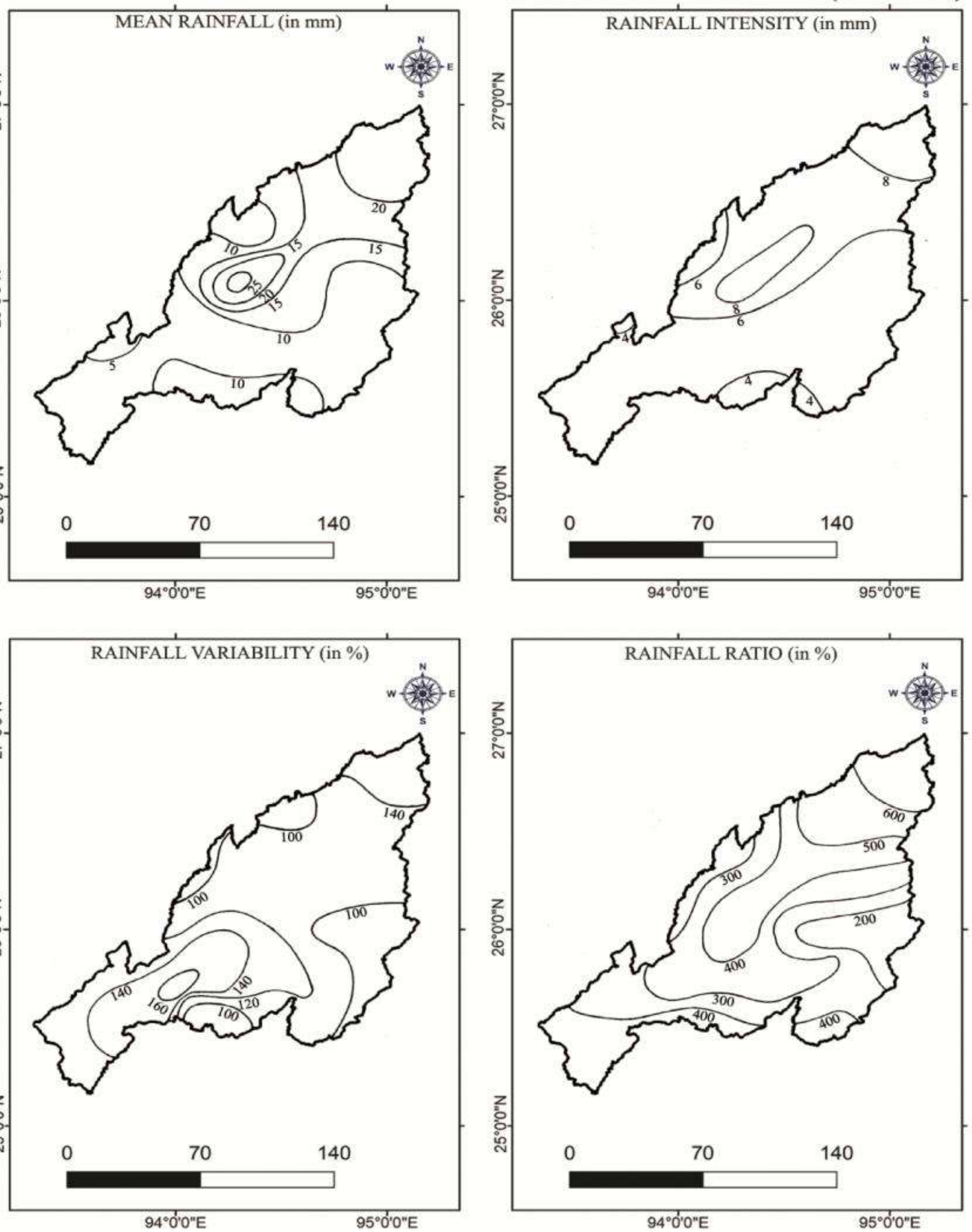

Fig. 3.1

3.1.2 February

The mean precipitation between minimum and maximum in the month of February differs with wide values. The rain-gauge station of Zunheboto shows the minimum mean precipitation by 7 mm and Wokha station with maximum of 50 mm. The average mean precipitation was 20 mm, where Kohima, Mon and Yisemyong rain-gauge stations recorded above the average mean precipitation **(Table 3.2)**. The spatial distribution shows less than 15 mm in the east, north and in western corridor. In the southern parts it shows above 30 mm. The maximum concentration above 45 mm was observed in the central part of the study area **(Fig. 3.2)**. The analyses shows that Kiphire station recorded the minimum rainfall intensity with 3 mm/ a rainy day while Wokha station by 13 mm/ a rainy day shows the maximum rainfall intensity. The average rainfall intensity during the month of February was 7 mm/ a rainy day. The spatial distribution of rainfall intensity shows that Jalukie, Tseminyu and Yisemyong recorded above the average. The spatial distribution of rainfall intensity shows 3 mm/ a rainy day to 6 mm/ a rainy day to the east, west, north and south. In the tip of the south-west the value was recorded with 9 mm/ a rainy day. The highest value was shown in the central part that ranges from 9 mm/ a rainy day to more than 12 mm/ a rainy day. The rainfall variability ranges from 67 percent as minimum at Bhandari station to 192 percent at Wokha as maximum. The average rainfall variability during this month was 127 percent. The rainfall variability value was spatially distributed with less than 100 percent to 120 percent to the east, west and northern part of Nagaland, while to the south and south-western it varies from 80 percent to 140 percent. The maximum value was recorded in the central part by 160 percent to 180 percent. The rainfall ratio ranges from a minimum of 212 percent at Bhandari station to maximum of 948 percent at Dimapur station. The average rainfall ratio was 501 percent. The spatial distribution of rainfall ration shows that rain-gauge stations of Jalukie, Meluri, Phek, Wokha, Yisemyong and Zunheboto recorded above the average rainfall ratio. The distribution of rainfall ratio shows less than 250 percent in the eastern, western and northern parts of the area. The maximum value increases from 250 percent to 850 percent to the central part of the study area.

Table 3.2: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(February)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	15	5	67	212
2	Dimapur	12	6	92	948
3	Jalukie	19	10	158	588
4	Kiphire	9	3	144	473
5	Kohima	37	7	100	392
6	Mangkolemba	20	5	135	459
7	Meluri	11	6	145	546
8	Mokokchung	13	7	123	468
9	Mon	33	7	97	415
10	Phek	15	4	140	548
11	Sechu	17	4	106	264
12	Tseminyu	18	9	133	454
13	Tuensang	14	4	114	363
14	Wokha	50	13	192	824
15	Yisemyong	37	12	135	545
16	Zunheboto	7	4	143	520

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (FEBRUARY)

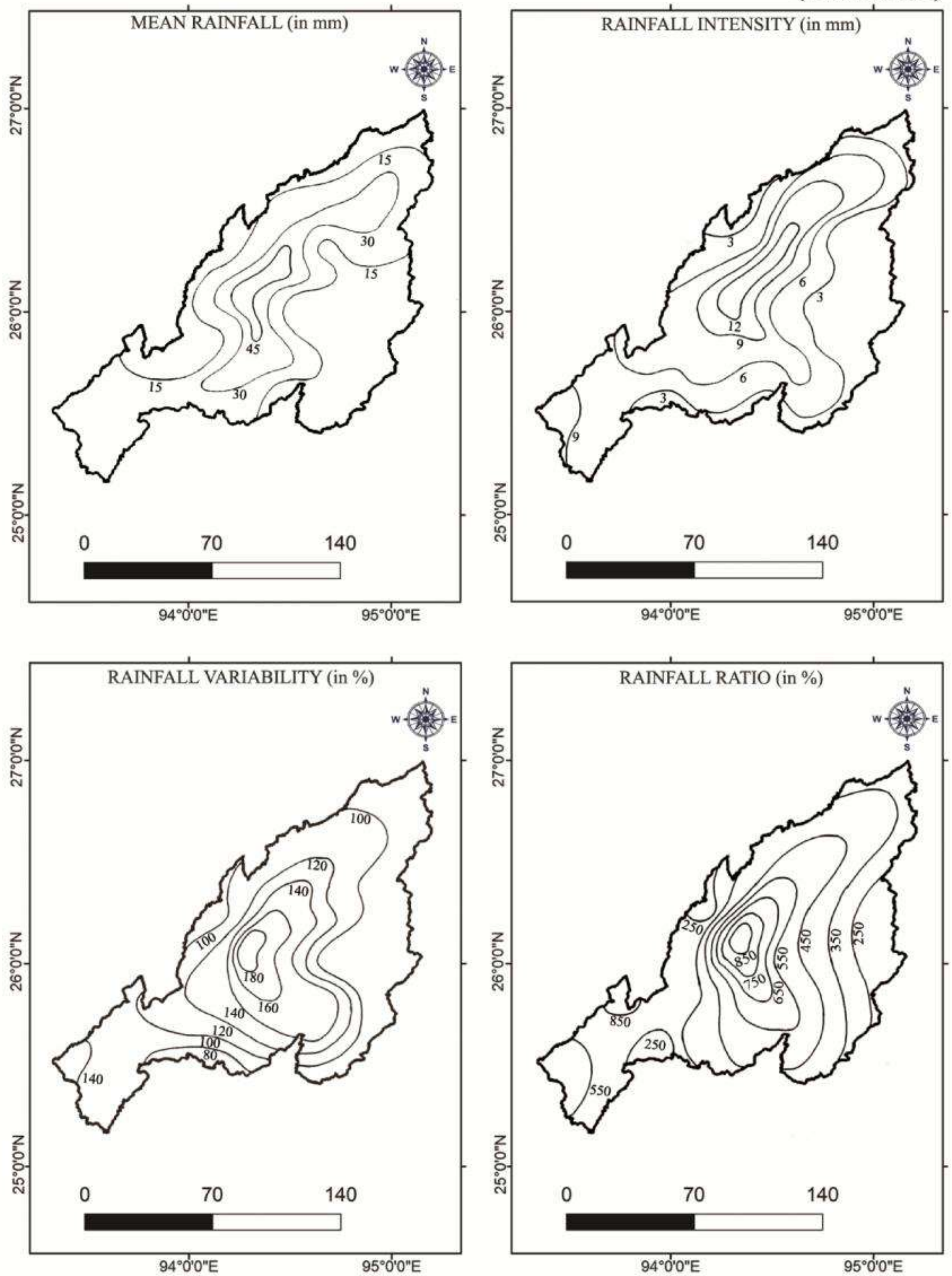

Fig. 3.2

3.1.3 March

In the month of March, mean monthly precipitation values widely vary from a minimum of 18 mm at Meluri rain-gauge station to a maximum of 98 mm at Yisemyong station. The average precipitation value was 45 mm. The stations of Kohima, Mangkolemba, Mokokchung, Mon and Wokha received precipitation above the average. The spatial distribution of mean monthly precipitation increases from the east and southern parts by 20 mm to 80 mm in northern part of the study area **(Table 3.3)**. The intensity of the rainfall varies from 3 mm/ a rainy day at Kiphire rain-gauge to a maximum of 14 mm/ a rainy day at Yisemyong station. The average rainfall intensity was 8 mm/ a rainy day. The stations of Jalukie, Kohima, Mangkolemba, Mokokchung, Mon and Wokha recorded above the rainfall intensity average. The value was less than 5 mm/ a rainy day in the southern and eastern part while to the central part it increases more than 12.5 mm/ a rainy day, and at the tip of the south-west the value was recorded with 12.5 mm/ a rainy day. The rainfall variability ranges from 50 percent at Kohima station to a maximum of 131 percent at Wokha station. The average rainfall variability was 88 percent. The spatial distribution shows below 60 percent of rainfall variability in the parts of east, peak of the north and at the edge of the southern part. The maximum distribution was found in the central part that exceeded 120 percent. The minimum rainfall ratio with 208 percent was recorded at Sechu station and maximum of 609 percent at Wokha station. The average rainfall ratio of this month was 325 percent, where the station of Jalukie, Kohima, Phek and Yisemyong shows above the average. The spatial distribution of rainfall ratio indicates 200 percent to 400 percent to the south, east, north and south-western parts of the area. The distribution of rainfall ratio shows high concentration in the central part that exceeded 600 percent **(Fig. 3.3)**.

Table 3.3: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(March)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	35	7	80	245
2	Dimapur	24	6	96	288
3	Jalukie	38	13	105	373
4	Kiphire	21	3	81	279
5	Kohima	54	8	50	337
6	Mangkolemba	59	10	93	253
7	Meluri	18	4	78	271
8	Mokokchung	54	9	70	271
9	Mon	87	10	71	301
10	Phek	31	4	103	464
11	Sechu	44	7	75	208
12	Tseminyu	20	7	90	293
13	Tuensang	34	5	74	239
14	Wokha	77	11	131	609
15	Yisemyong	98	14	112	453
16	Zunheboto	25	5	96	322

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (MARCH)

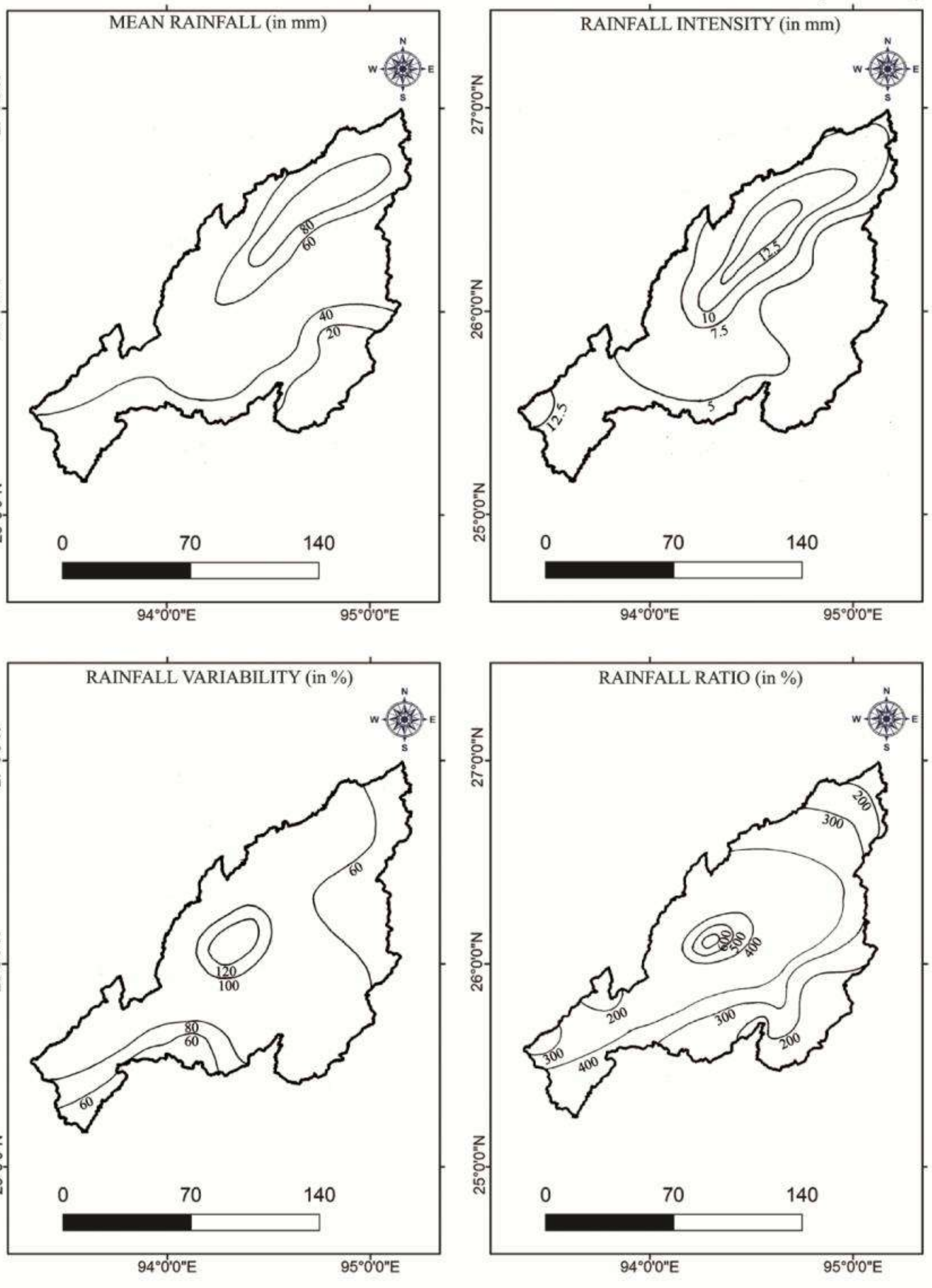

Fig. 3.3

3.1.4 April

During the month of April, the minimum mean rainfall of 51 mm was observed at Kiphire and Tseminyu stations while maximum value of 165 mm at Mangkolemba station. The average mean precipitation was 102 mm **(Table 3.4)**. The values above the average mean precipitation were shown at Bhandari, Kohima, Mokokchung, Mon, Wokha, Yisemyong and Zunheboto rain-gauge stations. The distribution of mean precipitation shows 60 mm to 90 mm in the tip of south and south-western parts, and in central and northern part the value concentration ranges from 90 mm to 120 mm. The maximum value of 120 mm to 150 mm was distributed in the western parts **(Fig. 3.4)**. The rainfall intensity was recorded from 4 mm/ a rainy day at Kiphire station to a maximum of 14 mm/ a rainy day at Jalukie and Mangkolemba stations. The average rainfall intensity was 10 mm/ a rainy day where Bhandari, Mokokchung, Mon, Wokha and Yisemyong stations show above the rainfall intensity average. The monthly intensity of rainfall distribution shows low value along the east with 5 mm/ a rainy day. In the south the value was recorded less than 10 mm/ a rainy day and in the southern-west it was observed above 10 mm/ a rainy day. The maximum value was shown more than 15 mm/ a rainy day in the central parts of the state. The distribution of rainfall variability was minimum at Dimapur with 34 percent and maximum at Zunheboto station by 102 percent. The average rainfall variability was 65 percent where only Bhandari, Jalukie, Kiphire, Meluri, Mokokchung, Phek and Yisemyong station recorded above the average. The distribution of rainfall variability indicates less than 55 percent in the east and northern parts. In the south-western the value was above 55 percent. The maximum value was recorded at the central part which exceeded 95 percent. The rainfall ratio widely ranges from 120 percent at Tuensang station to a maximum of 412 percent at Zunheboto. The average rainfall ratio was 252 percent. The rain-gauge station of Jalukie, Mangkolemba, Mokokchung, Mon, Sechu, Tseminyu and Yisemyong were found below the average. The spatial distribution of rainfall ratio below 200 percent to 300 percent occurred along the eastern flank, western corridor, northern peak and tip of the southern-west of the study area. The maximum value of rainfall ratio more than 400 percent was recorded at the central part around Zunheboto station.

Table 3.4: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(April)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	126	11	79	280
2	Dimapur	62	10	34	370
3	Jalukie	100	14	75	218
4	Kiphire	51	4	75	291
5	Kohima	104	9	48	284
6	Mangkolemba	165	14	49	165
7	Meluri	67	7	76	290
8	Mokokchung	120	12	97	200
9	Mon	148	11	62	241
10	Phek	85	7	71	324
11	Sechu	82	7	56	190
12	Tseminyu	51	9	43	140
13	Tuensang	96	7	45	120
14	Wokha	134	12	65	263
15	Yisemyong	140	13	66	249
16	Zunheboto	106	10	102	412

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (APRIL)

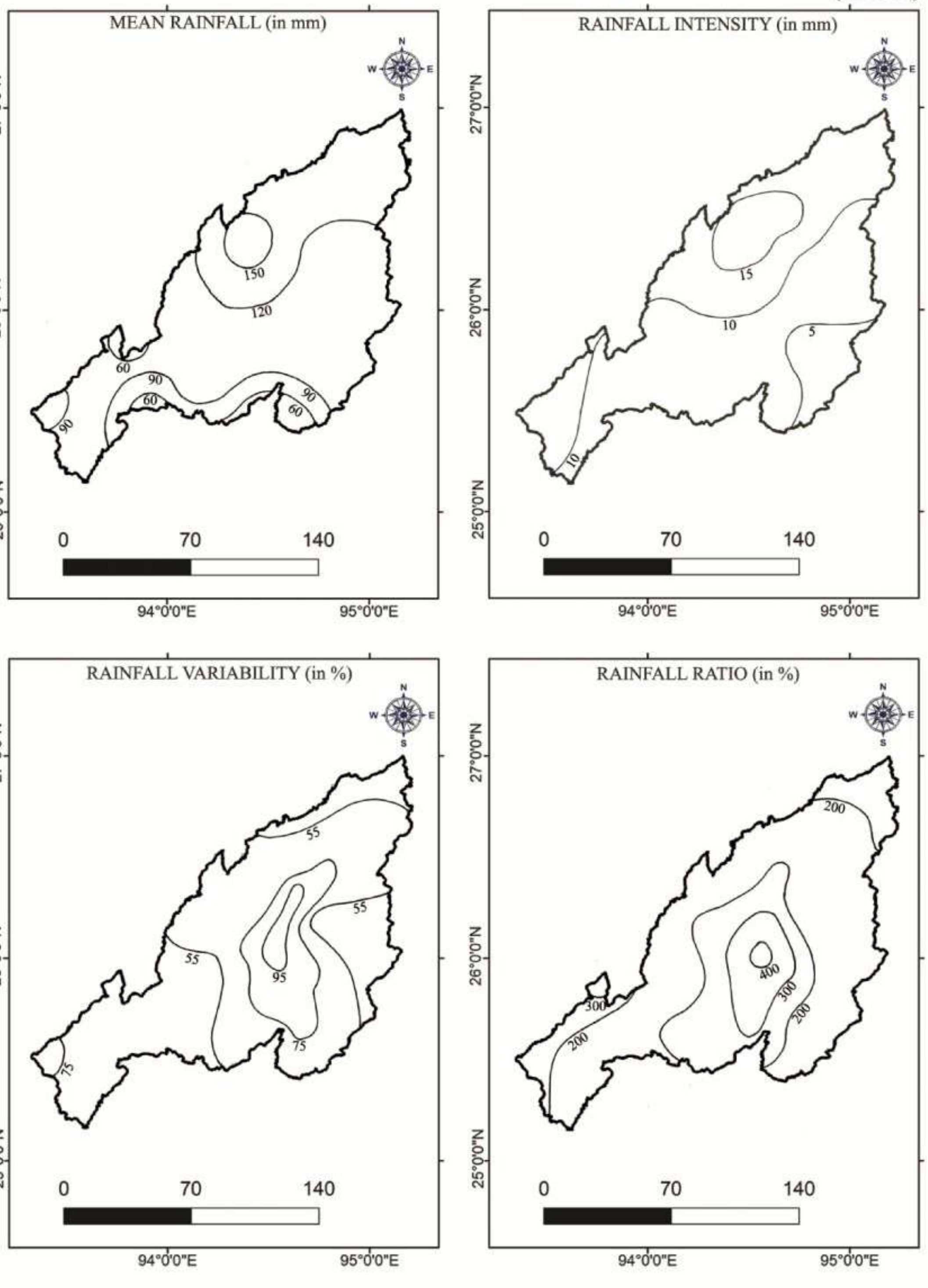

Fig. 3.4

3.1.5 May

In the month of May, minimum mean rainfall recorded 102 mm at Kiphire station whereas Wokha station recorded a maximum mean precipitation of 268 mm. The average mean precipitation was 168 mm **(Table 3.5)**. The spatial distribution of mean monthly precipitation shows 100 mm to 150 mm in the southern and eastern parts of Nagaland. To the west and northern parts, it ranges between 150 mm and 200 mm. The maximum value was distributed at the central part around Wokha station by 250 mm. The rainfall intensity with a minimum of 6 mm/ a rainy day was found at Kiphire station while Mokokchung station shows the maximum rainfall intensity with 15 mm/ a rainy day. The average rainfall intensity was 11 mm/ a rainy day. The monthly rainfall intensity spatially presents low values to the east, south and northern parts below 9 mm/ a rainy day. To the west the rainfall intensity shows 12 mm/ a rainy day. In the central part and around Jalukie rain-gauge station at the southern-west maximum value of 15 mm/ a rainy day was shown. The rainfall variability varies from 31 percent at Kohima station to a maximum of 86 percent at Dimapur station. The average rainfall variability was 51 percent. The rainfall variability was spatially distributed across the area during this month. In the east, west and northern parts, it shows less than 40 percent. In the tip of the south, around Phek rain-gauge station 70 percent value was shown. To the southern-west the rainfall variability shows 40 percent to 80 percent. The maximum value above 60 percent was shown in the central part of the area **(Fig. 3.5)**. The rainfall ratio varies from a minimum of 104 percent at Mangkolemba to a maximum of 329 percent at

Dimapur station. The average rainfall ratio was 196 percent. The spatial distribution of rainfall ratio value shows less than 200 percent along the east, west, north and southern part. In the central part of Nagaland the value exceeded 250 percent. The highest value concentration of 300 percent was revealed around the Phek station in the south and Dimapur station in the south-west.

Table 3.5: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(May)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	152	12	42	133
2	Dimapur	105	12	86	329
3	Jalukie	146	13	52	194
4	Kiphire	102	6	51	200
5	Kohima	186	10	31	137
6	Mangkolemba	218	13	33	104
7	Meluri	118	10	42	162
8	Mokokchung	216	15	63	264
9	Mon	185	11	33	145
10	Phek	164	9	71	324
11	Sechu	129	9	66	180
12	Tseminyu	142	11	36	131
13	Tuensang	141	7	34	122
14	Wokha	268	17	64	267
15	Yisemyong	199	13	56	208
16	Zunheboto	214	11	62	232

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (MAY)

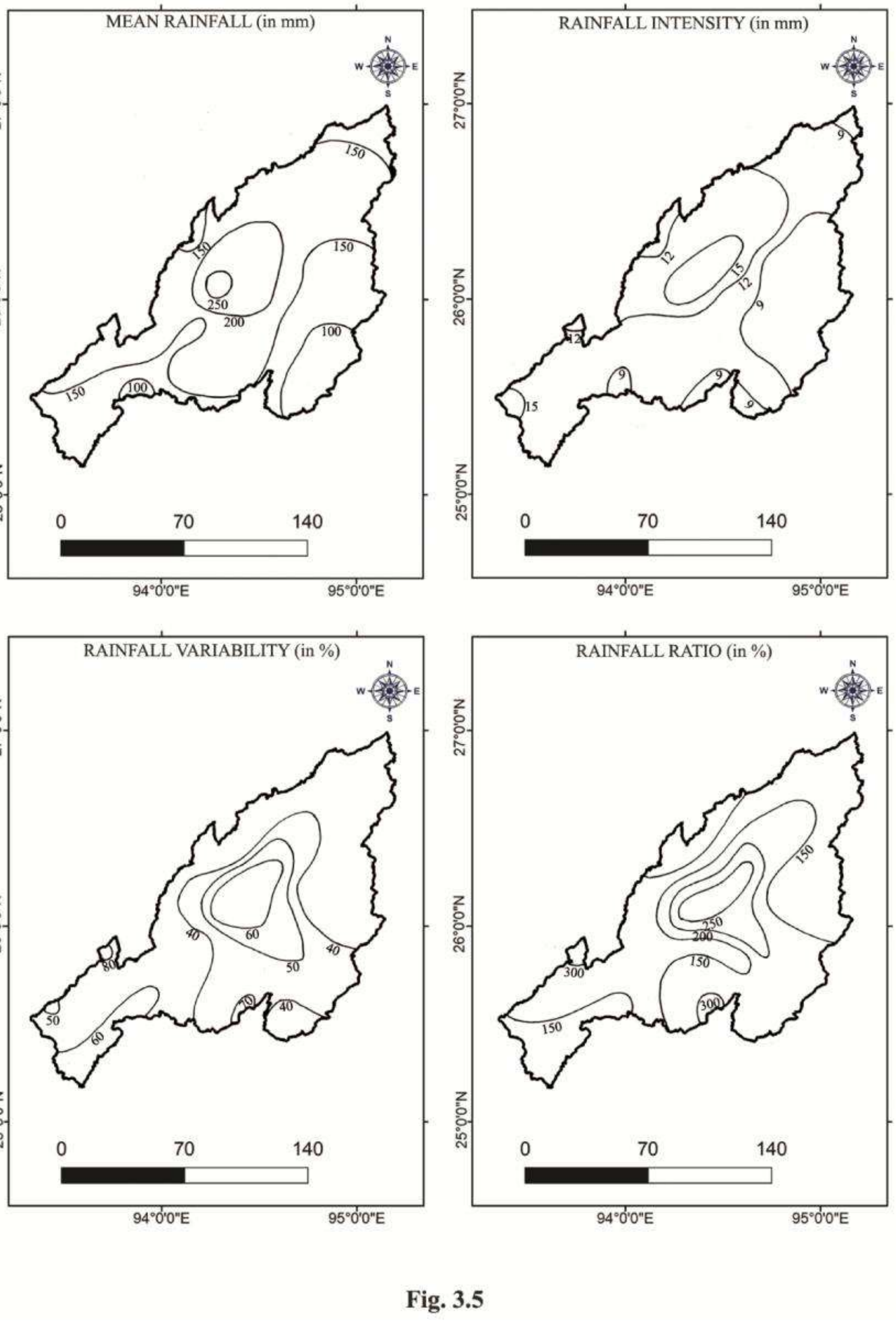

Fig. 3.5

3.1.6 June

The mean rainfall ranges from 133 mm at Kiphire station to a maximum of 361 mm at Wokha rain-gauge station **(Table 3.6)**. The average mean precipitation in the month of June was 256 mm. The spatial distribution of precipitation above average was recorded at Bhandari, Kohima, Mangkolemba, Mokokchung, Mon, Tseminyu, Yisemyong and Zunheboto stations **(Fig. 3.6)**. The spatial distribution of the monthly mean precipitation shows less than 200 mm in the east and in small pocket in the south-west while in the west it varies from 250 mm to 300 mm. In the peak of the north around Mon station shows 300 mm. The maximum value was concentrated in the central part that exceeded 350 mm. The rainfall intensity varies from a minimum of 7 mm/ a rainy day at Kiphire to a maximum at Mokokchung rain-gauge station with 19 mm/ a rainy day. The average rainfall intensity was 13 mm/ a rainy day. The value of rainfall intensity was less than 10 mm/ a rainy day to the east and in southern parts. The maximum value above 17.5 mm/ a rainy day was found in central parts. The rainfall variability during this month varies from 23 percent at Mon station to a maximum of 57 percent at Jalukie station. The average rainfall variability was 39 percent. The rainfall intensity indicates that Bhandari, Dimapur, Mokokchung, Phek, Sechu and Yisemyong recorded above the average. The rainfall variability was spatially distributed less than 30 percent in the south, eastern flank and to the north. In the central and south-west parts, it ranges from 30 percent to 40 percent of rainfall variability. The maximum rainfall variability was shown in south-western and central part of the area by 50 percent. The rainfall ratio ranges from 66 percent at Tuensang station to a maximum of 214 percent at Jalukie station, with an average rainfall ratio of 142 percent. The monthly rainfall ratio shows less than 100 percent in the east, south and in the north and, 150 percent in the central part. The maximum rainfall ratio above 200 percent was shown in the parts of south-west and in western pocket around Bhandari station.

Table 3.6: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(June)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	267	15	52	206
2	Dimapur	190	15	46	122
3	Jalukie	186	13	57	214
4	Kiphire	133	7	36	131
5	Kohima	264	11	28	153
6	Mangkolemba	357	17	31	101
7	Meluri	174	12	31	141
8	Mokokchung	337	19	55	165
9	Mon	316	14	23	99
10	Phek	213	10	48	198
11	Sechu	222	10	52	153
12	Tseminyu	294	18	33	103
13	Tuensang	225	10	24	66
14	Wokha	361	18	32	120
15	Yisemyong	268	14	40	145
16	Zunheboto	282	12	36	155

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND **(JUNE)**

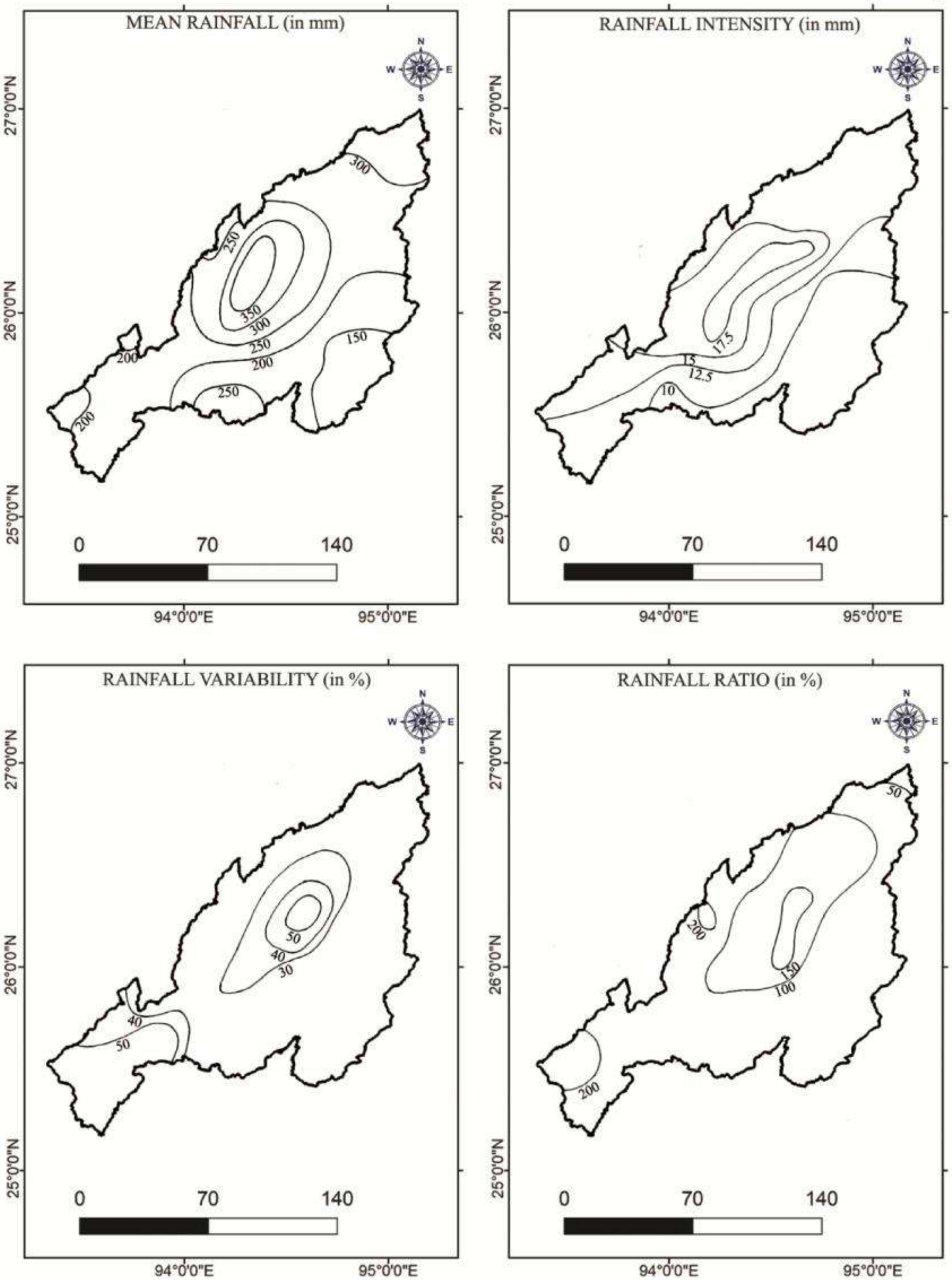

Fig. 3.6

3.1.7 July

The minimum mean precipitation in the month of July was 176 mm at Dimapur rain-gauge station and maximum at Mokokchung by 454 mm **(Table 3.7)**. The average monthly mean precipitation was 314 mm. The spatial distribution of mean precipitation recorded 250 mm to 300 mm to the east, south and south-western parts of the study area. In the northern parts it increases to 350 mm, and 300 mm to 350 mm in the western part. The maximum spatial distribution of mean precipitation in the central part of Nagaland varies from 300 mm to 400 mm **(Fig. 3.7)**. The rainfall intensity varies from 8 mm/ a rainy day at Kiphire station to a maximum of 20 mm/ a rainy day at Mokokchung station. The average rainfall intensity was 15 mm/ a rainy day. The spatial analysis shows less than 10 mm/ a rainy day to the east. In the southern parts a small pocket around Kohima rain-gauge station shows more than 12.5 mm/ a rainy day. The maximum value above 17.5 mm/ a rainy day of rainfall intensity was concentrate in central parts. The rainfall variability ranges from 15 percent at Mangkolemba station to a maximum of 60 percent at Zunheboto rain-gauge station with an average rainfall variability of 35 percent. The distribution of rainfall variability was spatially distributed across the study area. To the eastern flank and tip of the south the value was less than 25 percent. In the southern-west and parts of west it varies from 45 percent to 55 percent. In the central parts, concentrates 35 percent to 55 percent. The rainfall ratio recorded minimum of 51 percent at Mangkolemba while Yisemyong rain-gauge station revealed maximum of 245 percent. The average rainfall ratio was 128 percent. The rainfall ratio in the month of July spatially shows less than 100 percent in the east, west, north and southern parts. In the south-west it exceeded 150 percent. The central part close to north shows more than 200 percent.

Table 3.7: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(July)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	326	16	54	172
2	Dimapur	176	14	38	149
3	Jalukie	230	16	49	194
4	Kiphire	181	8	26	108
5	Kohima	355	14	25	135
6	Mangkolemba	413	18	15	51
7	Meluri	220	12	25	82
8	Mokokchung	454	20	33	128
9	Mon	398	17	23	97
10	Phek	286	12	30	90
11	Sechu	284	12	59	173
12	Tseminyu	363	17	29	107
13	Tuensang	290	11	16	56
14	Wokha	409	17	29	93
15	Yisemyong	337	16	49	245
16	Zunheboto	297	14	60	175

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (JULY)

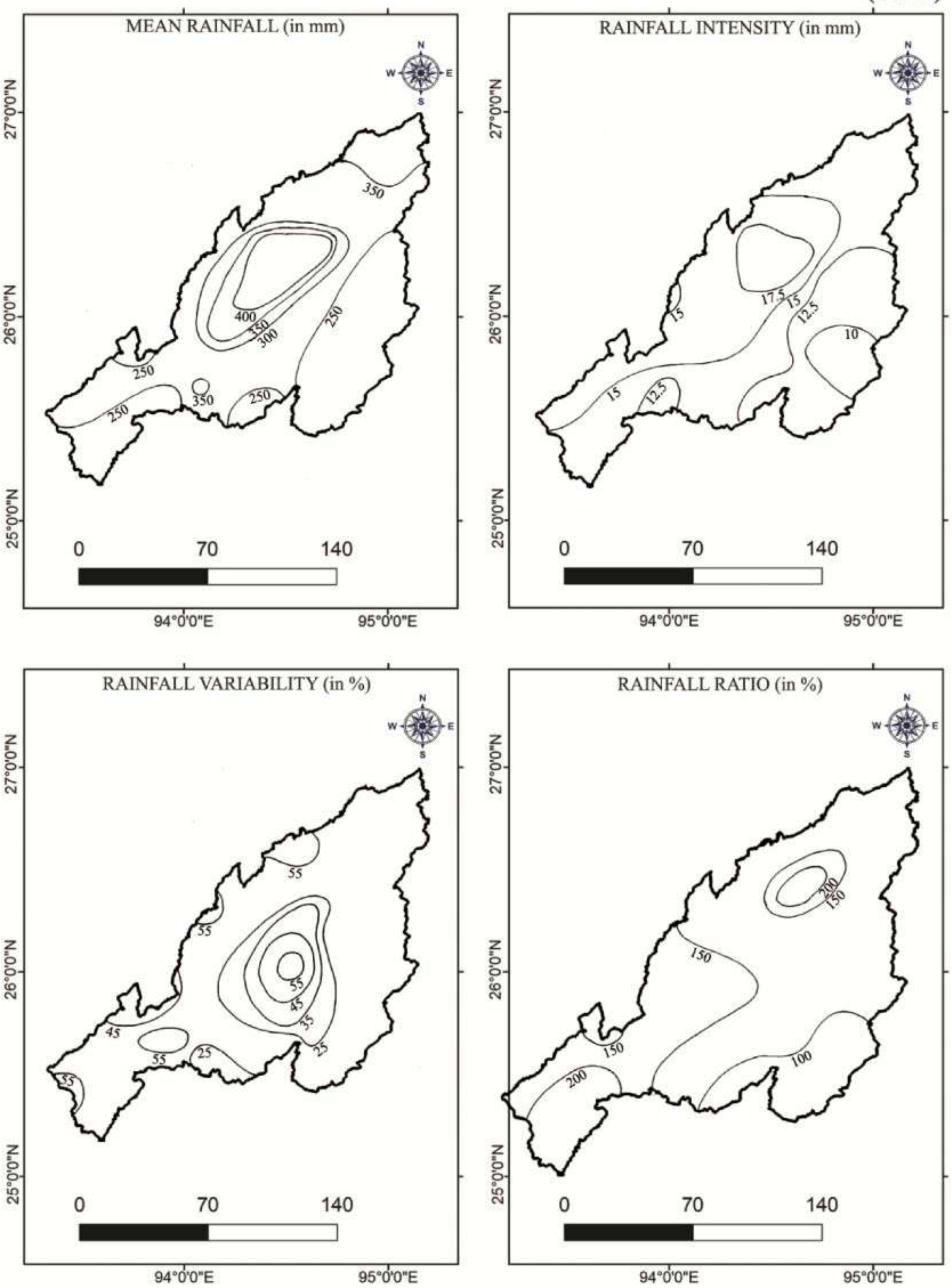

Fig. 3.7

3.1.8 August

In the month of August, the station of Kiphire recorded a minimum mean rainfall of 169 mm while Wokha station shows the maximum main precipitation by 401 mm **(Table 3.8)**. The average mean precipitation was 278 mm. The distribution of mean precipitation in the parts of the east and south-west observed less than 200 mm and more than 200 mm shown to the north, west and in southern parts around Kohima station. In the central parts, concentration was more than 400 mm. The rainfall intensity of August shows minimum at Kiphire station by 9 mm/ a rainy day to a maximum of 19 mm/ a rainy day at Mokokchung. The average intensity was 15 mm/ a rainy day. The spatial distribution of rainfall intensity indicates less than 13 mm/ a rainy day observed in the east and southern parts and 15 mm/ a rainy day to 17 mm/ a rainy day to the north, south-west and central parts of the study area. The rainfall variability in the state during this month ranges from 27 percent at Kohima station to a maximum of 67 percent at Dimapur station. The average rainfall variability was 41 percent where the stations of Jalukie, Meluri, Sechu, Tseminyu and Zunheboto recorded above the average. The rainfall variability was spatially distributed during this month. In the east, west and northern parts it shows less than 40 percent. In the south-west and in central part, it ranges between 40 percent and 50 percent. The highest value of 60 percent rainfall variability was noticed in the south-west. The rainfall ratio widely varies from 43 percent at Kohima station to a maximum of 249 percent at Jalukie rain-gauge station. The average rainfall ratio was 149 percent. The spatial distribution of rainfall ratio revealed less than 100 percent in the eastern and in small pocket of western corridor and more than 150 percent in the south and in central part. The maximum value of 200 percent was shown in the peak of the north and south-west **(Fig. 3.8)**.

Table 3.8: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(August)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	331	17	39	135
2	Dimapur	175	16	67	224
3	Jalukie	235	17	56	249
4	Kiphire	169	9	36	121
5	Kohima	352	15	27	43
6	Mangkolemba	332	18	40	150
7	Meluri	201	13	43	136
8	Mokokchung	392	19	33	132
9	Mon	317	16	41	157
10	Phek	249	12	33	123
11	Sechu	217	10	53	155
12	Tseminyu	249	16	53	201
13	Tuensang	241	10	30	103
14	Wokha	401	18	30	111
15	Yisemyong	290	15	37	156
16	Zunheboto	292	14	45	184

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND

(AUGUST)

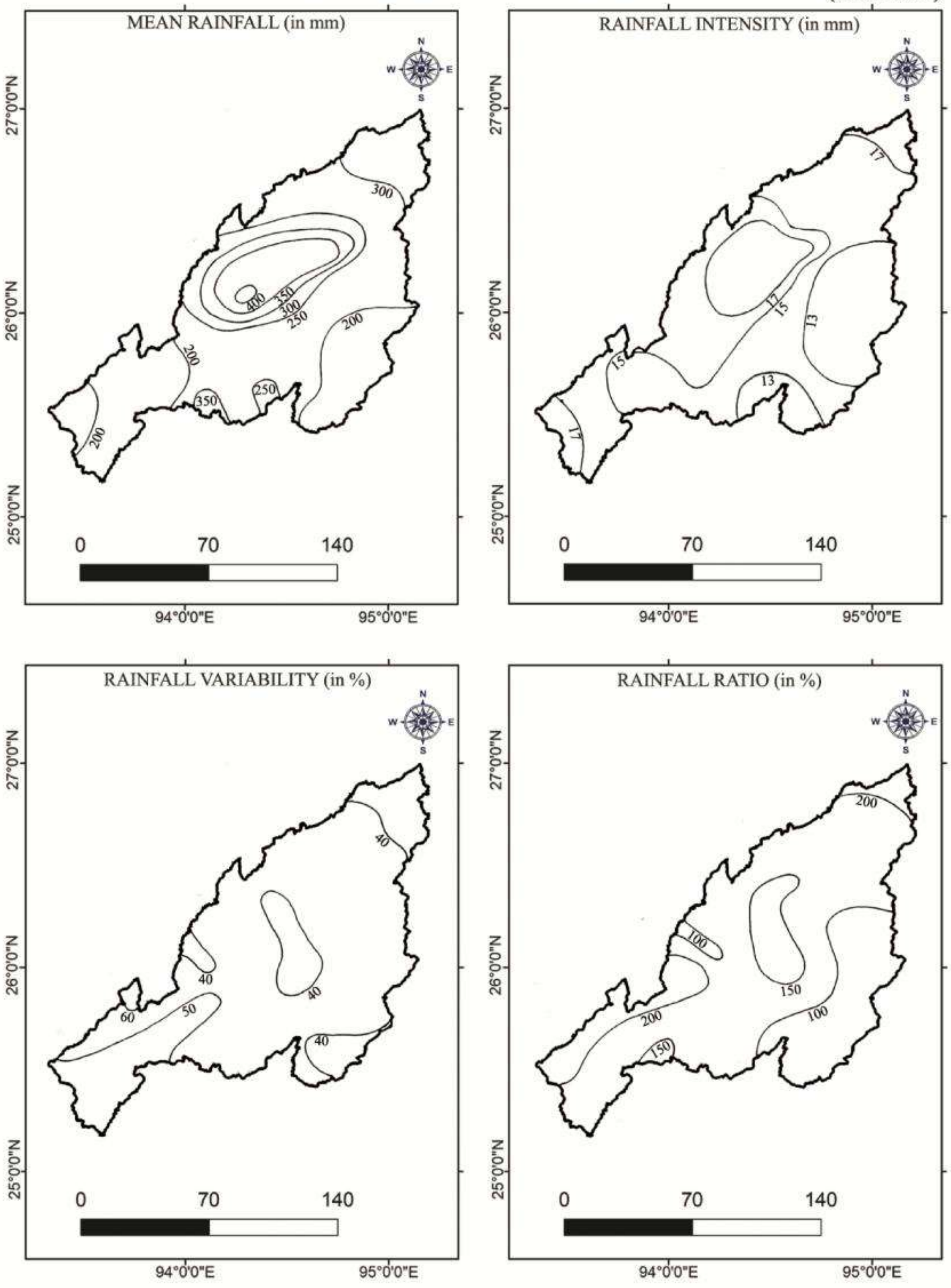

Fig. 3.8

3.1.9 September

The values of mean precipitation in the month of September ranges from 109 mm at Kiphire station to a maximum of 299 mm at Mangkolemba and Wokha station **(Table 3.9)**. The average mean precipitation was 209.5 mm. The rain-gauge stations of Mon, Mokokchung, Wokha, Zunheboto and Kohima station shows above the average mean precipitation. The spatial distribution of mean precipitation shows less than 150 mm in eastern, western and in a small pocket in south-west parts. It varies from 200 mm to more than 250 mm in the central and south-western parts. The rainfall intensity varies from 7 mm/ a rainy day at Kiphire to a maximum of 17 mm/ a rainy day at Mangkolemba and Mokokchung stations. The average rainfall intensity was 12.6 mm/ a rainy day. The value of rainfall intensity distribution shows less than 10 mm/ a rainy day to 12 mm/ a rainy day to the east and in tip of south-west. In the central parts it ranges from 12 mm/ a rainy day to more than 14 mm/ a rainy day. The rainfall variability varies from 18 percent at Kohima station to a maximum of 65 percent at Jalukie station. The average rainfall variability was 40.3 percent. The spatial distribution shows that eastern part around Tuensang rain-gauge station and Kohima station were recorded below 20 percent of rainfall variability. In the south and northern parts the value shows 40 percent. In the western and central part of the Nagaland the value ranges from 30 percent to 50 percent. The maximum concentration was shown along the south-west by 60 percent. The rainfall ratio ranges from 64 percent at Tuensang station to a maximum of 268 percent at Jalukie station. The average rainfall ratio was 150 percent. The spatial distribution of rainfall ratio was less than 100 percent in the eastern part. The value in the south ranges between 150 percent and 200 percent, 150 percent in the north and north-west, 150 percent to 200 percent in the central and maximum values of 200 percent to 250 percent was shown in the south-west of the study area **(Fig. 3.9)**.

Table 3.9: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(September)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	222	15	52	161
2	Dimapur	138	13	55	174
3	Jalukie	164	15	65	268
4	Kiphire	109	7	28	100
5	Kohima	277	13	18	137
6	Mangkolemba	299	17	36	126
7	Meluri	160	11	38	124
8	Mokokchung	269	17	31	113
9	Mon	226	13	40	158
10	Phek	174	11	49	212
11	Sechu	196	9	46	144
12	Tseminyu	190	13	35	124
13	Tuensang	166	8	19	64
14	Wokha	299	16	38	143
15	Yisemyong	229	13	42	140
16	Zunheboto	235	12	53	206

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (SEPTEMBER)

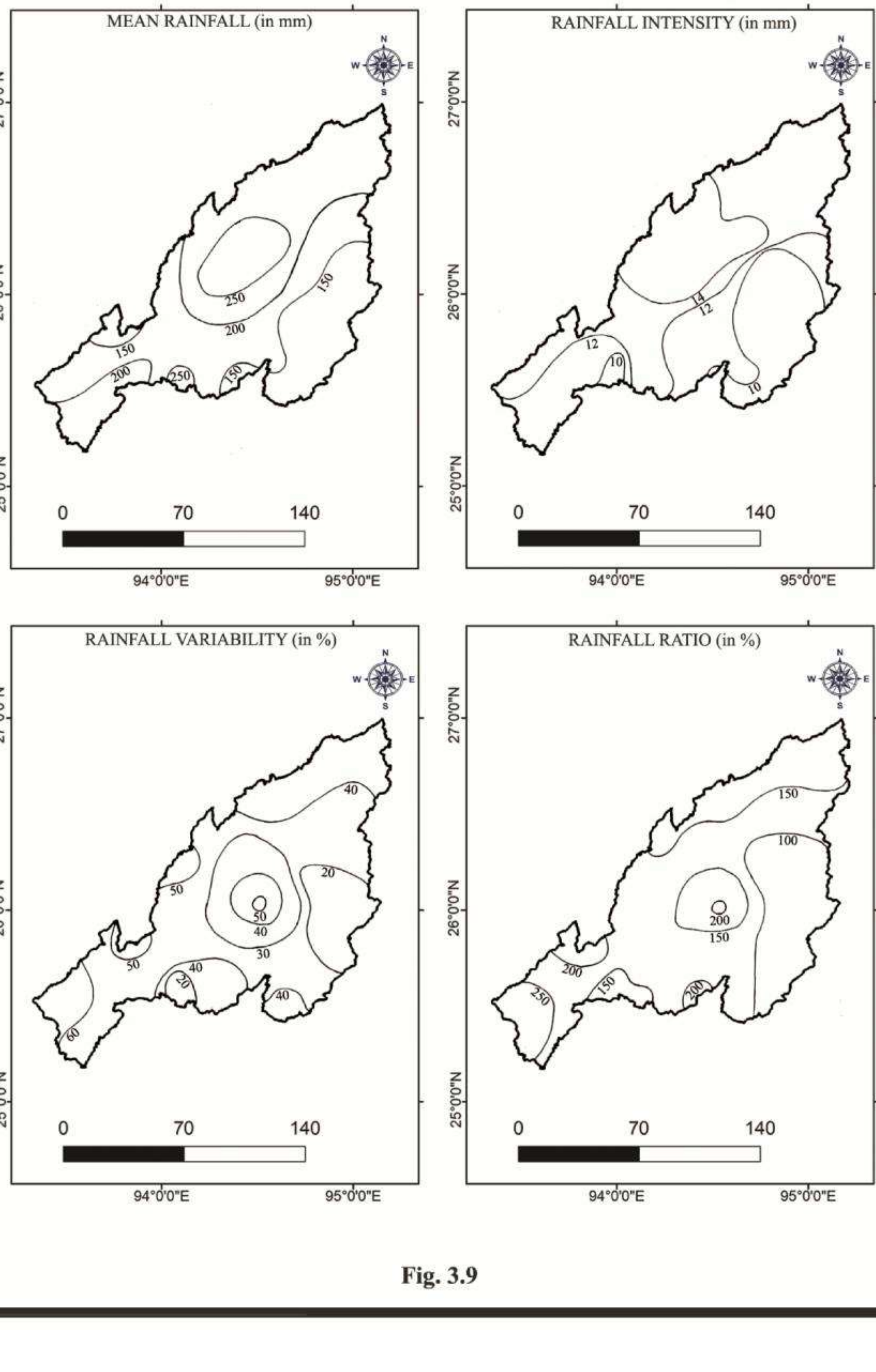

Fig. 3.9

3.1.10 October

In the month of October, values of mean precipitation vary from 79 mm at Tuensang station to a maximum of 160 mm at Yisemyong station**.** The average mean precipitation was 107 mm **(Table 3.10)**. The monthly value of mean precipitation was spatially distributed less than 90 mm in the east, south-west and in northern parts. In the south and western parts, the value varies from 90 mm to 110 mm. The maximum mean rainfall value that ranges from 110 mm to more than 130 mm was concentrated in the central parts of the state **(Fig. 3.10)**. The rainfall intensity ranges between 7 mm/ a rainy day at Kiphire and Tuensang station to 17 mm/ a rainy day at Jalukie rain-gauge station. The average rainfall intensity was 11 mm/ a rainy day. The spatial distribution of rainfall intensity below 10 mm/ a rainy day was observed in eastern and southern parts to 12 mm/ a rainy day distributed in central and western parts of the study area. It varies from 12 mm/ a rainy day to 14 mm/ a rainy day experienced in small pockets of the north-west and western parts, and more than 14 mm/ a rainy day in the south-west and north-west parts of Nagaland. The rainfall variability ranges from 3 percent at Tuensang station to a maximum of 89 percent at Zunheboto rain-gauge station. The average rainfall variability was 59 percent. The spatial distribution of rainfall variability recorded less than 50 percent in the south and eastern parts and it varies from 50 percent to 60 percent in the north and western parts. It ranges from 60 percent to 70 percent in the central, small pockets in the south and in south-west. It exceeded 70 percent only in the central parts of Nagaland. The rainfall ratio ranges from 105 percent at Tuensang station to a maximum of 316 percent at Zunheboto station. The average rainfall ratio was 198 percent. The rainfall ratio was spatially distributed less than 150 percent to 200 percent in the east, west, north and southern parts. The values from 200 percent to 250 percent were concentrated in the south-west and in central parts. The maximum rainfall ratio was concentrated in the central parts by more than 300 percent.

Table 3.10: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(October)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	104	13	63	201
2	Dimapur	87	15	57	198
3	Jalukie	86	17	74	260
4	Kiphire	85	7	42	129
5	Kohima	127	11	46	179
6	Mangkolemba	102	13	51	160
7	Meluri	97	11	74	138
8	Mokokchung	119	12	65	246
9	Mon	103	10	66	235
10	Phek	134	10	54	209
11	Sechu	101	8	58	154
12	Tseminyu	120	15	70	251
13	Tuensang	79	7	30	105
14	Wokha	131	12	40	155
15	Yisemyong	160	16	64	225
16	Zunheboto	82	9	89	316

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (OCTOBER)

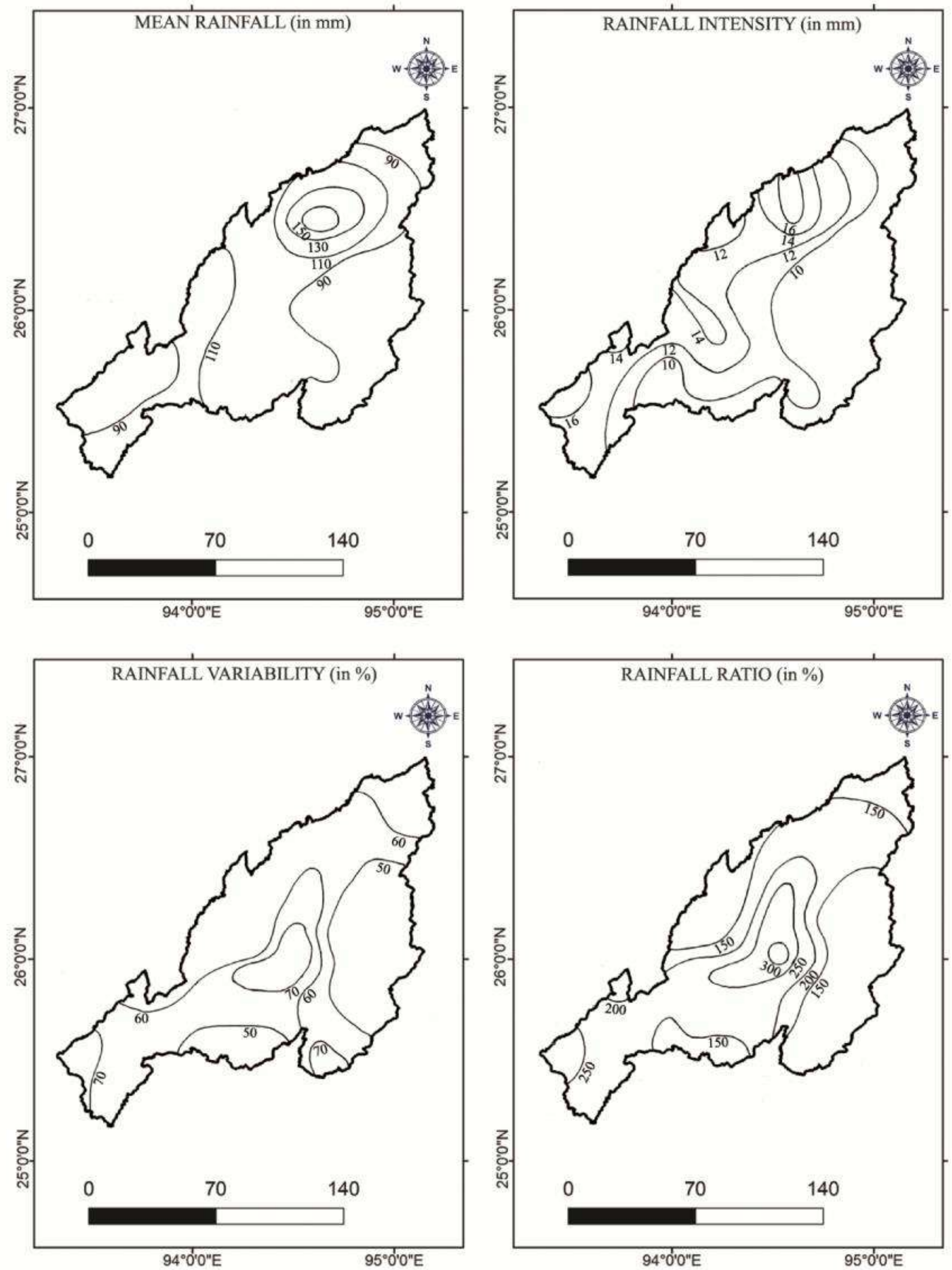

Fig. 3.10

3.1.11 November

The mean monthly precipitation values vary from a minimum of 8 mm at Dimapur, Tseminyu and Tuensang stations to a maximum of 55 mm at Yisemyong station **(Table 3.11)**. The average mean precipitation was 19.25 mm. The stations of Jalukie, Kohima, Phek and Wokha reveals above the average. The monthly spatial distribution of mean precipitation revealed less than 10 mm in the eastern and in the parts of the west. It ranges from 10 mm to 20 mm in the north, west, south and south-western parts. In the central and tip of south-west shows more than 30 mm and above 50 mm in the northern part of the state **(Fig. 3.11)**. The rainfall intensity varies from 4 mm/ a rainy day at Tuensang to a maximum of 28 mm/ a rainy day at Yisemyong station. The average rainfall intensity was 9 mm/ a rainy day. The values of rainfall intensity were spatially distributed less than 5 mm/ a rainy day to the east and in parts of the south. In the south-west, it varies from 10mm/ a rainy day to 15 mm/ a rainy day and more than 15 mm/ a rainy day concentrated in the north. The highest intensity above 25 mm was noticed in the northern parts. The minimum rainfall variability ranges from 100 percent at Meluri, Mon and Tuensang stations to a maximum of 188 percent at Dimapur station. The average rainfall variability was 126 percent. The spatial distribution of rainfall variability indicates less than 120 percent in the south, east and northern parts. In the central and north-western parts, the value ranges from 120 percent to 140 percent, while south-west part of the study area reveals high value concentration by more than 140 percent. The rainfall ratio ranges from 293 percent at Tuensang to a maximum of 709 percent at Jalukie station. The average rainfall ratio was 411 percent. The rainfall ratio was less than 300 percent in the flank of the east, at the peak of the north and tip of the south. In the central part it shows above 400 percent and 400 percent to 600 percent in the north-western part of the study area. The maximum distribution above 700 percent was concentrated in the south-west.

Table 3.11: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(November)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	13	7	138	446
2	Dimapur	8	8	188	584
3	Jalukie	31	16	177	709
4	Kiphire	14	5	114	326
5	Kohima	22	7	105	361
6	Mangkolemba	17	9	124	327
7	Meluri	19	10	100	301
8	Mokokchung	12	6	125	375
9	Mon	16	5	100	333
10	Phek	20	7	115	398
11	Sechu	10	5	110	360
12	Tseminyu	8	8	150	408
13	Tuensang	8	4	100	293
14	Wokha	39	13	105	299
15	Yisemyong	55	28	150	625
16	Zunheboto	16	8	113	424

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (NOVEMBER)

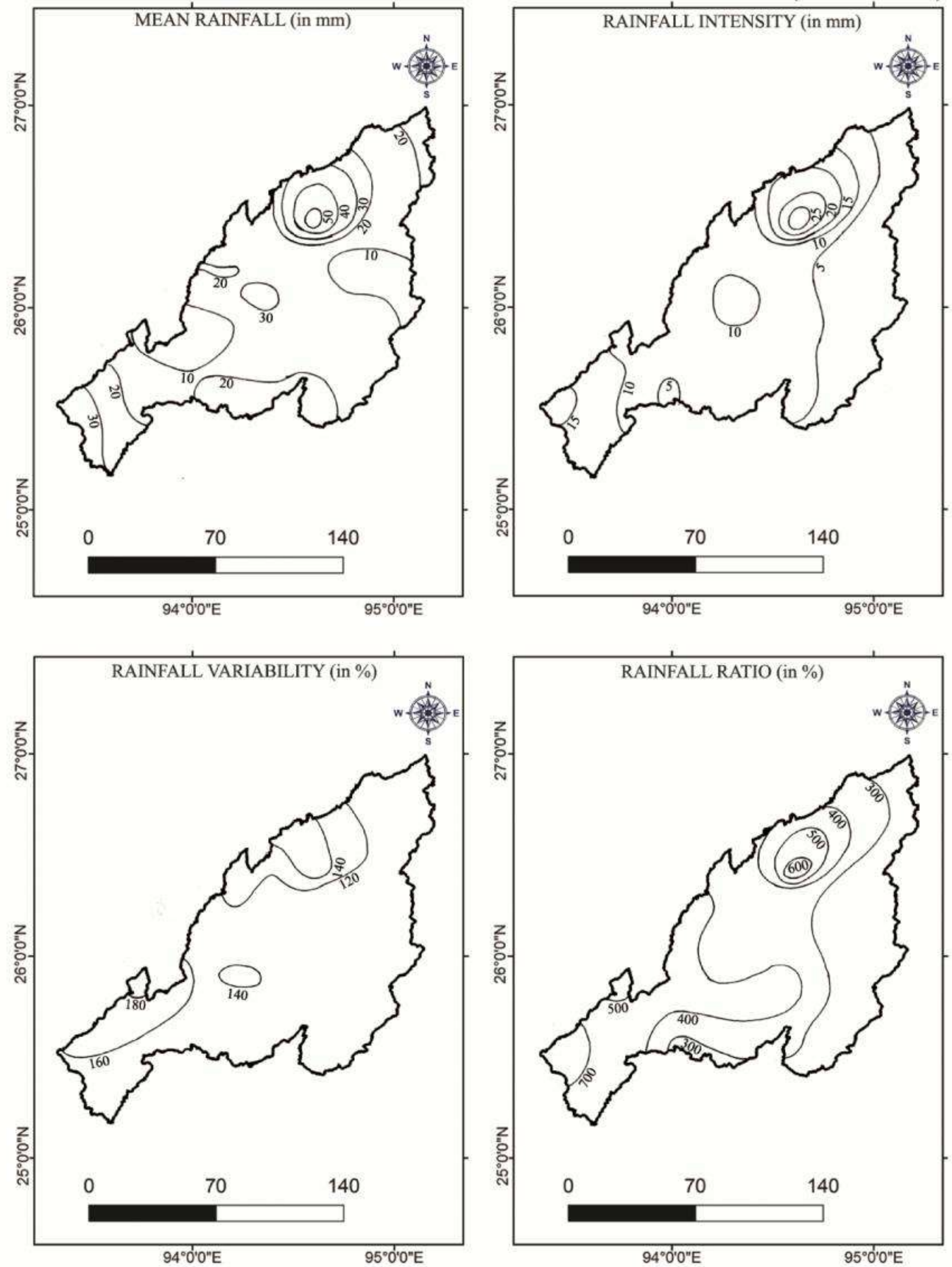

Fig. 3.11

3.1.12 December

In the month of December, the mean precipitation values vary from 2 mm at Tseminyu rain-gauge station to a maximum of 10 mm at Wokha station. The average mean precipitation was 6 mm **(Table 3.12)**. The monthly spatial distribution of mean precipitation in the parts of north and central area were recorded by less value of 4.5 mm. In the east, south and northern parts the value ranges between 4.5 mm and 9.5 mm. The maximum spatial distribution of mean precipitation more than 9.5 mm was shown in the western part around Wokha and Tuensang rain-gauge station to the east **(Fig. 3.12)**. The rainfall intensity varies from 2 mm/ a rainy day at the station of Tseminyu to a maximum of 9 mm/ a rainy day at Phek and Tuensang stations. The average rainfall intensity was 5 mm/ a rainy day. The rainfall intensity was spatially distributed less than 4 mm/ a rainy day to 8 mm/ a rainy day in the east, west and southern parts of Nagaland. In the north-west and in small pockets in south, it shows the value more than 8 mm/ a rainy day. The rainfall variability ranges from 100 percent at Tseminyu station to a maximum of 238 percent at Yisemyong station. The average rainfall variability was 162 percent. The distribution of rainfall variability in this month shows less than 180 percent in the north, east and southern parts of the area, and it ranges from 180 percent to above 200 percent in the northern parts. The rainfall ratio varies from 210 percent at Tseminyu station to a maximum of 969 percent at Yisemyong station. The average rainfall ratio was 596 percent. The spatial distribution of rainfall ratio shows less than 500 percent in the east, west and south. It varies 500 percent to 700 percent in the south-western parts and highest value above 900 percent was concentrated in the north.

Table 3.12: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(December)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	9	5	133	508
2	Dimapur	3	3	200	643
3	Jalukie	3	3	200	873
4	Kiphire	3	3	167	567
5	Kohima	7	7	171	746
6	Mangkolemba	6	6	133	400
7	Meluri	6	6	150	582
8	Mokokchung	4	4	125	363
9	Mon	5	5	180	820
10	Phek	9	9	144	567
11	Sechu	3	3	200	407
12	Tseminyu	2	2	100	210
13	Tuensang	9	9	189	623
14	Wokha	10	5	130	442
15	Yisemyong	8	8	238	969
16	Zunheboto	3	3	133	810

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (DECEMBER)

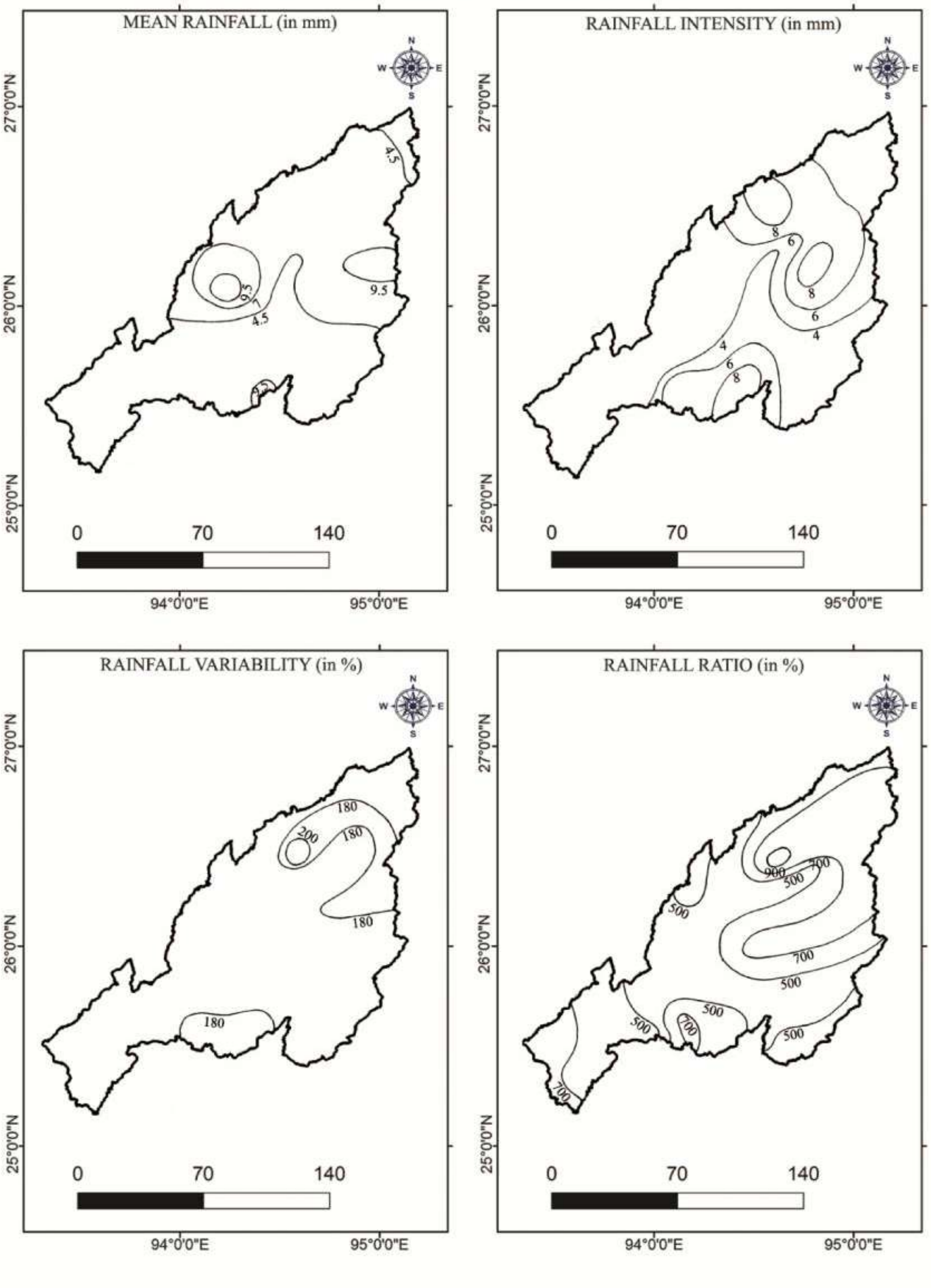

Fig. 3.12

3.2 Analysis of Monthly Mean Rainfall

The mean monthly rainfall analysis of Nagaland shows that the mean rainfall less than 100 mm were recorded during the months of November, December, January, February and March (five months). Out of which, the month of December shows less value of 6 mm, where the rain-gauge station of Tseminyu recorded the lowest value of 2 mm. The months of April, May, June, July, August, September and October recorded mean monthly rainfall above 100 mm. The maximum monthly mean rainfall of 314 mm was recorded in the month of August, where the rain-gauge station of Mokokchung received the highest value of 454 mm **(Table 3.13)**. The monthly mean rainfall intensity of less than 10 mm/ a rainy day were found out in the months of November, December, January, February and March. The lowest intensity was recorded in December by 5 mm/ a rainy day, where Tseminyu station recorded less intensity of 2 mm/ a rainy day. The months of April, May, June, July, August, September and October recorded 10 mm/ a rainy day and above. The maximum intensity of 15 mm/ a rainy day was recorded during the months of July and August, where Mokokchung station recorded the highest intensity during these two months by 20 mm/ a rainy day and 19 mm/ a rainy day respectively. The mean rainfall variability above 100 percent were recorded during the months of November, December, January and February, where the maximum mean variability of 162 percent was recorded in December. The rain-gauge station of Yisemyong shows the highest mean variability of 238 percent. The months of March, April, May and October recorded above 50 percent while the months of June, July, August and September recorded less than 50 percent of rainfall variability, where July revealed the lowest variability by 35 percent on which the rain-gauge station of Mangkolemba recorded less variability by 15 percent. The monthly mean rainfall ratio above 400 percent was recorded in the months of November, December, January and February. The month of December shows the highest mean ratio of 596 percent where Yisemyong station was shown with highest ratio of 969 percent. The mean ratio above 200 percent was concentrated in the months of March and April. The months of May, June, July, August, September and October revealed below 200 percent, where July recorded less ratio of 128 percent in which Mangkolemba rain-gauge station recorded lowest mean rainfall ratio of 51 percent.

Table 3.13: The analysis of mean monthly rainfall

Sl. No	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Bhandari	12	15	35	126	152	267	326	331	222	104	13	9
2	Dimapur	4	12	24	62	105	190	176	175	138	87	8	3
3	Jalukie	6	19	38	100	146	186	230	235	164	86	31	3
4	Kiphire	9	9	21	51	102	133	181	169	109	85	14	3
5	Kohima	10	37	54	104	186	264	355	352	277	127	22	7
6	Mangkolemba	7	20	59	165	218	357	413	332	299	102	17	6
7	Meluri	10	11	18	67	118	174	220	201	160	97	19	6
8	Mokokchung	16	13	54	120	216	337	454	392	269	119	12	4
9	Mon	23	33	87	148	185	316	398	317	226	103	16	5
10	Phek	12	15	31	85	164	213	286	249	174	134	20	9
11	Sechu	10	17	44	82	129	222	284	217	196	101	10	3
12	Tseminyu	6	18	20	51	142	294	363	249	190	120	8	2
13	Tuensang	10	14	34	96	141	225	290	241	166	79	8	9
14	Wokha	27	50	77	134	268	361	409	401	299	131	39	10
15	Yisemyong	15	37	98	140	199	268	337	290	299	160	55	8
16	Zunheboto	14	7	25	106	214	282	297	292	235	82	16	3

Source: Compiled by the Scholar.

3.3 Seasonal Mean Rainfall

To study the season-wise mean rainfall, it is divided into four seasons. These are Winter (December to February), Pre-monsoon (March to May), Monsoon (June to August) and Post-monsoon (September to November).

3.3.1 Winter

In the winter season, the mean rainfall value ranges from 19 mm at Dimapur station to a maximum of 87 mm at Wokha rain-gauge station **(Table 3.14)**. The average mean precipitation was 38 mm. In the tip of the south, the value was recorded 40 mm. The spatial distribution of mean rainfall shows less than 20 mm around Dimapur rain-gauge station and in part of south-east. The highest value of mean precipitation was recorded in the central and western parts of Nagaland that ranges from 40 mm to 80 mm **(Fig. 3.13)**. The rainfall intensity during this season was recorded a minimum value of 4 mm/ a rainy day at Kiphire, Sechu and Zunheboto rain-gauge stations to a maximum of 10 mm/ a rainy day at Wokha and Yisemyong stations. The average value of rainfall intensity was 6 mm/ a rainy day. The stations of Bhandari, Dimapur, Mangkolemba, Meluri, Phek, and Tuensang rain-gauge stations were recorded below the average. The spatial distribution indicates low intensity of 5 mm/ a rainy day to 7 mm/ a rainy day along the eastern, southern and parts of the west. The high intensity above 9 mm/ a rainy day was observed at the central part of Nagaland. The minimum rainfall variability was recorded 20 percent at Bhandari, Phek and Tuensang rain-gauge stations and maximum at Kohima station by 80 percent. The average rainfall variability was 51 percent. The spatial distribution of rainfall variability revealed that below 25 percent concentrated in the east, south-east and parts of the west. The average rainfall variability was 51 percent. The highest concentration of 75 percent and above was noticed in the southern part and above 50 percent concentrated in the central and northern parts of Nagaland. The rainfall ratio widely varies from 45 percent at Tuensang to a maximum of 178 percent at Jalukie station and an average of 119 percent. The spatial distribution shows high rainfall ratio in Dimapur, Jalukie, Kohima and Tseminyu stations by 150 percent and above while the rest parts of the area indicates below 150 percent.

Table 3.14: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(Winter)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	36	5	20	50
2	Dimapur	19	5	64	150
3	Jalukie	28	7	74	178
4	Kiphire	21	4	40	86
5	Kohima	54	7	80	167
6	Mangkolemba	33	5	58	127
7	Meluri	27	5	24	56
8	Mokokchung	33	7	46	109
9	Mon	61	7	59	140
10	Phek	36	5	20	50
11	Sechu	30	4	57	140
12	Tseminyu	26	7	79	177
13	Tuensang	33	5	20	45
14	Wokha	87	10	57	138
15	Yisemyong	60	10	62	145
16	Zunheboto	24	4	57	138

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (WINTER)

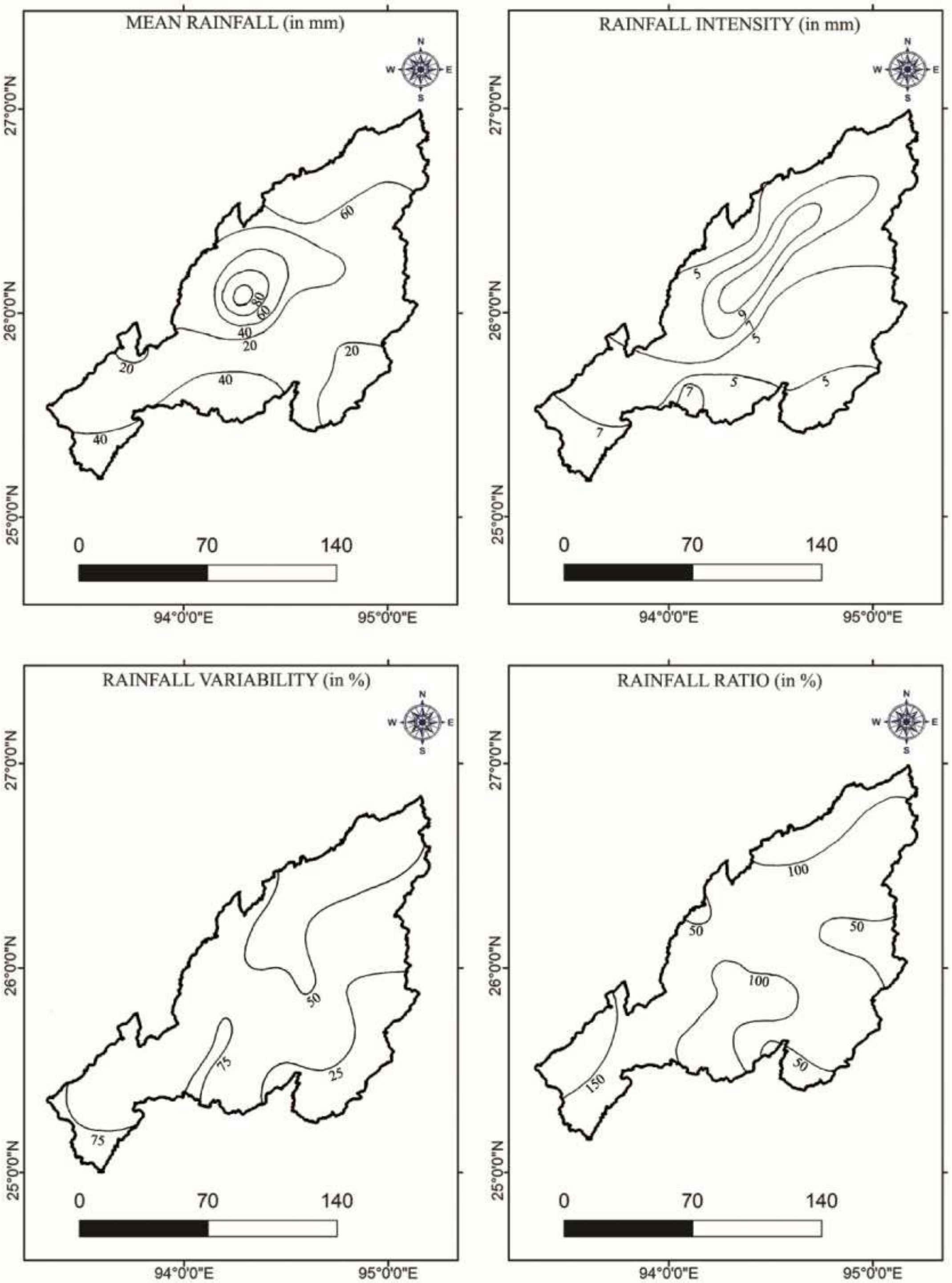

Fig. 3.13

3.3.2 Pre-monsoon

The mean rainfall values of the pre-monsoon season were observed from 174 mm at Kiphire station to a maximum of 479 mm at Wokha station **(Table 3.15)**. The average mean rainfall was 315 mm. The spatial distribution of precipitation indicates less than 200 mm in the south-west, in the south and in eastern parts of the state. The highest concentration of mean precipitation was shown in central and northern parts by 400 mm **(Fig. 3.14)**. The rainfall intensity varies from 5 mm/ a rainy day at Kiphire station to a maximum of 14 mm/ a rainy day at Jalukie and Wokha rain-gauge stations. The average rainfall intensity was 10 mm/ a rainy day. The spatial distribution of rainfall intensity shows that in the eastern part of the state around Kiphire station shows low intensity of 5 mm/ a rainy day. The highest intensity was recorded in the central and in southern-west of the study area by 12.5 mm/ a rainy day and above. The rainfall variability of minimum value 28 percent was recorded at Yisemyong station and maximum at Tseminyu station by 73 percent. The average rainfall variability was 51 percent. The spatial distribution of rainfall variability shows high concentration from 50 percent to 70 percent and above in the central parts, below 50 percent in the south-western and above 30 percent in northern parts of the study area. The rainfall ratio of this season recorded a minimum of 69 percent at Yisemyong rain-gauge station while Bhandari station shows 334 percent as maximum value. The average rainfall ratio was 135 percent. The spatial rainfall ratio distribution shows below 100 percent in the north, east and southern parts of the state. The highest concentration from 200 percent to above 300 percent was shown in the western parts of the study area.

Table 3.15: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(Pre-monsoon)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	313	10	48	334
2	Dimapur	191	10	52	127
3	Jalukie	284	14	47	114
4	Kiphire	174	5	58	140
5	Kohima	344	9	47	115
6	Mangkolemba	442	13	50	108
7	Meluri	203	8	60	147
8	Mokokchung	390	13	55	125
9	Mon	420	11	29	70
10	Phek	280	7	59	143
11	Sechu	255	8	41	100
12	Tseminyu	213	10	73	172
13	Tuensang	271	7	49	119
14	Wokha	479	14	50	119
15	Yisemyong	437	13	28	69
16	Zunheboto	345	10	67	164

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (PRE-MONSOON)

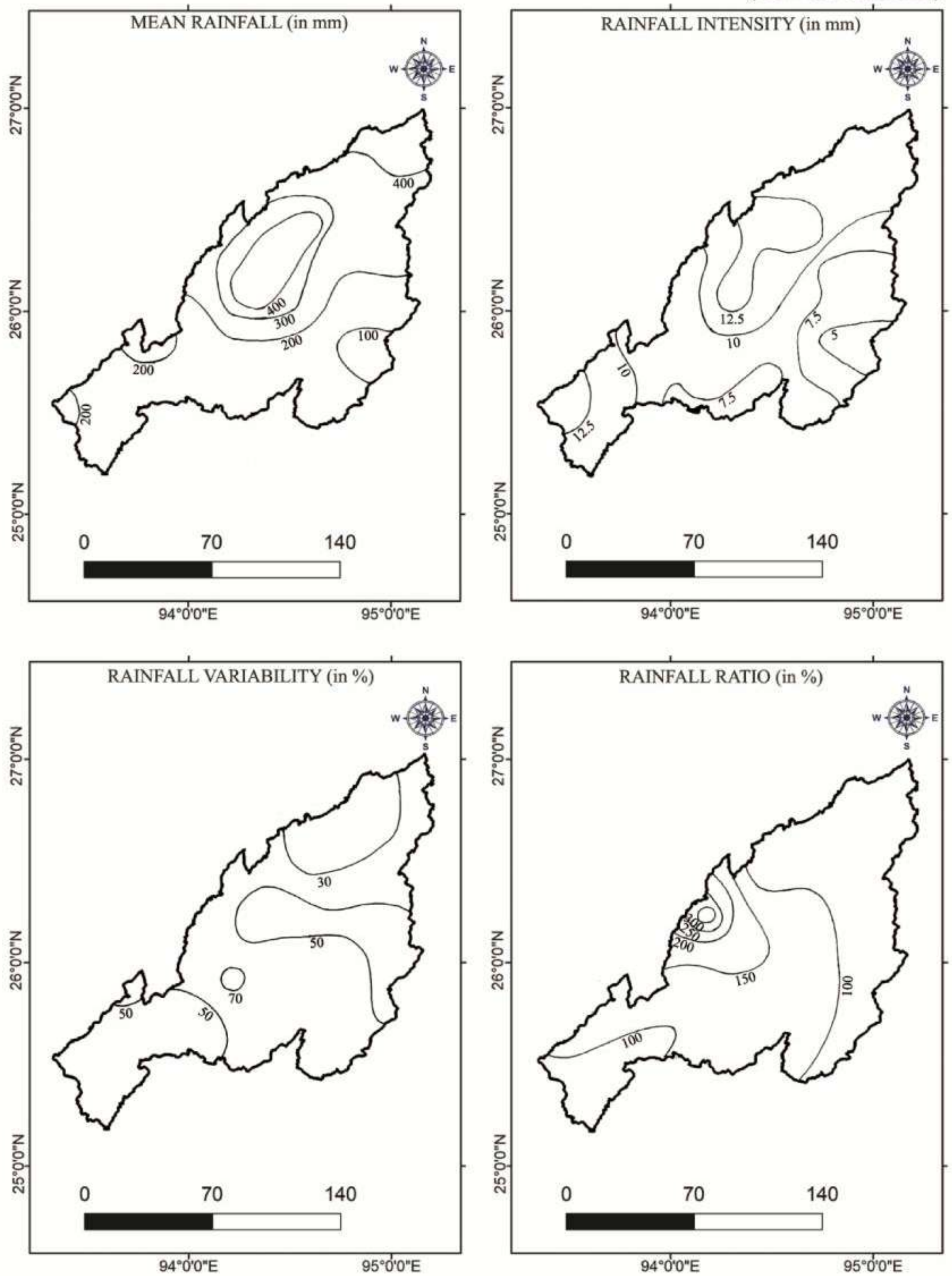

Fig. 3.14

3.3.3 Monsoon

The monsoon seasonal mean rainfall varies from 483 mm at Kiphire station to a maximum of 1183 mm at Mokokchung station. The average mean rainfall was 847 mm. The rain-gauge stations of Dimapur, Jalukie, Meluri, Phek, Sechu and Tuensang recorded below the average **(Table 3.16)**. The spatial distribution of mean precipitation shows less than 700 mm in the eastern and southern parts. In the tip of the south, 900 mm value was recorded around Kohima rain-gauge station. The maximum concentration of mean precipitation was observed in the western corridor that varies from 900 mm to above 1100 mm. **(Fig. 3.15)**. The rainfall intensity of minimum value of 8 mm/ a rainy day was recorded at Kiphire to a maximum of 19 mm/ a rainy day at Mokokchung rain-gauge station. The average rainfall intensity was 14 mm/ a rainy day where Bhandari, Dimapur, Jalukie, Mangkolemba, Mon, Tseminyu, Wokha and Yisemyong stations recorded above the average. The spatial distribution shows high prevalence in central and western parts that ranges from 16 mm/ a rainy day to 18 mm/ a rainy day. In the north and south-western it shows 16 mm/ a rainy day while in the east it was observed 12 mm/ a rainy day. The rainfall variability with a minimum of 2 percent at Zunheboto to a maximum of 16 percent was recorded at Tseminyu rain-gauge station. The average rainfall variability was 10 percent. The spatial distribution of rainfall variability were revealed 10 percent and above in the eastern flank and in southern part. In the western part, it was concentrated between 5 percent and 10 percent. The highest concentration was observed in the central parts around Tseminyu rain-gauge station. The rainfall ratio was recorded 5 percent at Zunheboto station as minimum and 38 percent at Tseminyu as maximum value. The average rainfall ratio of monsoon season was 23 percent. The spatial distribution of rainfall ratio shows below 25 percent in the east, west and northern parts, while southern part experienced more than 35 percent of rainfall ratio.

Table 3.16: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(Monsoon)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	924	16	9	19
2	Dimapur	541	15	4	8
3	Jalukie	651	16	10	23
4	Kiphire	483	8	13	30
5	Kohima	971	13	13	28
6	Mangkolemba	1102	17	9	22
7	Meluri	595	12	10	23
8	Mokokchung	1183	19	12	30
9	Mon	1031	16	11	24
10	Phek	748	11	12	29
11	Sechu	723	11	13	28
12	Tseminyu	906	16	16	38
13	Tuensang	756	10	11	26
14	Wokha	1171	18	5	12
15	Yisemyong	895	15	10	23
16	Zunheboto	871	13	2	5

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND **(MONSOON)**

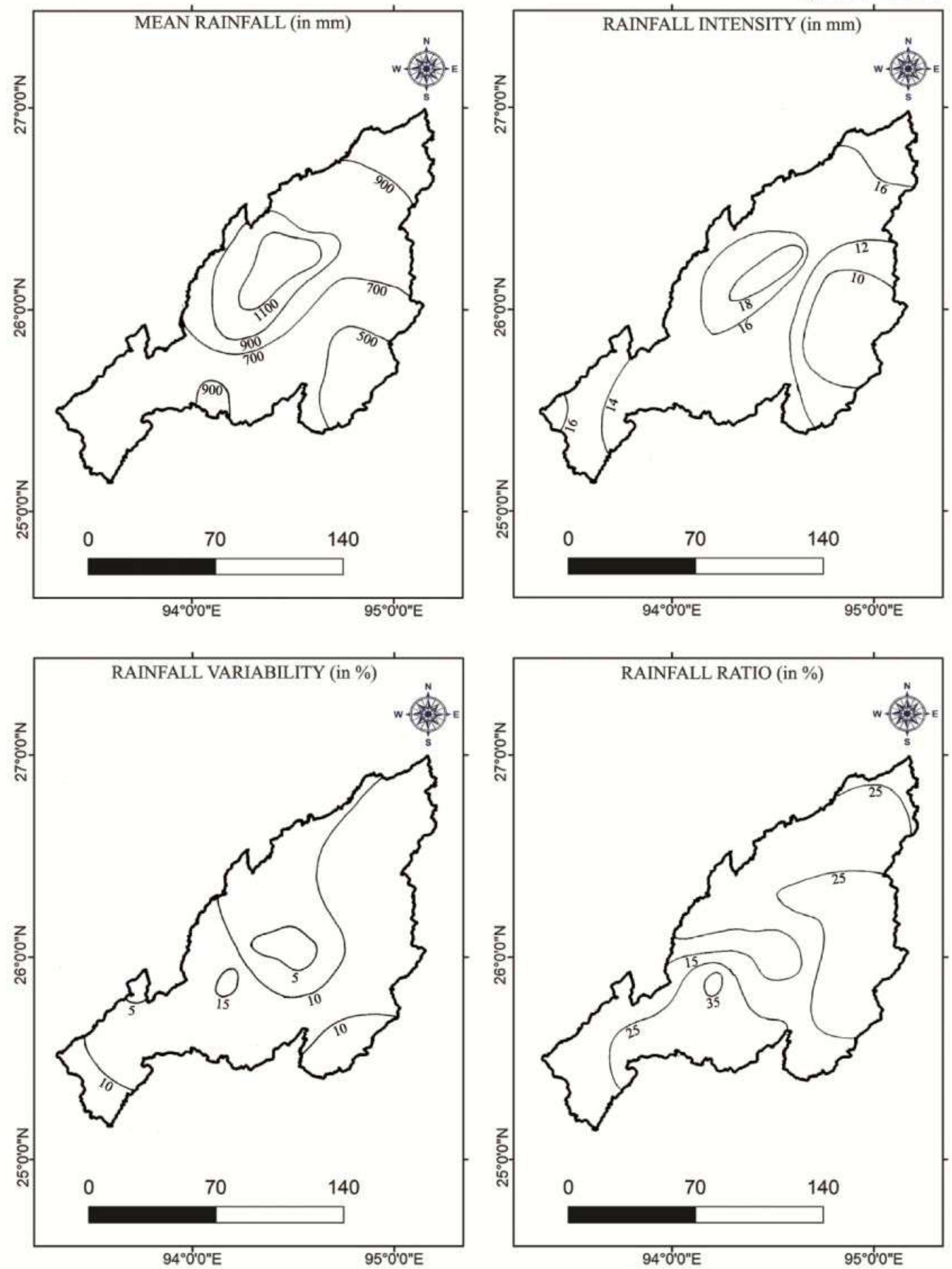

Fig. 3.15

3.3.4 Post-monsoon

In the post-monsoon period, mean rainfall was recorded 208 mm at Kiphire to a maximum of 469 mm at Wokha rain-gauge station **(Table 3.17)**. The average mean precipitation was 336 mm. The spatial distribution of post-monsoon varies from 200 mm to 250 mm in the east, 400 mm in the south, 300 mm to 350 mm in the western and above 450 mm in the central part of Nagaland **(Fig. 3.16)**. The rainfall intensity at Kiphire station was recorded minimum by 5 mm/ a rainy day while Jalukie station recorded maximum value of 16 mm/ a rainy day. The average rainfall intensity of this season was 12 mm/ a rainy day. The spatial distribution revealed 5 mm/ a rainy day to 10 mm/ a rainy day in the east and in southern parts. The maximum intensity of 15 mm/ a rainy day was recorded in the south-west and in northern parts of the area. The rainfall variability varies from a minimum of 49 percent at Yisemyong station to a maximum of 85 percent at Mangkolemba rain-gauge station with an average value of 70 percent. The spatial distribution of rainfall variability was observed 60 percent to 70 percent in the flank of the east, south and western parts. In the north-western part the concentration revealed 50 percent to 70 percent. The highest rainfall variability was concentrated in the central part by above 80 percent. The rainfall ratio varies from 118 percent at Yisemyong station to a maximum of 203 percent at Mangkolemba rain-gauge station. The average rainfall ratio was 169 percent. The spatial distribution of rainfall ratio shows above 140 percent in the south-east and in south-western, 180 percent in the north and south, and high rainfall ratio above 200 percent in the western part of Nagaland.

Table 3.17: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(Post-Monsoon)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	339	14	76	185
2	Dimapur	233	13	68	167
3	Jalukie	281	16	58	141
4	Kiphire	208	5	58	138
5	Kohima	426	12	74	180
6	Mangkolemba	418	15	85	203
7	Meluri	276	11	63	153
8	Mokokchung	400	14	79	193
9	Mon	345	12	75	183
10	Phek	328	10	60	141
11	Sechu	307	9	75	182
12	Tseminyu	318	15	71	172
13	Tuensang	253	7	77	188
14	Wokha	469	14	69	167
15	Yisemyong	444	15	49	118
16	Zunheboto	333	11	83	197

Source: Soil and Water Conservation Department, Nagaland.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND (POST-MONSOON)

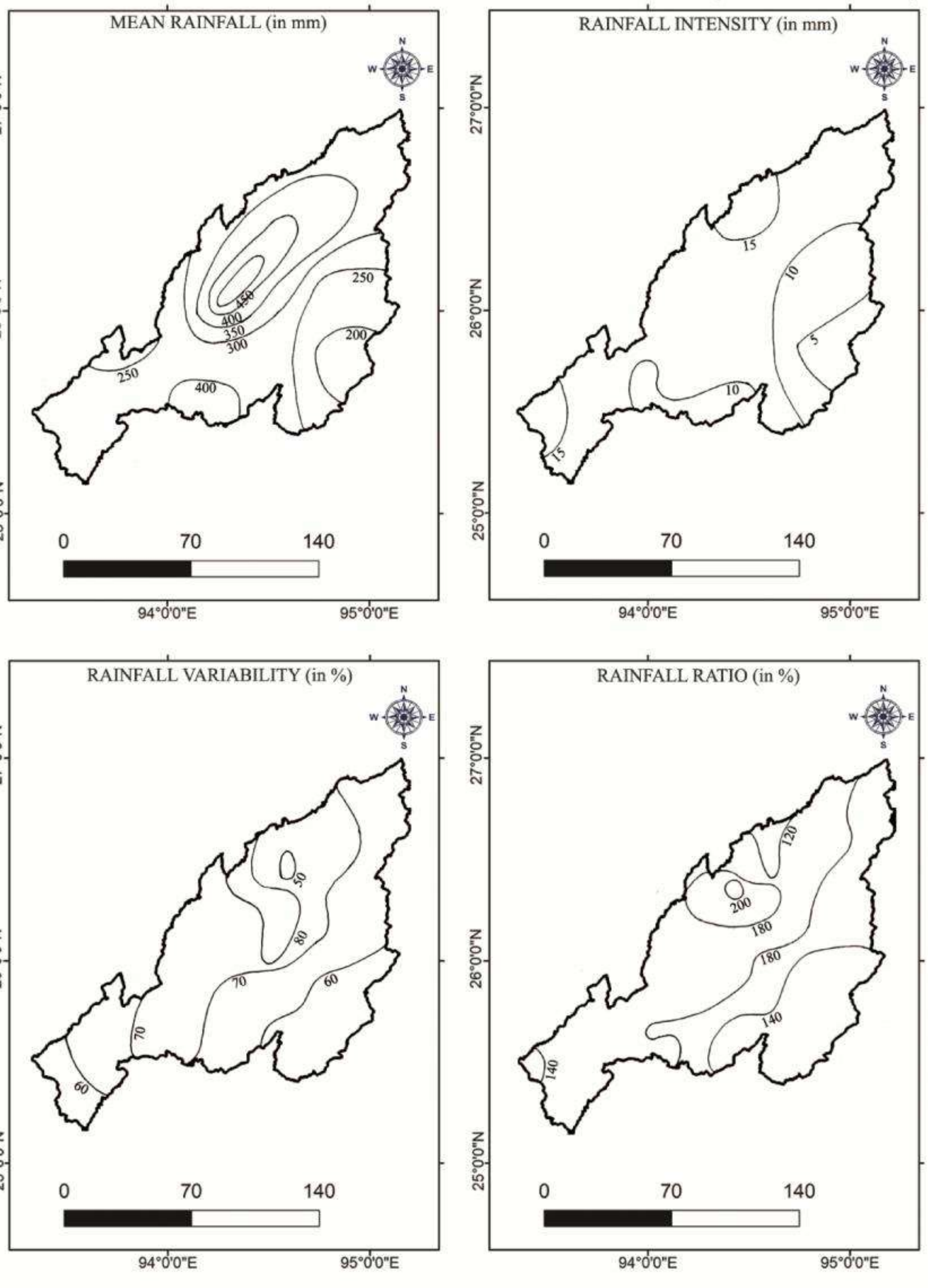

Fig. 3.16

3.4 Analyses of Seasonal Mean Rainfall

The analyses of seasonal mean rainfall shows that the study area received maximum rainfall during monsoon season which recorded 847 mm **(Table 3.18)**. The seasons of pre-monsoon and post-monsoon received mean rainfall of 315 mm and 336 mm respectively. The winter season recorded minimum mean rainfall of 38 mm. The analysis of rainfall intensity indicates that monsoon season shows maximum intensity of 14 mm/ a rainy day while winter season recorded minimum intensity of 6 mm/ a rainy day. The seasons of pre-monsoon and post-monsoon recorded intensity value of 10 mm/ a rainy day and 12 mm/ a rainy day respectively. The rainfall variability was highest during post-monsoon season by 70 percent. The seasons of winter and pre-monsoon recorded 51 percent each. The rainfall variability of less value was shown in monsoon season by 10 percent. The concentration of rainfall ratio reveals that the post-monsoon season recorded high ratio of 169 percent. The rainfall ratio of winter was shown 119 percent and pre-monsoon by 135 percent. The lowest ratio was shown in monsoon season by 23 percent.

Table 3.18: Season-wise Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

Sl. No.	Seasons	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Winter	38	6	51	119
2	Pre-monsoon	315	10	51	135
3	Monsoon	847	14	10	23
4	Post-monsoon	336	12	70	169

Source: Compiled by Scholar.

3.5 Annual Mean Rainfall

The annual mean rainfall widely varies from a minimum of 886 mm at Kiphire to a maximum of 2206 mm at Wokha rain-gauge station **(Table 3.19)**. The average mean rainfall was 1536 mm. The rain-gauge stations of Bhandari, Kohima, Mangkolemba, Mokokchung, Mon, Yisemyong and Zunheboto recorded above the average mean rainfall. The spatial distribution varies from 900 mm to 1300 mm in the eastern and south-western parts, 1300 mm to 1700 mm in the tip of the south and in the central part, high concentration above 2100 mm was observed **(Fig. 3.17)**. The rainfall intensity varies from 23 mm/ a rainy day at Kiphire to 56 mm/ a rainy day at Wokha station. The average rainfall intensity was 42 mm/ a rainy day. The spatial distribution of annual rainfall intensity shows that less than 30 mm/ a rainy day were concentrated in the east and above 40 mm/ a rainy day in the south, to the north and western parts. The highest concentration above 50 mm/ a rainy day was observed in central and south-western parts of the study area. The annual rainfall variability varies from 71 percent at Yisemyong to 99 percent at Tseminyu station with an average of 86 percent. The spatial distribution of rainfall variability revealed minimum concentration less than 75 percent observed around Yisemyong rain-gauge station and less than 85 percent in the eastern flank. In the southern and western parts it ranges from 85 percent to 95 percent where maximum concentration above 95 percent was observed around Tseminyu station. The rainfall ratio recorded a minimum of 150 percent at Yisemyong while Tseminyu station recorded a maximum value of 296 percent. The annual rainfall ratio average was 238 percent.

The rainfall ratio was spatially distributed that varies from 200 percent to 240 percent in the east, central and south-west, and above 240 percent in the west and northern parts of the study area. The minimum rainfall ratio was observed in parts of north-west around Yisemyong station with less than 160 percent and maximum recorded in the south-west above 280 percent around Tseminyu station.

Table 3.19: Mean Rainfall, Rainfall Intensity, Rainfall Variability and Rainfall Ratio of Nagaland (1986-2015)

(Annual)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Rainfall Intensity in mm	Rainfall Variability in %	Rainfall Ratio in %
1	Bhandari	1612	45	89	240
2	Dimapur	984	42	86	228
3	Jalukie	1244	52	80	223
4	Kiphire	886	23	84	241
5	Kohima	1795	41	85	232
6	Mangkolemba	1995	49	88	245
7	Meluri	1101	36	85	233
8	Mokokchung	2006	53	93	269
9	Mon	1857	44	83	254
10	Phek	1392	33	84	239
11	Sechu	1315	32	86	255
12	Tseminyu	1463	47	99	296
13	Tuensang	1313	29	89	258
14	Wokha	2206	56	80	216
15	Yisemyong	1836	53	71	150
16	Zunheboto	1573	38	90	224

Source: Compiled by Scholar.

MEAN RAINFALL, RAINFALL INTENSITY, RAINFALL VARIABILITY AND RAINFALL RATIO OF NAGALAND

(ANNUAL)

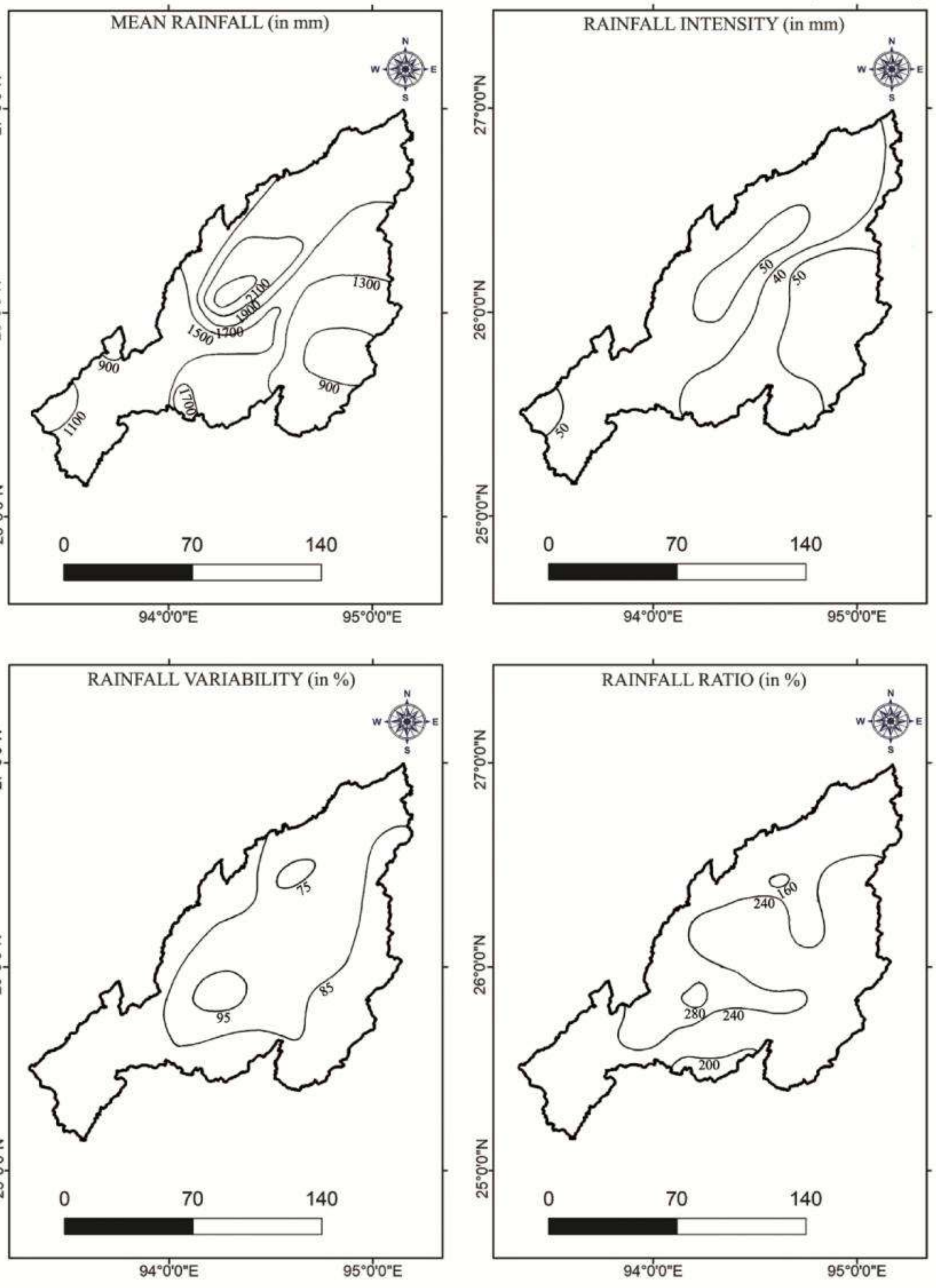

Fig. 3.17

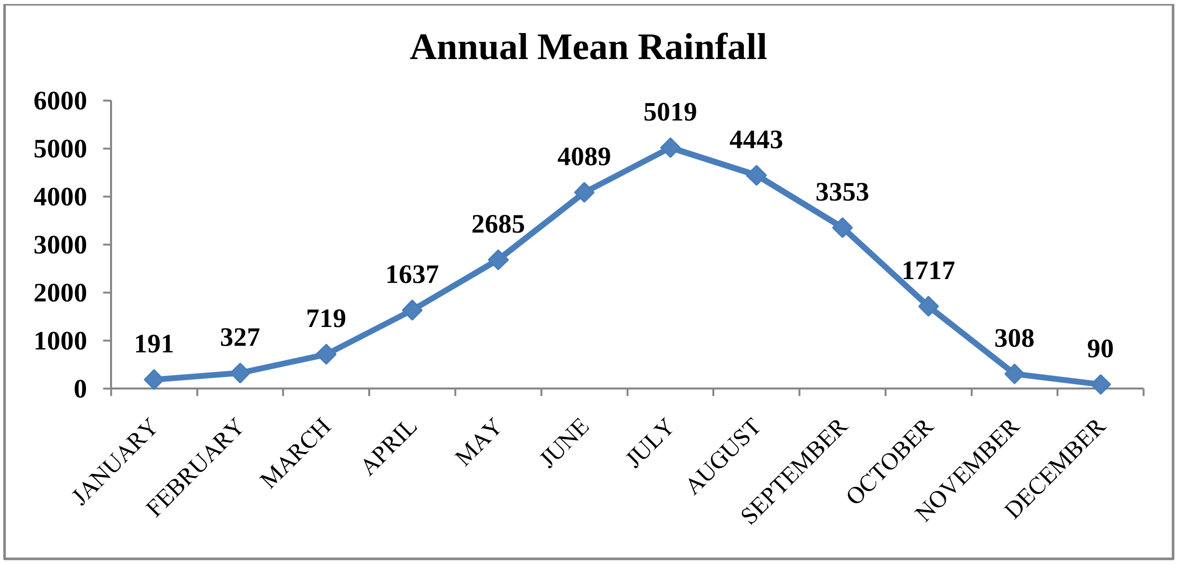

Fig. 3.18

3.6 Annual Groundwater Recharge

The annual groundwater recharge of Nagaland was estimated through the following methods of Radhakrishna *et al*. (1974), U.S. Geological (1962), Seghal's (1973) and Krishna Rao (1970).

According to Radhakrishna *et al.* (1974) method the groundwater recharge of an area or basin is 10 percent of the mean annual rainfall. The groundwater recharge varies from a minimum of 89 mm at Kiphire station to a maximum of 221 mm at Wokha station **(Table 3.20 & Fig 3.18)**. The average annual groundwater recharge was 154 mm. The spatial distribution shows that the annual groundwater recharge was less than 150 mm in the east, above 150 mm in the north and west. The value was around 150 mm in the south and below 100 mm in the south-west. The groundwater recharge was higher in the central part of Nagaland with above 200 mm.

U.S. Geological method (1962) calculates that the annual groundwater recharge of an area is 15 percent of the annual average rainfall. According to this method the Kiphire station shows minimum value of 133 mm and the maximum recharge of 331 mm at Wokha station. The annual recharge of the study area was 230 mm. The spatial distribution shows that the annual recharge was less than 200 mm in eastern and south-west of the study area. In the south, it shows above 200 mm and above 250 mm in the north and western part. The groundwater recharge was more than 300 mm in the central part of Nagaland.

The Seghal's Method (1973) estimates groundwater recharge by the formula $G = 2.5\ (P-16)^{0.5}$ where precipitation is in inches. According to this method the annual groundwater recharge were relatively high. The minimum groundwater value of 276 mm was noticed at Kiphire station to a maximum of 535 mm in Wokha station. The average annual recharge was 417 mm. The spatial distribution shows that the annual recharge was less than 400 mm. The spatial distribution shows that the annual recharge was less than 400 mm in eastern and southern-west parts of the area. The annual recharge exceeded 400 mm in the southern and western parts. To the north the value exceeded 450 mm and the central part of the study area shows high value above 500 mm.

According to Krishna Rao Method (1970), the annual groundwater recharge R=0.20 (P-400) when precipitation is between 400 to 600 mm, R=0.25 (P-400) when precipitation is 600 to 1000 mm, and R=0.35 (P-600) when precipitation is 100 mm and above. By this method, the annual recharge varies from a minimum of 122 mm in Kiphire station to a maximum of 562 mm at Wokha station. The annual recharge was 330 mm. The spatial distribution shows that the annual recharge was less than 300 mm in eastern and south-west. In the southern part the value ranges from 300 mm to 400 mm. In the western and northern part the recharge value was between 300 mm to 450 mm. the recharge value was higher in central parts to the west of Nagaland by more than 500 mm.

The estimation of all the available rain-gauge stations of Nagaland through these four methods shows that the average annual recharge varies from a minimum of 413 mm at Kiphire station to a maximum of 1247 mm at Wokha station. The average groundwater recharge was 818 mm. The total groundwater resources have been estimated to be (Total geographical area X mean groundwater recharge) 13,561,622,000 m^3.

Table 3.20: Annual Groundwater Recharge
(All values in mm)

Sl. No.	Rain-gauge station	Mean Rainfall in mm	Radha-krishna *et al.* Method (1974)	U.S. Geological Method (1962)	Seghal's Method (1973)	Krishna Rao Method (1970)	Average Annual Recharge
1	Bhandari	1612	161	242	438	354	867
2	Dimapur	984	98	148	303	146	468
3	Jalukie	1244	124	187	365	225	627
4	Kiphire	886	89	133	276	122	413
5	Kohima	1795	180	269	470	418	984
6	Mangkolemba	1995	200	299	502	488	1112
7	Meluri	1101	110	165	332	175	533
8	Mokokchung	2006	201	301	504	492	1120
9	Mon	1857	186	279	480	440	1024
10	Phek	1392	139	209	396	277	724
11	Sechu	1315	132	197	380	250	674
12	Tseminyu	1463	146	219	410	302	770
13	Tuensang	1313	131	197	380	250	673
14	Wokha	2206	221	331	535	562	1247
15	Yisemyong	1836	184	275	477	433	1011
16	Zunheboto	1573	157	236	431	341	842

Source: Compiled by the Scholar.

ANNUAL GROUNDWATER RECHARGE OF NAGALAND

(Recharge in mm)

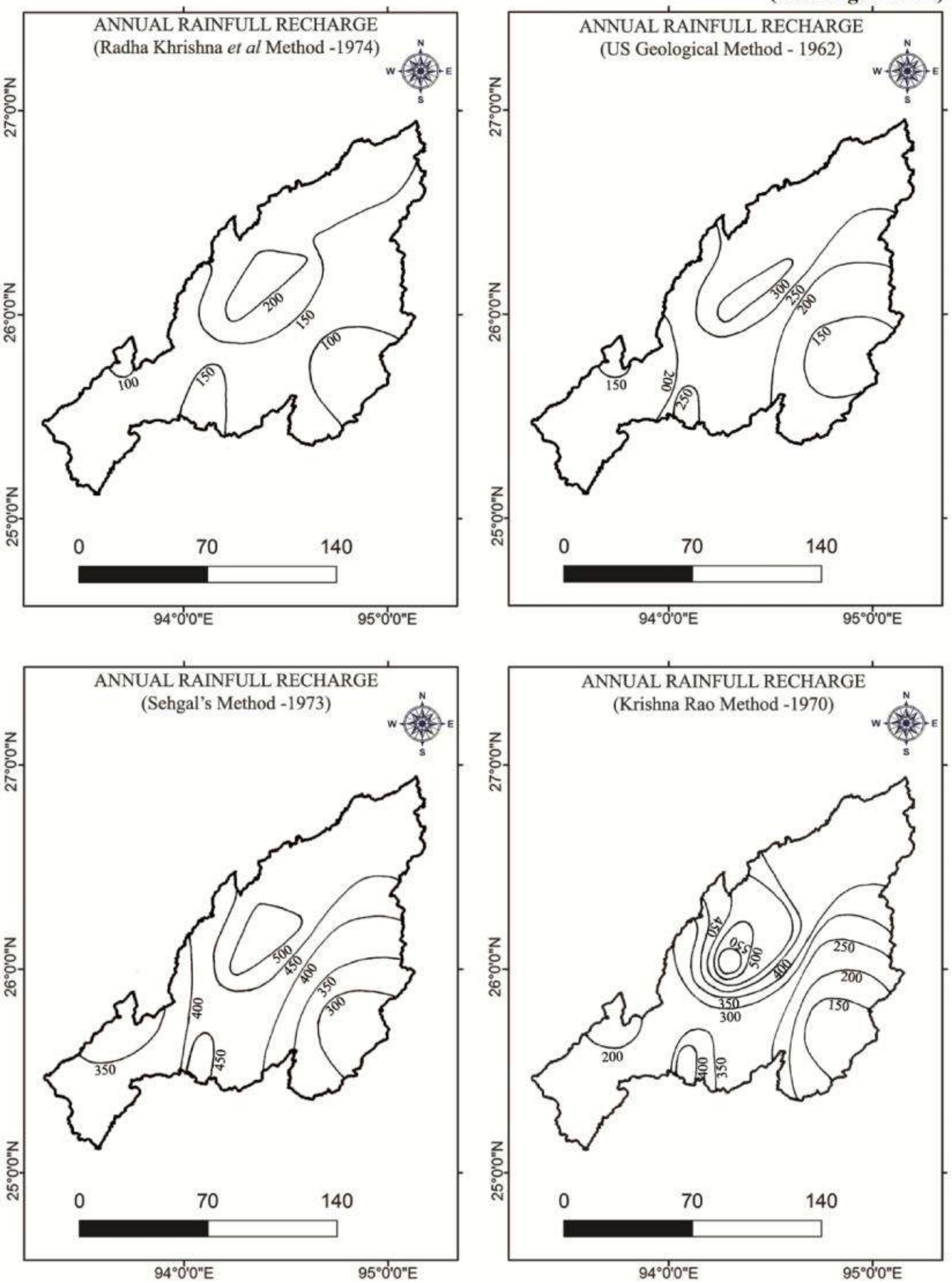

Fig. 3.19

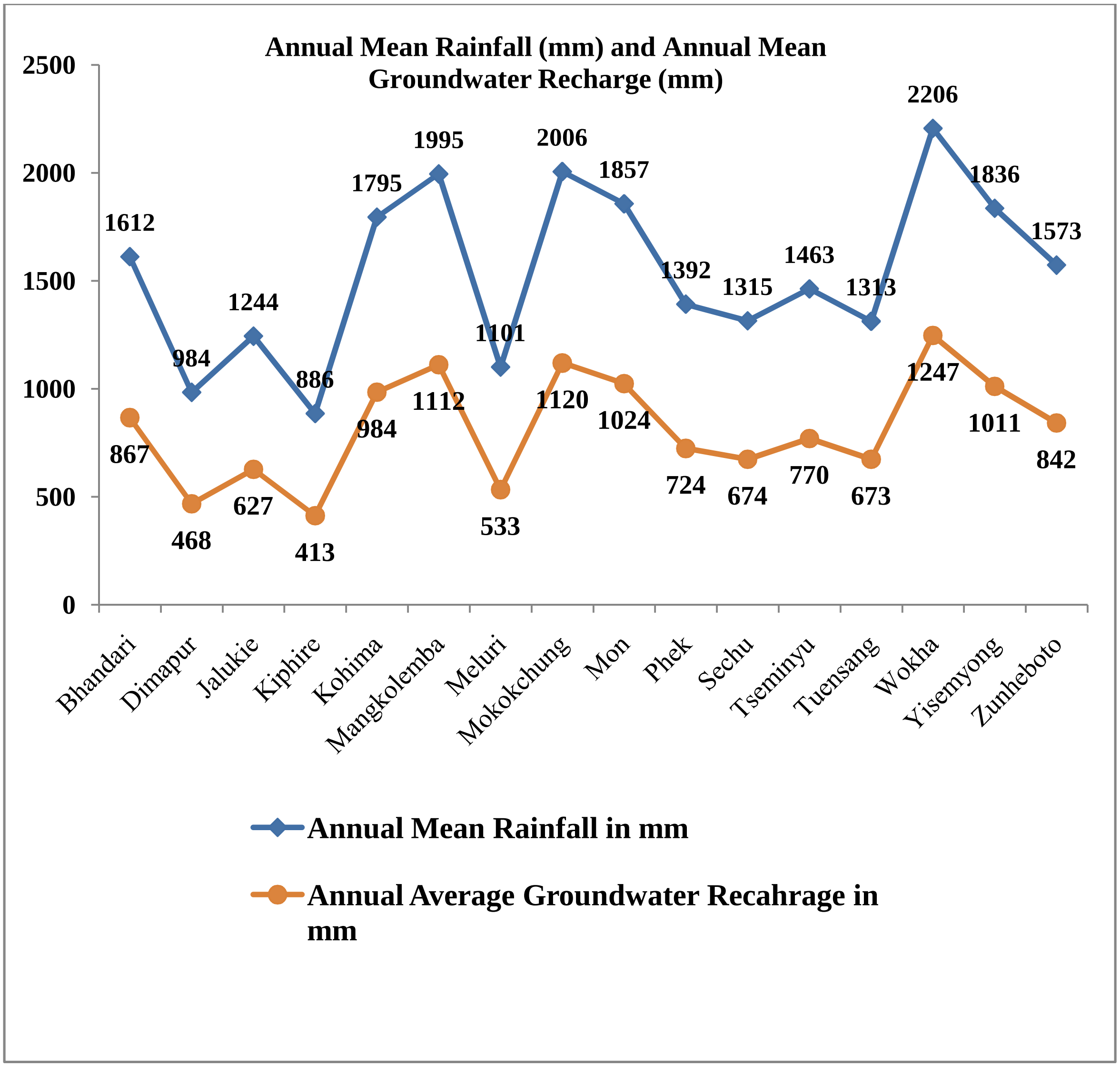

Fig. 3.20

3.7 Estimation of Surface Water Resources.

1. Mean annual rainfall: 1536 mm.
2. Total surface water resources: 25,465,344,000 m^3.
3. The annual average groundwater recharge: 818 mm.
4. Surface water recharge to groundwater: 13,561,622,000 m^3.

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Chapter 4

Water Balance Elements of Nagaland

Water balance refers to the balance between the income of water from precipitation and outflow of water by way of evapotranspiration. Water balance technique is one of the main subjects in hydrology, a means of solution for important theoretical and practical hydrological problems. It is applicable in identification of water surplus and water deficit zones. Water balance estimation is an important tool to ascertain the current state and trends of water resources availability in an area over a specific period of time. It strengthens decision making for water management, assess water demand for agricultural activities and analyse soil moisture. The study of water balance provides information on increase and decreases of water bodies; substantiate hydrological data for rational exploitation, control and redistribution of water resources in time and space. It also explain authentic effect of human activities on hydrological cycle, climatic change, vegetative cover, etc. hence, it plays a significant role in the development of agriculture. It is well established that the primary water supply of a region is through precipitation and water loss is entirely due to evaporation and evapotranspiration. Hence, water balance estimation gives quantitative idea in the assessment of arid or wet type of climate of a region.

The important components of water balance are precipitation, potential evapotranspiration, actual evapotranspiration, water deficit, water surplus, soil moisture utilisation and soil moisture index. The major input is the precipitation and output 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 or 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, it results as 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 30 years (1986-2015) were collected from sixteen rain-gauge stations of Nagaland to analyse the rainfall data on monthly, seasonal, annual and rain gauge stations-wise.

4.1 Monthly-wise Water Balance Elements

4.1.1 January

The mean monthly precipitation in the month of January varies from 4 mm at Dimapur rain-gauge station to a maximum of 27 mm at Wokha station **(Table 4.1)**. The average precipitation of the study area was 12 mm. The Potential Evapotranspiration (PE) of minimum value was recorded at Mangkolemba, Mokokchung and Phek stations while the Yisemyong station recorded maximum of 50 mm. The average PE in this month was 42 mm. The Actual Evapotranspiration (AE) of minimum value ranges from 25 mm at Bhandari, Mangkolemba, Mokokchung, Phek and Tuensang rain-gauge stations to a maximum of 40 mm at Yisemyong rain-gauge station. The average value of AE was 29 mm. During the month of January, the water deficit value varies from 6 mm at Zunheboto station to a maximum of 20 mm at Bhandari and Tseminyu station. The average water deficit value was 13 mm. The rain-gauge stations of Bhandari, Jalukie, Mon, Sechu and Tuensang shows above the water deficit average. In the month of January, none of the station recorded the value of water surplus. The values for Moisture Adequacy

Index ranges from a minimum of 56 percent at Bhandari station to a maximum of 85 percent at Zunheboto station. The average value of Moisture Adequacy Index in the study area was 70 percent. The Aridity Index value shows 15 percent at Zunheboto to a maximum of 44.44 percent at Bhandari station. The average value of Aridity Index was 30 percent. Climatologically, the moisture Index value shows Dry sub-humid type of climate in all the stations.

Table 4.1: Water Balance Elements of Nagaland (1986-2015)

(January)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	12	45	25	20	0	56	44.44	-26.67	C1
2	Dimapur	4	42	26	16	0	62	38.1	-22.86	C1
3	Jalukie	6	45	30	15	0	67	33.33	-20	C1
4	Kiphire	9	40	28	12	0	70	30	-18	C1
5	Kohima	10	40	30	10	0	75	25	-15	C1
6	Mangkolemba	7	35	25	10	0	71	28.57	-17.14	C1
7	Meluri	10	42	32	10	0	76	23.81	-14.29	C1
8	Mokokchung	16	35	25	10	0	71	28.57	-17.14	C1
9	Mon	23	44	30	14	0	68	31.82	-19.09	C1
10	Phek	12	35	25	10	0	71	28.57	-17.14	C1
11	Sechu	10	44	30	14	0	68	31.82	-19.09	C1
12	Tseminyu	6	48	28	20	0	58	41.67	-25	C1
13	Tuensang	10	42	25	17	0	60	40.48	-24.29	C1
14	Wokha	27	45	35	10	0	78	22.22	-13.33	C1
15	Yisemyong	15	50	40	10	0	80	20	-12	C1
16	Zunheboto	14	40	34	6	0	85	15	-9	C1

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.

4.1.2 February

The minimum mean precipitation value during this month was 7 mm at Zunheboto station and maximum value at Wokha station with 50 mm **(Table 4.2)**. The average mean precipitation shows 20 mm. The rain-gauge stations of Kohima, Mon and Yisemyong recorded above the average. The minimum Potential Evapotranspiration value at Mangkolemba was 40 mm while Yisemyong station recorded maximum of 60 mm. The average value of PE was 50 mm. The recorded value of Kohima, Mokokchung, Phek, Tuensang and Zunheboto stations shows below the PE average value. The Actual Evapotranspiration value was minimum at Phek station with 26 mm and maximum at Yisemyong station with 57 mm. The average AE value was 37 mm. The water deficit value varies from 3 mm at Kohima and Yisemyong stations to a maximum of 23 mm at Tseminyu station. The average value of water deficit in the month of February was 13 mm. There was no water surplus value during this month in the study area. The Moisture Adequacy Index varies from a minimum of 55 percent at Phek to a maximum of 100 percent recorded at Wokha rain-gauge station. The average Moisture Adequacy Index of the study area was 74 percent. In the month of February, the minimum value of Aridity Index was 5 percent at Yisemyong station while Phek station shows maximum value of 44.68 percent. The average value of Aridity Index was 26 percent. The climatic classification of the month defines Dry subhumid type of climate in Nagaland.

Table 4.2: Water Balance Elements of Nagaland (1986-2015)

(February)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	15	55	35	20	0	64	36.36	-21.82	C1
2	Dimapur	12	53	37	16	0	70	30.19	-18.11	C1
3	Jalukie	19	55	35	20	0	64	36.36	-21.82	C1
4	Kiphire	9	50	30	20	0	60	40	-24	C1
5	Kohima	37	45	42	3	0	93	6.67	-4	C1
6	Mangkolemba	20	40	35	5	0	88	12.5	-7.5	C1
7	Meluri	11	53	44	9	0	83	16.98	-10.19	C1
8	Mokokchung	13	45	35	10	0	78	22.22	-13.33	C1
9	Mon	33	56	38	18	0	68	32.14	-19.29	C1
10	Phek	15	47	26	21	0	55	44.68	-26.81	C1
11	Sechu	17	52	32	20	0	62	38.46	-23.08	C1
12	Tseminyu	18	56	33	23	0	59	41.07	-24.64	C1
13	Tuensang	14	45	35	10	0	78	22.22	-13.33	C1
14	Wokha	50	50	50	0	0	100	0	0	C1
15	Yisemyong	37	60	57	3	0	95	5	-3	C1
16	Zunheboto	7	45	32	13	0	71	28.89	-17.33	C1

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.

4.1.3 March

In the month of March, the mean precipitation value widely varies from a minimum of 18 mm at Meluri to a maximum of 98 mm at Yisemyong rain-gauge station. The average mean precipitation was 45 mm where the stations of Kohima, Mangkolemba, Mokokchung, Mon and Wokha shows above the average value. The Potential Evapotranspiration of minimum value was recorded at Tuensang with 47 mm and maximum of 85 mm at Bhandari station **(Table 4.3)**. The average value of PE was 68 mm. The monthly Actual Evapotranspiration was shown with 40 mm at Jalukie station to 84 mm value of maximum at Mon station. The average value of AE was 53 mm. The values above the average were noticed in Bhandari, Sechu, Wokha and Yisemyong stations of the study area. The value of water deficit varies from 5 mm at Kohima station to a maximum of 39 mm at Tseminyu rain-gauge station. The average water deficit value was 15 mm. In this month, the water surplus values were noticed in few stations. These were noticed at Mangkolemba, Mokokchung, Mon, Tuensang, Wokha and maximum at Yisemyong rain-gauge stations with 33 percent. The average value for water surplus was 5 mm, of which Mangkolemba, Tuensang and Wokha rain-gauge stations recorded above the average. The Moisture Adequacy Index value widely varies from a minimum of 54 percent at Tseminyu station to a maximum of 106 percent at Tuensang station. The average value of Moisture Adequacy Index was 81 percent. The Aridity Index minimum value of 9.09 percent was shown in the station of Kohima while Tseminyu station recorded maximum of 46.43 percent. The average moisture Adequacy Index value was 20 percent. Climatologically, the Moisture Index values classifies the prevalence of Dry subhumid type of climate at Bhandari, Dimapur, Jalukie, Kiphire, Kohima, Meluri, Phek, Sechu, Tseminyu and Zunheboto, Humid type of climate at Tuensang and Yisemyong stations, Moist subhumid climate at Mangkolemba, Mokokchung, Mon and Wokha stations while the rest stations experienced Dry subhumid type of climate.

Table 4.3: Water Balance Elements of Nagaland

(March)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	35	85	60	25	0	71	29.41	-17.65	C1
2	Dimapur	24	82	51	31	0	62	37.8	-22.68	C1
3	Jalukie	38	65	40	25	0	62	38.46	-23.08	C1
4	Kiphire	21	62	40	22	0	65	35.48	-21.29	C1
5	Kohima	54	55	50	5	0	91	9.09	-5.45	C1
6	Mangkolemba	59	50	50	0	9	100	0	15.25	C2
7	Meluri	18	73	48	25	0	66	34.25	-20.55	C1
8	Mokokchung	54	49	49	0	5	100	0	9.26	C2
9	Mon	87	84	84	0	3	100	0	3.45	C2
10	Phek	31	71	53	18	0	75	25.35	-15.21	C1
11	Sechu	44	84	64	20	0	76	23.81	-14.29	C1
12	Tseminyu	20	84	45	39	0	54	46.43	-27.86	C1
13	Tuensang	34	47	50	0	10	106	0	29.41	B1
14	Wokha	77	65	65	0	12	100	0	15.58	C2
15	Yisemyong	98	65	65	0	33	100	0	33.67	B1
16	Zunheboto	25	65	41	24	0	63	36.92	-22.15	C1

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.

4.1.4 April

The month of April recorded minimum mean precipitation by 51 mm at Tseminyu station and maximum value of 165 mm recorded at Mangkolemba rain-gauge station. The average monthly mean precipitation was 102 mm. The value indicates that the rain-gauge stations of Dimapur, Jalukie, Meluri, Phek, Sechu and Tuensang received precipitation below the monthly average **(Table 4.4)**. The Potential Evapotranspiration relatively varies from a minimum of 70 mm at Kohima, Mangkolemba, Mokokchung and Tuensang station to a maximum of 101 mm at Tseminyu station with an average value of 84 mm. The Actual Evapotranspiration at Kiphire shows 65 mm and maximum value at Mon station by 99 mm. The average value of AE was 79 mm. The water deficit values were noticed at Dimapur, Kiphire, Meluri, Sechu, Tseminyu and maximum at Tseminyu rain-gauge station with 30 mm. The average water deficit value was 5 mm. The monthly water surplus value ranges from 4 mm at Phek station to a maximum of 95 mm at Mangkolemba station. There was no water surplus during this month at the stations of Dimapur, Kiphire, Meluri, Sechu and Tseminyu. The average value of water surplus shows 28 mm. The Moisture Adequacy Index value ranges from 70 percent to 100 percent. The minimum value was found at Tseminyu station, followed by Kiphire 79 percent, Dimapur 80 percent and, Meluri and Sechu with 90 percent each. The remaining stations recorded 100 percent of Moisture Adequacy Index. The average Moisture Adequacy Index value was 94 percent. The Aridity Index value was found at

Dimapur, Kiphire, Meluri, Sechu and maximum value of 29.70 percent recorded at Tseminyu station. The monthly average Aridity Index was 6 percent. The analysis of Moisture Index revealed Humid type of climate at Bhandari, Kohima, Mangkolemba, Mokokchung, Mon, Tuensang, Wokha and Yisemyong stations. The stations of Jalukie, Phek and Zunheboto were classified under Moist subhumid type of climate while Dimapur, Kiphire, Meluri, Sechu and Tseminyu revealed Dry subhumid type of climate.

Table 4.4: Water Balance Elements of Nagaland

(April)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	126	96	96	0	30	100	0	23.81	B1
2	Dimapur	62	95	76	19	0	80	20	-12	C1
3	Jalukie	100	85	85	0	15	100	0	15	C2
4	Kiphire	51	82	65	17	0	79	20.73	-12.44	C1
5	Kohima	104	70	70	0	34	100	0	32.69	B1
6	Mangkolemba	165	70	70	0	95	100	0	57.58	B2
7	Meluri	67	83	75	8	0	90	9.64	-5.78	C1
8	Mokokchung	120	70	70	0	50	100	0	41.67	B2
9	Mon	148	99	99	0	49	100	0	33.11	B1
10	Phek	85	81	81	0	4	100	0	4.71	C2
11	Sechu	82	100	90	10	0	90	10	-6	C1
12	Tseminyu	51	101	71	30	0	70	29.7	-17.82	C1
13	Tuensang	96	70	70	0	26	100	0	27.08	B1
14	Wokha	134	75	75	0	59	100	0	44.03	B2
15	Yisemyong	140	74	74	0	66	100	0	47.14	B2
16	Zunheboto	106	90	90	0	16	100	0	15.09	C2

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.

4.1.5 May

The mean precipitation between minimum and maximum value varies from 102 mm to 268 mm at Kiphire and Wokha stations respectively. The average value recorded 168 mm, of which Kohima, Mangkolemba, Mokokchung, Mon, Yisemyong and Zunheboto rain-gauge stations recorded above the mean precipitation **(Table 4.5)**. The Potential Evapotranspiration of minimum value was recorded at Tuensang with a value of 72 mm while Mon station recorded maximum value of 123 mm. The average monthly PE in the study area was 101 mm. The value of Actual Evapotranspiration shows minimum at Tuensang with 72 mm and maximum at Mon rain-gauge station with 123 mm. The AE average value was 101 mm. In this month, the water deficit value was not accounted in the study area, therefore the value of Aridity Index do not exist. The water surplus value widely varies from a minimum of 5 mm at Dimapur to a maximum of 178 mm at Wokha station with an average of 67 mm. The values of Moisture Adequacy Index determine 100 percent in all the rain-gauge stations. The Moisture Index value of this month indicates Moist subhumid type of climate at Dimapur, Kiphire, Meluri, Sechu and Tseminyu rain-gauge stations while the remaining stations have Humid type of climate.

Table 4.5: Water Balance Elements of Nagaland (1986-2015)

(May)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	152	120	120	0	32	100	0	21.05	B1
2	Dimapur	105	100	100	0	5	100	0	4.76	C2
3	Jalukie	146	95	95	0	51	100	0	34.93	B1
4	Kiphire	102	92	92	0	10	100	0	9.8	C2
5	Kohima	186	90	90	0	96	100	0	51.61	B2
6	Mangkolemba	218	110	110	0	108	100	0	49.54	B2
7	Meluri	118	110	110	0	8	100	0	6.78	C2
8	Mokokchung	216	90	90	0	126	100	0	58.33	B2
9	Mon	185	123	123	0	62	100	0	33.51	B1
10	Phek	164	100	100	0	64	100	0	39.02	B1
11	Sechu	129	116	116	0	13	100	0	10.08	C2
12	Tseminyu	142	117	117	0	25	100	0	17.61	C2
13	Tuensang	141	72	72	0	69	100	0	48.94	B2
14	Wokha	268	90	90	0	178	100	0	66.42	B3
15	Yisemyong	199	85	85	0	114	100	0	57.29	B2
16	Zunheboto	214	110	110	0	104	100	0	48.6	B2

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.

4.1.6 June

During the month of June, minimum mean precipitation was recorded at Kiphire station with a value of 133 mm and maximum at Wokha station with 361 mm. The average value of mean precipitation was 256 mm. The value shows that the stations of Dimapur, Jalukie, Meluri and Tuensang received precipitation below the average **(Table 4.6)**. The Potential Evapotranspiration of minimum value was observed at Tuensang by 75 mm while Mon station recorded maximum PE value of 139 mm. The average value was 116 mm. The values of Actual Evapotranspiration vary from 75 mm at Tuensang to a maximum of 139 mm at Mon rain-gauge station with an average value of 116 mm. In the month of June, the water deficit value was not accounted; therefore, relatively the Aridity Index value was not observed. The water surplus value widely varies from a minimum of 21 mm at Kiphire to a maximum of 251 mm at Wokha rain-gauge station. The average value of water surplus was 140 mm, where only the stations of Kohima, Mangkolemba, Mokokchung, Mon, Tseminyu, Tuensang, Yisemyong and Zunheboto recorded above the average. The value of Moisture Adequacy Index was 100 percent in all the rain-gauge stations. Climatologically, the analysis of Moisture Index value classify that other than Kiphire station with Moist subhumid type of climate, remaining stations were classified under Humid type of climate.

Table 4.6: Water Balance Elements of Nagaland (1986-2015)

(June)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	267	135	135	0	132	100	0	49.44	B2
2	Dimapur	190	125	125	0	65	100	0	34.21	B1
3	Jalukie	186	110	110	0	76	100	0	40.86	B2
4	Kiphire	133	112	112	0	21	100	0	15.79	C2
5	Kohima	264	110	110	0	154	100	0	58.33	B2
6	Mangkolemba	357	115	115	0	242	100	0	67.79	B3
7	Meluri	174	115	115	0	59	100	0	33.91	B1
8	Mokokchung	337	115	115	0	222	100	0	65.88	B3
9	Mon	316	139	139	0	177	100	0	56.01	B2
10	Phek	213	115	115	0	98	100	0	46.01	B2
11	Sechu	222	124	124	0	98	100	0	44.14	B2
12	Tseminyu	294	124	124	0	170	100	0	57.82	B2
13	Tuensang	225	75	75	0	150	100	0	66.67	B3
14	Wokha	361	110	110	0	251	100	0	69.53	B3
15	Yisemyong	268	110	110	0	158	100	0	58.96	B2
16	Zunheboto	282	115	115	0	167	100	0	59.22	B2

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.

4.1.7 July

The monthly mean precipitation of July varies from 176 mm to 454 mm at Dimapur and Mokokchung rain-gauge station respectively. The average mean precipitation of the month was 314 mm **(Table 4.7)**. The Potential Evapotranspiration varies from a minimum of 76 mm at Tuensang to a maximum of 139 mm at Mon rain-gauge station with an average value of 121 mm. The Actual Evapotranspiration value at Tuensang recorded minimum and maximum at Mon station with 76 mm and 139 mm respectively. The average value of AE was 121 mm. In this month, the water deficit value was not observed in all the stations; hence the Aridity Index value was totally negligible. The water surplus value widely varies from a minimum of 41 mm at Dimapur station to a maximum value of 334 mm at Mokokchung rain-gauge station. The average value of water surplus was 193 mm. In this month of July, the stations of Kohima, Mangkolemba, Mon, Tseminyu, Tuensang, Wokha and Yisemyong shows water surplus above the average. The Moisture Adequacy Index was noted with the value of 100 percent in all the selected rain-gauge stations of the study area. The climatic classification analysis of Moisture Index value indicates that in the month of July all the stations have Humid type of climate.

Table 4.7: Water Balance Elements of Nagaland (1986-2015)

(July)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	326	138	138	0	188	100	0	57.67	B2
2	Dimapur	176	135	135	0	41	100	0	23.3	B1
3	Jalukie	230	120	120	0	110	100	0	47.83	B2
4	Kiphire	181	125	125	0	56	100	0	30.94	B1
5	Kohima	355	115	115	0	240	100	0	67.61	B3
6	Mangkolemba	413	120	120	0	293	100	0	70.94	B3
7	Meluri	220	120	120	0	100	100	0	45.45	B2
8	Mokokchung	454	120	120	0	334	100	0	73.57	B3
9	Mon	398	139	139	0	259	100	0	65.08	B3
10	Phek	286	117	117	0	169	100	0	59.09	B2
11	Sechu	284	126	126	0	158	100	0	55.63	B2
12	Tseminyu	363	127	127	0	236	100	0	65.01	B3
13	Tuensang	290	76	76	0	214	100	0	73.79	B3
14	Wokha	409	120	120	0	289	100	0	70.66	B3
15	Yisemyong	337	115	115	0	222	100	0	65.88	B3
16	Zunheboto	297	118	118	0	179	100	0	60.27	B3

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.

4.1.8 August

In the month of August, the minimum mean precipitation was recorded 169 mm at Kiphire station and maximum value at Wokha station with a value of 401 mm. The average value of mean precipitation was 278 mm. The minimum Potential Evapotranspiration value was shown at Phek station with 122 mm and maximum value of 143 mm at Mon station **(Table 4.8)**. The average value of PE was 125 mm. The Actual Evapotranspiration of minimum value 112 mm at Phek station and maximum value of 143 mm at Mon station with an average value of 125 was revealed in this month. In the month of August, the water deficit value was not revealed; therefore, the values of Aridity Index were not accounted. The value of water surplus greatly varies from 37 mm to 279 mm at Dimapur and Wokha stations respectively. The average water surplus value was 153 mm. The Moisture Adequacy Index values remain constant with 100 percent in all the stations. The study of Moisture Index value shows that at Dimapur and Kiphire stations Moist subhumid type of climate prevailed, while the remaining stations were classified with Humid type of climate in this month.

Table 4.8: Water Balance Elements of Nagaland (1986-2015)

(August)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	331	140	140	0	191	100	0	57.7	B2
2	Dimapur	175	138	138	0	37	100	0	21.14	C2
3	Jalukie	235	125	125	0	110	100	0	46.81	B2
4	Kiphire	169	128	128	0	41	100	0	24.26	C2
5	Kohima	352	120	120	0	232	100	0	65.91	B3
6	Mangkolemba	332	125	125	0	207	100	0	62.35	B3
7	Meluri	201	125	125	0	76	100	0	37.81	B1
8	Mokokchung	392	125	125	0	267	100	0	68.11	B3
9	Mon	317	143	143	0	174	100	0	54.89	B2
10	Phek	249	112	112	0	137	100	0	55.02	B2
11	Sechu	217	120	120	0	97	100	0	44.7	B2
12	Tseminyu	249	121	121	0	128	100	0	51.41	B2
13	Tuensang	241	115	115	0	126	100	0	52.28	B2
14	Wokha	401	122	122	0	279	100	0	69.58	B3
15	Yisemyong	290	117	117	0	173	100	0	59.66	B2
16	Zunheboto	292	125	125	0	167	100	0	57.19	B2

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.

4.1.9 September

The minimum mean precipitation in the month of September was recorded at Kiphire station by 109 mm while the maximum value of 299 mm was shown at Mangkolemba station **(Table 4.9)**. The average value of monthly mean precipitation was 210 mm. The Potential Evapotranspiration of minimum value 102 mm and maximum of 139 mm were shown at Phek and Mon rain-gauge station respectively. The average value of PE was 119 mm. The monthly Actual Evapotranspiration value at Phek was minimum and maximum at Mon station with 102 mm and 139 mm respectively. The average value was 119 mm. The water deficit values were not accounted so relatively Aridity Index in this month. The water surplus values were recorded minimum at Dimapur by 13 mm and maximum of 184 mm at Mangkolemba station. The average value of water surplus was 92 mm. The Moisture Adequacy Index was 100 percent in all the stations. The analysis of Moisture Index value indicate that Moist subhumid type of climate prevailed at Dimapur and Kiphire station, and Humid type of climate in the remaining stations.

Table 4.9: Water Balance Elements of Nagaland (1986-2015)

(September)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	222	125	125	0	97	100	0	43.69	B2
2	Dimapur	138	125	125	0	13	100	0	9.42	C2
3	Jalukie	164	120	120	0	44	100	0	26.83	B1
4	Kiphire	109	128	128	0	0	100	0	0	C2
5	Kohima	277	116	116	0	161	100	0	58.12	B2
6	Mangkolemba	299	115	115	0	184	100	0	61.54	B3
7	Meluri	160	125	125	0	35	100	0	21.88	B1
8	Mokokchung	269	115	115	0	154	100	0	57.25	B2
9	Mon	226	139	139	0	87	100	0	38.5	B1
10	Phek	174	102	102	0	72	100	0	41.38	B2
11	Sechu	196	109	109	0	87	100	0	44.39	B2
12	Tseminyu	190	110	110	0	80	100	0	42.11	B2
13	Tuensang	166	120	120	0	46	100	0	27.71	B1
14	Wokha	299	125	125	0	174	100	0	58.19	B2
15	Yisemyong	229	110	110	0	119	100	0	51.97	B2
16	Zunheboto	235	120	120	0	115	100	0	48.94	B2

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.

4.1.10 October

The minimum value of mean precipitation was recorded at Tuensang station with 79 mm while maximum value of 160 mm at Yisemyong station. The average value of mean precipitation was 107 mm **(Table 4.10)**. During this month, the Potential Evapotranspiration value was minimum at Kohima station with 83 mm and maximum of 123 mm recorded at Mon station. The average value was 99 mm. The Actual Evapotranspiration value varies from 83 mm at Kohima station to a maximum of 123 mm at Mon station. The average AE value was 98 mm. The values of water deficit were only found at Tuensang and Zunheboto stations with the value of 1 mm and 10 mm respectively. The value of water surplus in this month were shown at Kohima, Mangkolemba, Mokokchung, Phek, Sechu, Tseminyu, Wokha and maximum value at Yisemyong station with 70 mm. The average value of water surplus was 16 mm. The Moisture Adequacy Index value at Tuensang and Zunheboto rain-gauge station was 99 percent and 91 percent respectively, otherwise all the remaining stations were shown 100 percent. The average value of Moisture Adequacy Index was 99 percent. The Aridity Index was only revealed at Tuensang and Zunheboto rain-gauge stations with 1 percent and 9 percent respectively. The analyses of Moisture Index value reveals different types of climate were prevailed in this month. The station of Bhandari, Dimapur, Jalukie, Kiphire, Mangkolemba, Meluri, Mon, Sechu and Wokha station were classified under Moist subhumid, Kohima, Mokokchung, Phek, Tseminyu and Yisemyong station have Humid type of climate, Tuensang and Zunheboto stations have Dry subhumid climate.

Table 4.10: Water Balance Elements of Nagaland (1986-2015)

(October)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	104	115	115	0	0	100	0	0	C2
2	Dimapur	87	110	110	0	0	100	0	0	C2
3	Jalukie	86	90	90	0	0	100	0	0	C2
4	Kiphire	85	95	95	0	0	100	0	0	C2
5	Kohima	127	83	83	0	44	100	0	34.65	B1
6	Mangkolemba	102	90	90	0	12	100	0	11.76	C2
7	Meluri	97	110	110	0	0	100	0	0	C2
8	Mokokchung	119	90	90	0	29	100	0	24.37	B1
9	Mon	103	123	123	0	0	100	0	0	C2
10	Phek	134	86	86	0	48	100	0	35.82	B1
11	Sechu	101	87	87	0	14	100	0	13.86	C2
12	Tseminyu	120	93	93	0	27	100	0	22.5	B1
13	Tuensang	79	90	89	1	0	99	1.11	-0.67	C1
14	Wokha	131	120	120	0	11	100	0	8.4	C2
15	Yisemyong	160	90	90	0	70	100	0	43.75	B2
16	Zunheboto	82	110	100	10	0	91	9.09	-5.45	C1

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, $\mathbf{B_1}$-$\mathbf{B_4}$: Humid, $\mathbf{C_2}$: Moist subhumid,
$\mathbf{C_1}$: Dry subhumid, **D**: Semiarid, **E**: Arid.

4.1.11 November

The month of November recorded minimum mean precipitation of 8 mm at Dimapur, Tseminyu and Tuensang stations. The rain-gauge station of Yisemyong shows maximum value of 55 mm. The average mean precipitation was 19 mm. The value of monthly mean precipitation reveal Jalukie, Kohima, Phek and Wokha received above the average **(Table 4.11)**. The Potential Evapotranspiration of minimum value reported at Phek with 53 mm and maximum value recorded at Dimpaur and Zunheboto station with 90 mm. The average value of PE during this month was 73 mm. The Actual Evapotranspiration value was minimum at Phek and Mon station with 50 mm and maximum at Bhandari station with 78 mm. The average value was 63 mm. In this month, the value of water deficit varies from 1 mm at Yisemyong to a maximum of 25 mm at Dimapur rain-gauge station. The average value of water deficit was 10 mm. In this month, water surplus values were not noticed in all the rain-gauge stations. The Moisture Adequacy Index value shows a minimum of 72 percent at Dimapur and maximum at Yisemyong station with 99 percent. The average value of monthly Moisture Adequacy Index was 86 percent. The absence of water surplus value relatively shows Aridity Index. The minimum value was shown at Yisemyong station with 1.33 percent and maximum of 27.78 percent at Dimapur station. The average Aridity Index was 14 percent. The values of Moisture Index indicate that Dry subhumid type of climate was prevailed in all the rain-gauge stations of the study area.

Table 4.11: Water Balance Elements of Nagaland (1986-2015)

(November)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	13	85	78	7	0	92	8.24	-4.94	C1
2	Dimapur	8	90	65	25	0	72	27.78	-16.67	C1
3	Jalukie	31	70	51	19	0	73	27.14	-16.29	C1
4	Kiphire	14	75	55	20	0	73	26.67	-16	C1
5	Kohima	22	73	62	11	0	85	15.07	-9.04	C1
6	Mangkolemba	17	70	62	8	0	89	11.43	-6.86	C1
7	Meluri	19	80	70	10	0	88	12.5	-7.5	C1
8	Mokokchung	12	80	75	5	0	94	6.25	-3.75	C1
9	Mon	16	68	50	18	0	74	26.47	-15.88	C1
10	Phek	20	53	50	3	0	94	5.66	-3.4	C1
11	Sechu	10	68	60	8	0	88	11.76	-7.06	C1
12	Tseminyu	8	70	68	2	0	97	2.86	-1.71	C1
13	Tuensang	8	63	60	3	0	95	4.76	-2.86	C1
14	Wokha	39	62	52	10	0	84	16.13	-9.68	C1
15	Yisemyong	55	75	74	1	0	99	1.33	-0.8	C1
16	Zunheboto	16	90	75	15	0	83	16.67	-10	C1

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.

4.1.12 December

The mean monthly precipitation during this month recorded minimum at Tseminyu station with 2 mm to a maximum of 10 mm at Wokha rain-gauge station. The average value was 6 mm. The value of mean precipitation shows that the rain-gauge stations of Bhandari, Kohima, Phek, Tuensang and Yisemyong recorded above the monthly average **(Table 4.12)**. The Potential Evapotranspiration of minimum value at Phek station was 39 mm and maximum value at Dimapur station with 70 mm. The average value was 55 mm. The Actual Evapotranspiration of minimum value of 25 mm was accounted at Phek station and maximum value at Mokokchung and Sechu stations by 40 mm each. The average value of monthly AE was 35 mm. The water deficit value ranges from a minimum of 8 mm at Sechu to a maximum of 39 mm at Dimapur station. The average water deficit value of this month was 21 mm. In this month there was no water surplus value. The Moisture Adequacy Index value varies from 44 percent at Dimapur to a maximum value of 83 percent at Sechu rain-gauge station. The average monthly Moisture Adequacy Index value was 64 percent. The Aridity Index at Sechu station recorded 16.67 percent and maximum at Dimapur station with the value of 55.71 percent. The average value shows 36 percent. Climatologically, the Moisture Index value define Semiarid type of climate prevailed at Dimapur station and dry subhumid type of climate in the remaining stations.

Table 4.12: Water Balance Elements of Nagaland (1986-2015)

(December)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	9	60	32	28	0	53	46.67	-28	C1
2	Dimapur	3	70	31	39	0	44	55.71	-33.43	D
3	Jalukie	3	55	34	21	0	62	38.18	-22.91	C1
4	Kiphire	3	60	30	30	0	50	50	-30	C1
5	Kohima	7	60	35	25	0	58	41.67	-25	C1
6	Mangkolemba	6	55	36	19	0	65	34.55	-20.73	C1
7	Meluri	6	55	32	23	0	58	41.82	-25.09	C1
8	Mokokchung	4	60	40	20	0	67	33.33	-20	C1
9	Mon	5	53	35	18	0	66	33.96	-20.38	C1
10	Phek	9	39	28	11	0	72	28.21	-16.92	C1
11	Sechu	3	48	40	8	0	83	16.67	-10	C1
12	Tseminyu	2	52	35	17	0	67	32.69	-19.62	C1
13	Tuensang	9	50	36	14	0	72	28	-16.8	C1
14	Wokha	10	50	38	12	0	76	24	-14.4	C1
15	Yisemyong	8	60	38	22	0	63	36.67	-22	C1
16	Zunheboto	3	60	38	22	0	63	36.67	-22	C1

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.

4.2 Analyses of Monthly-wise Water Balance Elements

The monthly analyses of precipitation determines that during the month of November, December, January, February and March, the average mean precipitation in the study area received less than 50 mm value of rainfall. During this period of five months (November, December, January, February and March) only the month of March received average rainfall value was above 40 mm. The rain-gauge station of Yisemyong recorded a maximum mean precipitation of 98 mm in the month of March and Tseminyu station recorded minimum of 2 mm in the month of December. The months from April to October monthly average mean precipitation ranges from 100 mm to 300 mm, of which the months of April, May and October average value were low that varies from 100 mm to 150 mm, while high value of 200 mm to 300 mm was recorded in the months of June, July, August and September. Highest mean rainfall was recorded with 454 mm at Mokokchung in the month of July. The mean precipitation overall analyses from the month of April to October shows that Wokha rain-gauge station received maximum value of rainfall in the months of April, May, June, August and September.

The Potential Evapotranspiration (PE) average value below 100 mm was recorded during the months of October, November, December, January, February, March and April. The lowest mean PE value was reported at Mangkolemba, Mokokchung and Phek stations with 35 mm in the month of January and maximum value at Mon rain-gauge station during the month of October with 123 mm. The high concentration of average PE above 100 mm was recorded from the consecutive month of May to September. During these months, the maximum value of 143 mm was recorded at Mon rain-gauge station in the month of August while Tuensang rain-gauge station recorded minimum average PE of 72 mm in the month of May. The total average PE was 1053 mm. The Actual Evapotranspiration (AE) average values were recorded low in the months of October, November, December, January, February, March and April with the value below 100 mm. In the months of May, June, July, August and September, the value of average AE was above 100 mm. The maximum value of AE 143 mm was recorded at Mon rain-gauge station in the month of August while minimum value were shown at Bhandari, Mangkolemba, Mokokchung, Phek and Tuensang rain-gauge stations with 25 mm in the month of January. The water deficit period prevailed during the months of October, November, December, January, February, March and April. The average value shows maximum water deficit in the month of December with 21 mm where Dimapur station recorded maximum value of 39 mm during this month. The water surplus analyses determine that there was no value of surplus during the months of November, December, January and February. The water surplus value was above 100 mm during the months of June, July and August. The average maximum value of water surplus during the month of July was 193 mm where the rain-gauge of Mokokchung recorded maximum of 334 mm. The Moisture Adequacy Index value records 100 percent during the months of May, June, July, August and September. The minimum average Moisture Adequacy was recorded 64 percent in the month of December.

The values of Aridity Index prevailed during the months of October, November, December, January, February, March and April. The maximum Aridity Index value with an average of 36 percent was revealed in the month of December where Dimapur station recorded highest Aridity Index with an average value of 55.71 percent. Climatologically, the analyses of Moisture Index reveal Dry subhumid type of climate during the months of November, December, January and February. In the month of December, the Moisture Index indicates prevalence of semiarid type of climate in Dimapur station. In the month of March and April, climatic condition varies from Dry subhumid to Moist subhumid. From the month of May to September, Humid type of climate was prevailed in the entire study area of Nagaland.

The analysis of water balance elements concludes that from the month of March to September there was prevalence of water surplus. However, favorable climatic condition to grow crops prevails from the month of May to September. The months of November, December, January and February are extremely effective from water deficit; therefore, this dry spell will deter the crop to grow, unless the water requirements are irrigated.

4.3 Season-wise Water Balance Elements

4.3.1 Winter

The mean precipitation value during winter season widely varies from 19 mm at Dimapur station to a maximum of 87 mm at Wokha station **(Table 4.13)**. The average precipitation was 38 mm. The value indicates that in this season, only Kohima, Mon and Yisemyong stations recorded above the average precipitation. The Potential Evapotranspiration of minimum value 121 mm was shown at Phek station and Yisemyong station accounted maximum value of 170 mm. The average PE of winter season was 148 mm. The Actual Evapotranspiration widely varies from a minimum of 36 mm at Tuensang station to a maximum of 135 mm at Yisemyong station. The average value of AE was 97 mm. The water deficit value was high in the winter season. The minimum value of 22 mm was recorded at Wokha station while Dimapur station recorded maximum of 71 mm. The average water deficit value was 47 mm. The Moisture Adequacy Index was minimum at Tuensang and maximum at Wokha station with 26 percent and 85 percent respectively. The average Moisture Adequacy Index was 66 percent. There was no water surplus during this period, hence prevalence of high value of Aridity Index. The minimum Aridity Index of 15.17 percent was recorded at Wokha while Tuensang station viewed with maximum of 73.72 percent. The average Aridity Index was 34 percent. The climatic classification shows that in all the stations Dry subhumid type of climate was experienced during winter season.

Table 4.13: Water Balance Elements of Nagaland (Winter)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	36	160	92	68	0	58	42.5	-25.5	C1
2	Dimapur	19	165	94	71	0	57	43.03	-25.82	C1
3	Jalukie	28	155	99	56	0	64	36.13	-21.68	C1
4	Kiphire	21	150	80	70	0	53	46.67	-28	C1
5	Kohima	54	145	107	38	0	74	26.21	-15.72	C1
6	Mangkolemba	33	130	96	34	0	74	26.15	-15.69	C1
7	Meluri	27	150	108	42	0	72	28	-16.8	C1
8	Mokokchung	33	140	100	40	0	71	28.57	-17.14	C1
9	Mon	61	153	103	50	0	67	32.68	-19.61	C1
10	Phek	36	121	79	42	0	65	34.71	-20.83	C1
11	Sechu	30	144	102	42	0	71	29.17	-17.5	C1
12	Tseminyu	26	156	96	60	0	62	38.46	-23.08	C1
13	Tuensang	33	137	36	41	0	26	73.72	-44.23	C1
14	Wokha	87	145	123	22	0	85	15.17	-9.1	C1
15	Yisemyong	60	170	135	35	0	79	20.59	-12.35	C1
16	Zunheboto	24	145	104	41	0	72	28.28	-16.97	C1

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.

4.3.2 Pre-monsoon

The seasonal water balance elements of Pre-monsoon shows wide variation of mean precipitation between minimum value of 174 mm at Kiphire and maximum of 479 mm at Wokha station. The average value of pre-monsoon precipitation was recorded 315 mm **(Table 4.14)**. The Potential Evapotranspiration value was minimum at Tuensang and maximum at Mon station with the value of 192 mm and 306 mm respectively. The average value was 253 mm. The Actual Evapotranspiration value was minimum at Tuensang station with 192 mm and maximum at Mon station with 306 mm. The average value of AE was 233 mm. The water deficit values were experienced at Dimapur, Kiphire, Meluri, Sechu and Tseminyu stations with an average of 32 mm. This was minimum at Sechu and maximum at Dimapur rain-gauge station with 17 mm and 45 mm respectively. The maximum water surplus value was observed at Wokha station with 249 mm. However, there was no water surplus in stations of Dimapur, Kiphire, Meluri, Sechu and Tseminyu. The seasonal average value of water surplus was 128 mm. The Moisture Adequacy Index value of minimum was recorded at Tseminyu station with 77 percent and maximum value at Tuensang station with 102 percent. The average value of Moisture Adequacy Index was 93 percent. The Aridity Index value was only recorded at Dimapur, Kiphire, Meluri, Sechu, Tseminyu and Zunheboto rain-gauge stations in this season with an average of 14 percent. The analyses of

Moisture Adequacy value indicates that Humid, Moist subhumid and Dry subhumid type of climate prevailed during pre-monsoon season.

Table 4.14: Water Balance Elements of Nagaland (Pre-monsoon)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	313	301	276	0	37	92	0	-2.59	C1
2	Dimapur	191	277	227	45	0	82	18.05	-10.83	C1
3	Jalukie	284	245	220	0	41	90	0	1.41	C2
4	Kiphire	174	236	197	29	0	83	16.53	-9.92	C2
5	Kohima	344	215	210	0	125	98	0	36.05	B1
6	Mangkolemba	442	230	230	0	212	100	0	47.96	B2
7	Meluri	203	266	233	25	0	88	12.41	7.44	C1
8	Mokokchung	390	209	209	0	181	100	0	46.41	B2
9	Mon	420	306	306	0	114	100	0	27.14	B1
10	Phek	280	252	234	0	50	93	0	3.57	C2
11	Sechu	255	300	270	17	0	90	10	-6	C1
12	Tseminyu	213	302	233	44	0	77	22.85	-13.71	C1
13	Tuensang	271	192	192	0	95	102	0	30.26	B1
14	Wokha	479	230	230	0	249	100	0	51.98	B2
15	Yisemyong	437	224	224	0	213	100	0	48.74	B2
16	Zunheboto	345	265	241	0	96	91	5.78	16.23	C2

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, $\mathbf{B_1}$-$\mathbf{B_4}$: Humid, $\mathbf{C_2}$: Moist subhumid,
$\mathbf{C_1}$: Dry subhumid, **D**: Semiarid, **E**: Arid.

4.3.3 Monsoon

The seasonal mean precipitation of monsoon shows a minimum of 483 mm at Kiphire station to maximum of 1183 mm at Mokokchung station. The average value was 847 mm. The average value revealed that the rain-gauge stations of Bhandari, Kohima, Mangkolemba, Mon, Tseminyu, Wokha, Yisemyong and Zunheboto received precipitation above mean average **(Table 4.15)**. The Potential Evapotranspiration values were relatively distributed. This varies from a minimum of 266 mm at Tuensang and maximum at Mon 421 mm, with an average of 361 mm. The Actual Evapotranspiration value was minimum at Tuensang and maximum at Mon station with the value of 266 mm and 421 mm respectively. The average value of AE was 361 mm. During monsoonal period there was no water deficit in any stations, hence, there was no Aridity Index. In this season there was prevalence of water surplus in all the stations where the maximum water surplus value was observed at Mokokchung station with 823 mm. The average value of water surplus was 486 mm. The Moisture Adequacy Index values show 100 percent in all the stations. Climatologically, the analysis of Moisture Index value defines the prevalence of humid type of climate in the entire study area during monsoon season.

Table 4.15: Water Balance Elements of Nagaland (Monsoon)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	924	413	413	0	511	100	0	55.3	B2
2	Dimapur	541	398	398	0	143	100	0	26.43	B1
3	Jalukie	651	355	355	0	296	100	0	45.47	B2
4	Kiphire	483	365	365	0	118	100	0	24.43	B1
5	Kohima	971	345	345	0	626	100	0	64.47	B3
6	Mangkolemba	1102	360	360	0	742	100	0	67.33	B3
7	Meluri	595	360	360	0	235	100	0	39.5	B1
8	Mokokchung	1183	360	360	0	823	100	0	69.57	B3
9	Mon	1031	421	421	0	610	100	0	59.17	B2
10	Phek	748	344	344	0	404	100	0	54.01	B2
11	Sechu	723	370	370	0	353	100	0	48.82	B2
12	Tseminyu	906	372	372	0	534	100	0	58.94	B2
13	Tuensang	756	266	266	0	490	100	0	64.81	B3
14	Wokha	1171	352	352	0	819	100	0	69.94	B3
15	Yisemyong	895	342	342	0	553	100	0	61.79	B3
16	Zunheboto	871	358	358	0	513	100	0	58.9	B2

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.

4.3.4 Post-monsoon

The Post-monsoon minimum mean precipitation value was 208 mm at Kiphire station and maximum value recorded at Wokha station with 469 mm. The average value of mean precipitation was 336 mm. The analysis of seasonal mean precipitation revealed that the stations of Bhandari, Kohima, Mangkolemba, Mokokchung, Mon and Yisemyong recorded precipitation above the average value **(Table 4.16)**. The Potential Evapotranspiration of minimum value was observed at Phek station with 241 mm and Mon station recorded maximum value of 330 mm. The average value of PE was 291 mm. The Actual Evapotranspiration value was minimum at Phek with 238 mm and maximum at Bhandari station with 318 mm. The average AE was 280 mm. During the post-monsoon period water deficit values were recorded at Dimapur and Kiphire stations where maximum water deficit value was observed at Kiphire station by 20 mm. The average water deficit value was 16 mm. The maximum water surplus value of 194 mm was recorded at Kohima station and minimum value at Jalukie and Meluri stations with 25 mm. The stations of Dimapur and Kiphire do not exhibit water surplus, hence, the average value was 113 mm. The Moisture Adequacy Index was maximum at Yisemyong with 100 percent and minimum at Dimapur and Zunheboto stations with 92 percent. The average Moisture Adequacy Index was 96 percent. In the post-monsoon period Aridity Index were only found at Dimapur and Kiphire stations with an average of 7 percent. The

Moisture Index analysis concludes that in this season, Humid, Moist subhumid and Dry subhumid type of climate were experienced in the study area.

Table 4.16: Water Balance Elements of Nagaland (Post-monsoon)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	339	325	318	0	90	98	0	2.06	C2
2	Dimapur	233	325	300	12	0	92	7.69	-4.62	C1
3	Jalukie	281	280	261	0	25	93	0	-3.86	C1
4	Kiphire	208	298	278	20	0	93	6.71	-4.03	C1
5	Kohima	426	272	261	0	194	96	0	33.57	B1
6	Mangkolemba	418	275	267	0	188	97	0	3.49	B1
7	Meluri	276	315	305	0	25	97	0	-1.90	C1
8	Mokokchung	400	285	280	0	178	98	0	27.5	B1
9	Mon	345	330	312	0	69	95	0	-0.55	C1
10	Phek	328	241	238	0	117	99	0	25.61	B1
11	Sechu	307	264	256	0	93	97	0	13.03	C2
12	Tseminyu	318	273	271	0	105	99	0	13.52	C2
13	Tuensang	253	273	269	0	42	99	0	-0.88	C1
14	Wokha	469	307	297	0	175	97	0	32.41	B1
15	Yisemyong	444	275	274	0	188	100	0	37.84	B1
16	Zunheboto	333	320	295	0	90	92	0	3.60	C2

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, $\mathbf{B_1}$-$\mathbf{B_4}$: Humid, $\mathbf{C_2}$: Moist subhumid,
$\mathbf{C_1}$: Dry subhumid, **D**: Semiarid, **E**: Arid.

4.4 Analyses of Season-wise Water Balance Elements

The seasonal analyses of water elements revealed that the study area received maximum mean average precipitation value of 847 mm during monsoon period. The minimum average precipitation of 38 mm was observed in winter season. During pre-monsoon and post-monsoon period, the average mean values were recorded 315 mm and 336 mm respectively. The Potential Evapotranspiration of maximum value was observed in monsoon by 361 mm and minimum value of 148 mm in the winter season. The Actual Evapotranspiration of maximum value prevailed during monsoon period with an average of 361 mm. The minimum AE mean value was recorded during winter period with 97 mm. The prevalence of water deficit value was very high in winter season with an average of 47 mm. The water deficit values do not exist in monsoon but during pre-monsoon and post-monsoon prevalence of water deficit with an average were recorded 32 mm and 16 mm respectively. The water surplus values were remarkably observed during monsoon season with an average of 486 mm. The water surplus values were also identified during pre-monsoon and post-monsoon with 128 mm and 113 mm respectively. In winter there was no water surplus. The Moisture Adequacy Index was noticed minimum in winter period with 66 percent. In the pre-monsoon it was reported 93 percent and 96 percent during post-monsoon period. The maximum Moisture Adequacy Index value was 100 percent in monsoon period. The Aridity Index values were highly concentrated in winter season with 34 percent. During the seasons of pre-monsoon and post-monsoon, the values of Aridity Index were recorded 14 percent and 7 percent respectively, hence, there was no Aridity Index observed during monsoon season. The analysis of water balance elements concludes that the study area received high amount of rainfall during monsoon and moderate during pre-monsoon and post-monsoon. During monsoon, the water surplus and Moisture Adequacy Index value was high, thereby no water deficit prevail in this season. In winter season, there was high value of water deficit, therefore Moisture Index values were recorded low, wherein Aridity Index was very high. Finally, the seasonal analysis of water balance elements conclude that crop cultivation is highly favourable during monsoonal period. The climatic classification from Moisture Index value identifies Dry Subhumid type of climate in winter, Moist subhumid and Dry subhumid in pre-monsoon and post-monsoon, and pre-humid type of climate during monsoon season.

4.5 Annual Water Balance Elements

The annual water balance elements of Nagaland depict minimum mean precipitation of 886 mm at Kiphire station and maximum of 2206 mm at Wokha rain-gauge station **(Table 4.17)**. The average value of mean precipitation was 1536 mm. The Potential Evapotranspiration varies from 868 mm at Tuensang station to a maximum of 1210 mm at Mon station. The average PE of the study area was 1054 mm. The Actual Evapotranspiration ranges from a minimum of 823 mm at Tuensang station to a maximum of 1142 mm at Mon station. The average annual AE was 976 mm. The value of water deficit was shown only at Meluri rain-gauge station with 75 mm, hence the value of Aridity Index was only concentrated in this station with 6.87 percent. The water surplus value was shown in all station except Meluri station. The maximum value was highlighted at Wokha station with 1140 mm. The average water surplus of Nagaland was noted by 483 mm. The Moisture Adequacy Index reveals a minimum value of 87 percent at Dimapur and maximum at Wokha station with 97 percent. The average Moisture Adequacy Index was 93 percent. The annual analyses of Moisture Index value indicate Moist subhumid type of climate at Bhandari, Dimapur, Jalukie, Kiphire, Sechu and Tseminyu station, and Humid type of climate at Kohima, Mangkolemba, Mokokchung, Mon, Phek, Tuensang, Wokha, Yisemyong and Zunheboto stations. The station of Meluri alone shows prevalence of dry subhumid type of climate.

Table 4.17: Water Balance Elements of Nagaland (Annual)

Sl. No.	Rain-gauge Station	P in mm	PE in mm	AE in mm	WD in mm	WS in mm	Ima in %	Ia in %	Im in %	CC
1	Bhandari	1612	1199	1099	0	313	92	0	19.42	C2
2	Dimapur	984	1165	1019	0	35	87	0	3.56	C2
3	Jalukie	1244	1035	935	0	109	90	0	8.76	C2
4	Kiphire	886	1049	928	0	42	88	0	4.74	C2
5	Kohima	1795	977	923	0	764	94	0	42.56	B2
6	Mangkolemba	1995	995	953	0	958	96	0	48.02	B2
7	Meluri	1101	1091	1006	75	0	92	6.87	-4.12	C1
8	Mokokchung	2006	994	949	0	967	95	0	48.21	B2
9	Mon	1857	1210	1142	0	579	94	0	31.18	B1
10	Phek	1392	963	900	0	366	93	0	26.29	B1
11	Sechu	1315	1078	998	0	157	93	0	11.94	C2
12	Tseminyu	1463	1103	972	0	229	88	0	15.65	C2
13	Tuensang	1313	868	823	0	406	95	0	30.92	B1
14	Wokha	2206	1034	1002	0	1140	97	0	51.68	B2
15	Yisemyong	1836	1011	975	0	789	96	0	42.97	B2
16	Zunheboto	1573	1088	998	0	395	92	0	25.11	B1

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.

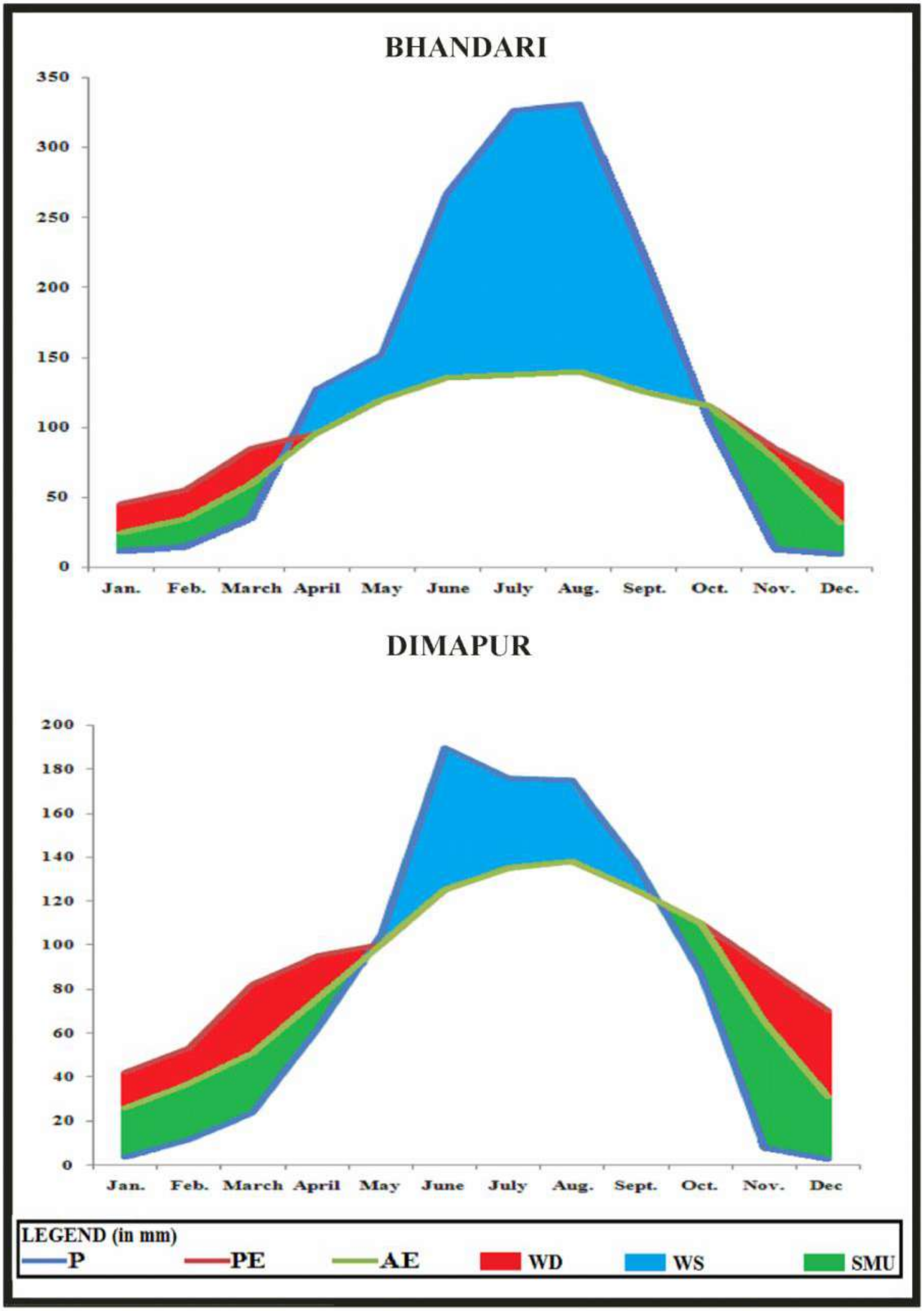
4.6 Analyses of Annual Water Balance Elements

The analyses of annual water balance elements determine that the entire study area received an average mean rainfall of 1536 mm, mean annual Potential Evapotranspiration of 1054 mm and the mean Actual evapotranspiration average value of 976 mm. The annual water deficit analyses identified 75 mm of water deficit at Meluri rain-gauge station only. Meanwhile, the average annual water surplus was recorded 483 mm. The Moisture Adequacy Index revealed 93 percent and Aridity Index observed 6.87 percent at Meluri station only. Climatologically, overall analyses of annual water balance elements shows that the area experience humid type of climate.

4.7 Rain-gauge Station-wise Analyses of Water Balance Elements

The rain-gauge station wise analysis of water balance elements of Nagaland highlight that in the station of Bhandari the average mean precipitation was recorded 134 mm. The maximum value of precipitation was received in the month of July with 326 mm. The maximum Potential Evapotranspiration and Actual Evapotranspiration value of 140 mm each reported in the month of August with an average of 100 mm and 92 mm respectively. The water deficit exists in the months of November, December and from January to March. The water surplus values were shown from the month of April to September. The Moisture Adequacy Index indicates that soil moisture utilisation was found during the months of November, December and from January to March **(Fig. 4.1)**.

In the Dimapur station the maximum precipitation was recorded in the month of June with the value of 190 mm. The average mean precipitation shows 82 mm. The maximum value of Potential Evapotranspiration and Actual Evapotranspiration in the month of August was 138 mm each. The average value was 97 mm and 85 mm respectively. The concentration of maximum value of water deficit was revealed in the month of December with 39 mm. The scarcity of water was observed in the months of November, December and from January to April. The soil moisture utility in this station was observed during the months of November, December and from January to April **(Fig. 4.1)**.


BHANDARI
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DIMAPUR
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Nov.
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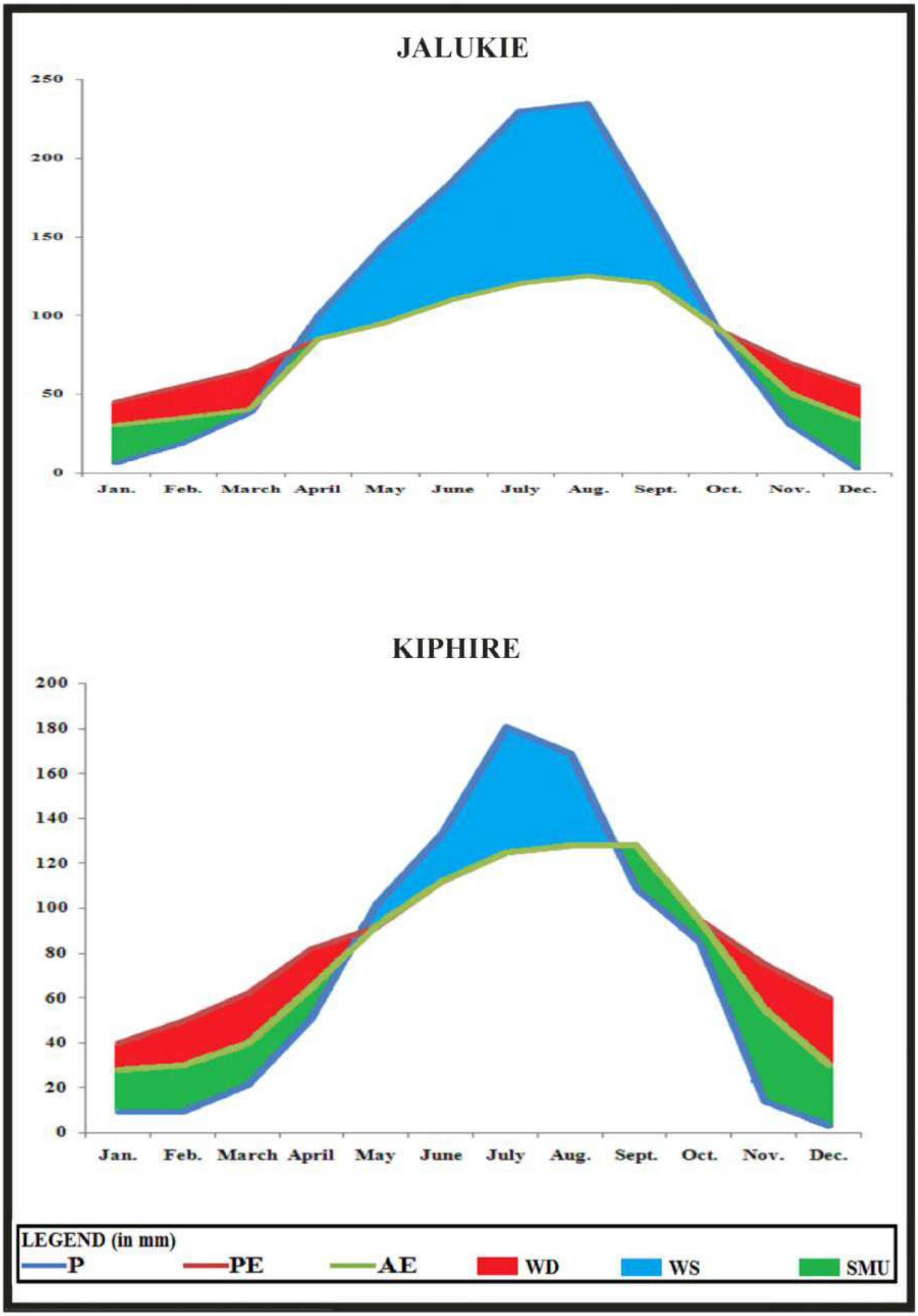
LEGEND (in mm)
P
PE
AE
WD
WS
SMU

Fig. 4.1

The Jalukie rain-gauge station recorded an average mean precipitation value of 104 mm. The maximum mean rainfall value was recorded in the month of August with 235 mm **(Fig. 4.2)**. The value of Potential Evapotranspiration and Actual Evapotranspiration were recorded by 125 mm each. The average values were 86 mm and 78 mm respectively. The water deficit value was reported during the months of November, December and from January to March. The maximum value was 25 mm in the month of March. The water surplus period was shown from April to August, in which the month of July and August noticed highest value of 110 mm each. The analysis shows soil moisture utilisation during the months of November, December and from January to March.

The maximum mean precipitation value of 181 mm at Kiphire station was recorded in the month of July. The average mean rainfall was 74 mm. The value of 128 mm in the months of August and September shows maximum value for the Potential Evaotranspiration and Actual Evapotranspiration. The average PE was 87 mm and AE with 77 mm. The water deficit values were found out in the months of November, December and from January to April. In this station high concentration of water deficit was revealed in the month of December with 30 mm. The water surplus period exists from May to August where the month of July recorded maximum value of 56 mm. The soil moisture utilisation months were observed during November, December and from January to April **(Fig. 4.2)**.


JALUKIE
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KIPHIRE
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160
140
120
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July
Aug.
Sept.
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Nov.
Dec.
LEGEND (in mm)
P
PE
AE
WD
WS
SMU

Fig. 4.2

The station of Kohima received 355 mm of maximum mean precipitation in the month of July with an annual average of 150 mm. The maximum values of Potential Evapotranspiration and Actual Evapoptranspiration were shown by 115 mm each in July. The average value of PE and AE were indicated by 81 mm and 77 mm respectively. The water deficit values were prevailed during the months of November, December and from January to March. The scarcity of water was very high during the month of December that recorded 25 mm. The water surplus periods began from the months of April to October. This rain-gauge station recorded highest value of water surplus 240 mm in the month of July. The average value of water surplus was 80 mm. The value of soil moisture utilisation was exhibited during November, December and from January to March **(Fig. 4.3)**.

The Mangkolemba rain-gauge station recorded a maximum value of 413 mm mean precipitation in the month of July. The average value was noted with 166 mm. In June, the maximum mean rainfall of 242 was accounted. The Potential Evapotranspiration and Actual Evapotranspiration of maximum values were recorded 125 mm each in the month of August. The average value of PE and AE were 83 mm and 79 mm respectively. The water deficit values were only reported during the months of November, December, January and February. The average value of water deficit was 4 mm. The water surplus value was highlighted from the month of March to October. The average water surplus of this station was 96 mm.

The soil moisture utilisation was operated during the months of November, December, January and February **(Fig.4.3)**.

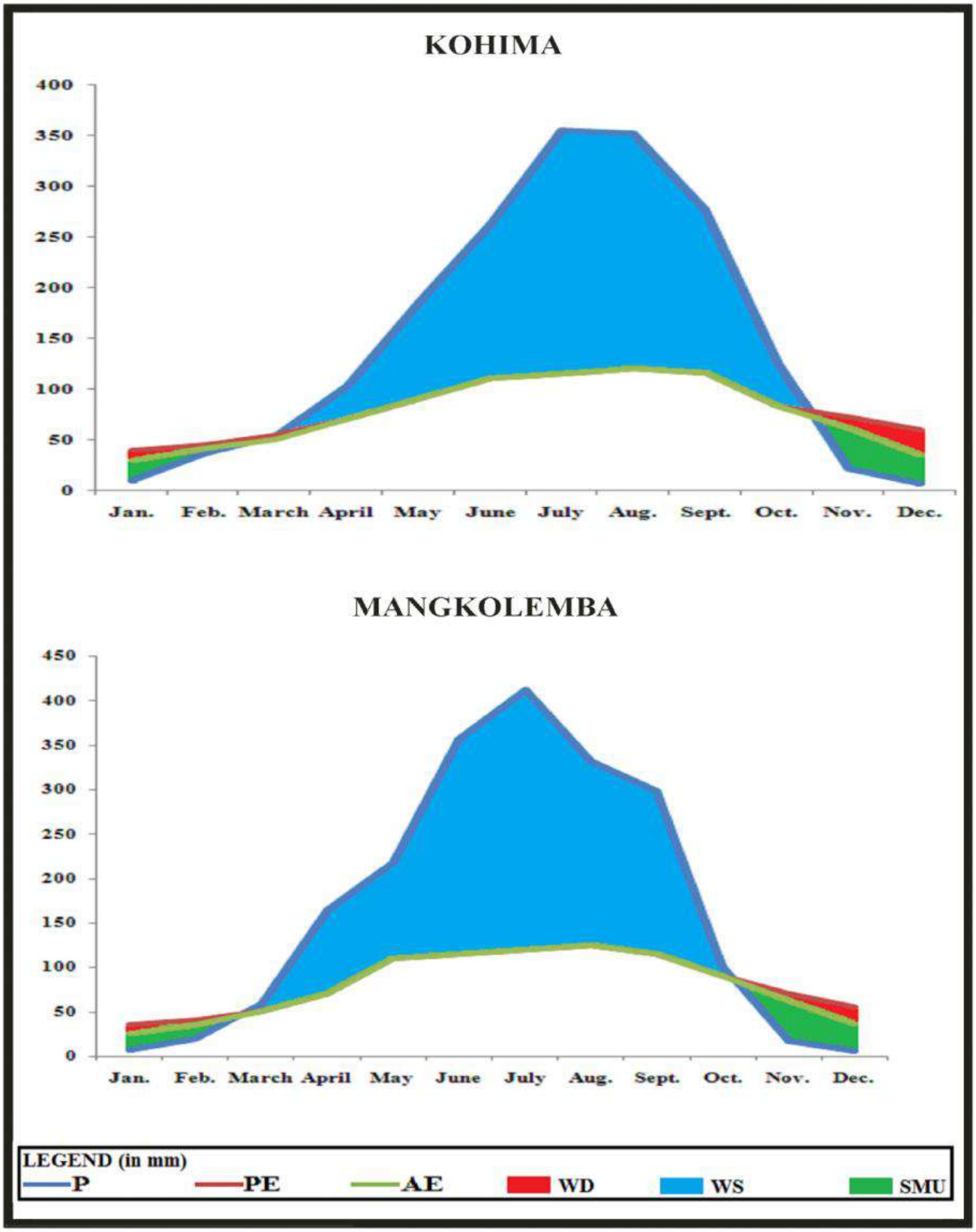
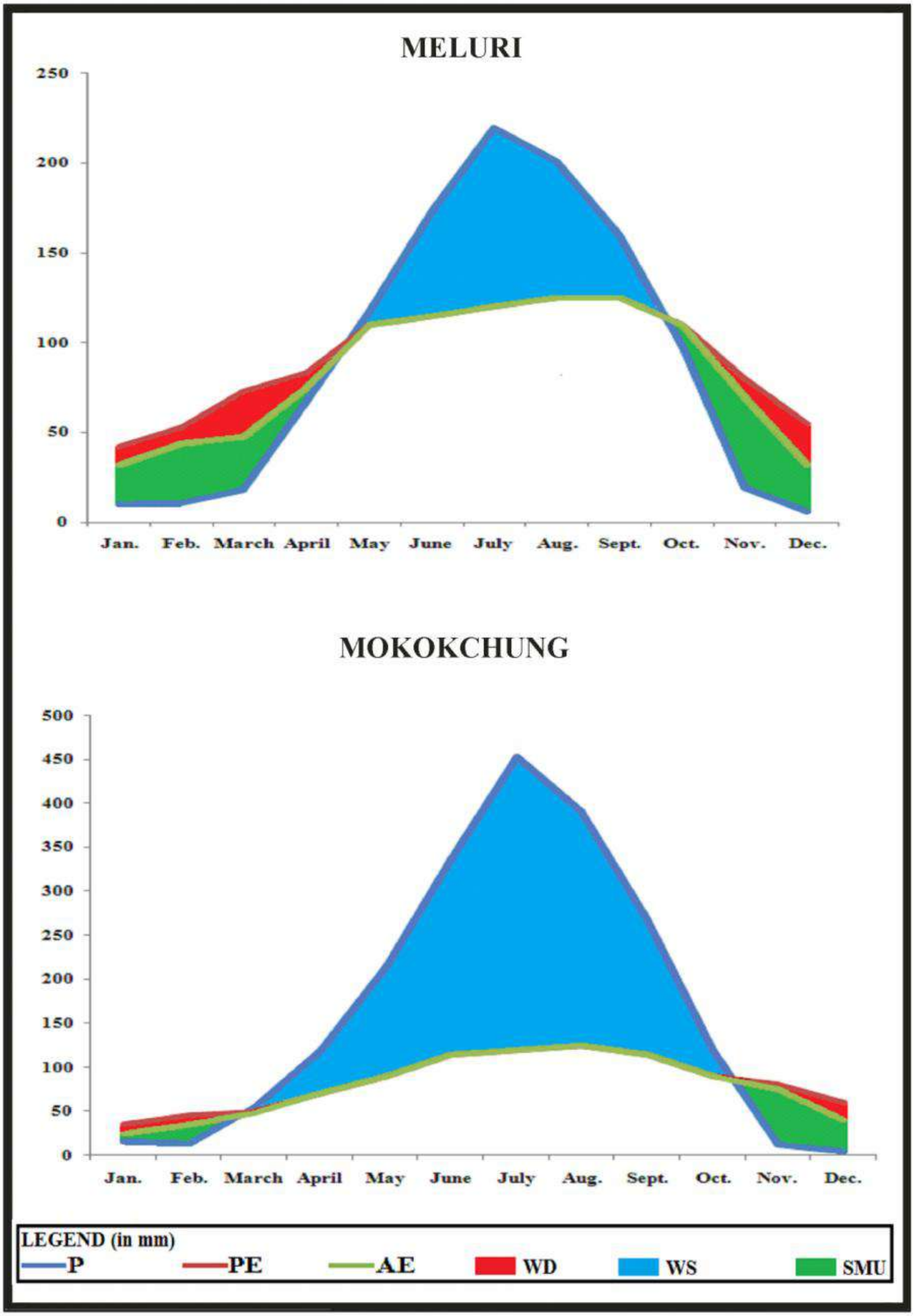


Fig. 4.3

The Meluri rain-gauge station received 220 mm of maximum mean rainfall during July. The average value was 92 mm. The maximum value of Potential Evapotranspiration and Actual Evapotranspiration of 125 mm were recorded during August and September respectively. The average value of PE was 91 mm and AE was 84 mm. The water deficit values were found out in the months of November, December and from January to March. The maximum value was shown in March with 25 mm. The water surplus periods were witnessed from May to September. The month of July receive highest value of 100 mm. The average value of water surplus was 23 mm. The soil moisture utilisation was observed in the months of November, December and from January to April **(Fig 4.4)**.

The mean precipitation of maximum value was recorded in the month of July at Mokokchung station with 454 mm. The average value was 167 mm. The Potential Evapotranspiration and Actual Evapotranspiration value recorded maximum in the month of August with 125 mm each. The average value was 83 mm and 79 mm respectively. The water deficit period was concentrated during the months of November, December, January and February with an average of 4 mm. The maximum value of 20 mm concentrated in the month of December. The water surplus values were recorded from March to October. The maximum water surplus value of 334 mm was received in the month of July. The annual average of water surplus was 99 mm. Soil moisture utilisation was operational in the months of November, December, January and February **(Fig 4.4)**.



MELURI
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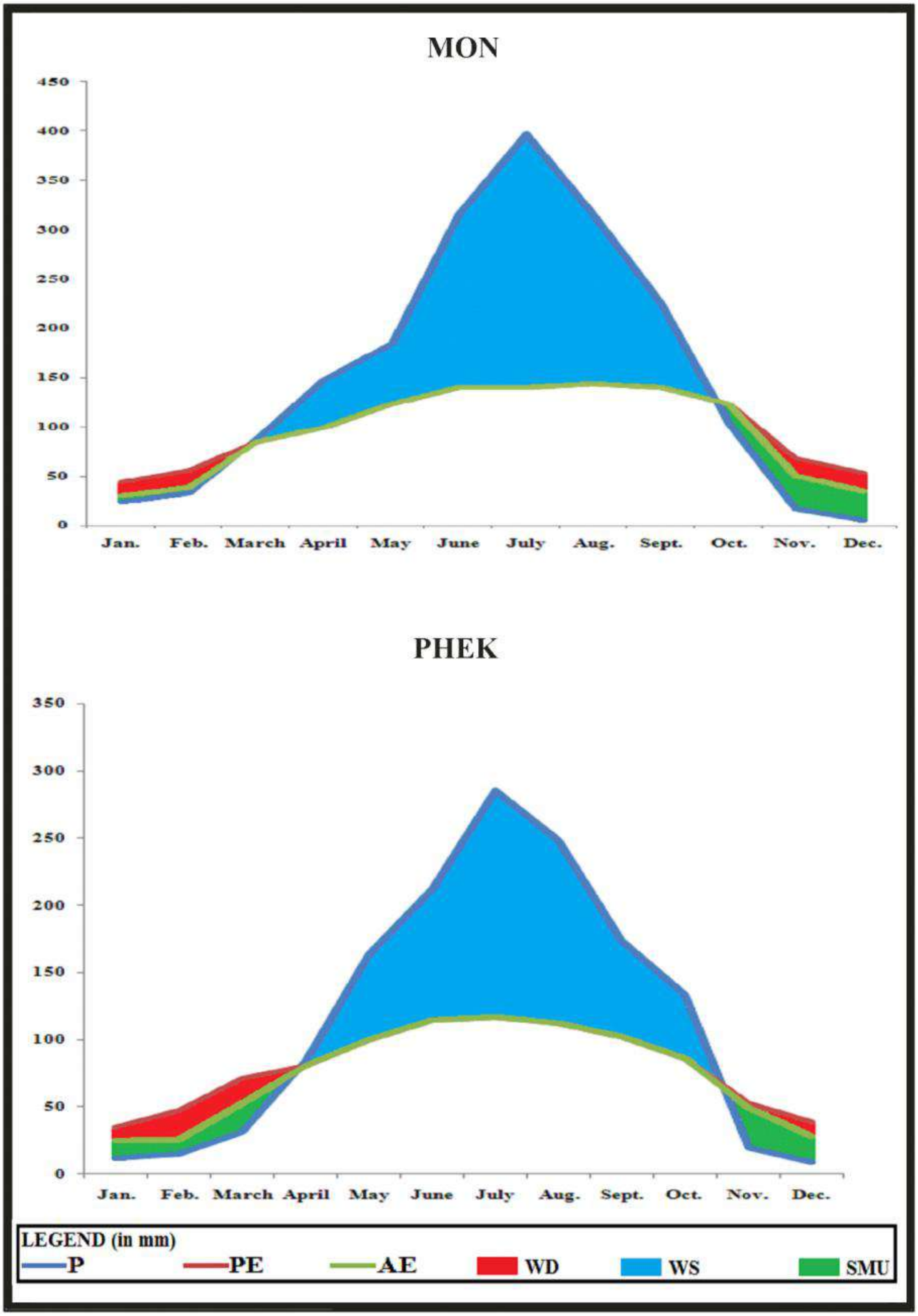
LEGEND (in mm)
P
PE
AE
WD
WS
SMU

Fig. 4.4

The rain-gauge station of Mon recorded maximum value of mean precipitation in the month of July with 398 mm with an annual average of 155 mm. The maximum Potential Evapotranspiration and Actual Evapotranspiration values were recorded 143 mm each in the month of August. The average value shows 101 mm and 95 mm respectively. The water deficit prevailed in the months of November, December, January and February with an average of 6 mm. The water surplus period were observed from March to September where July received maximum value of 259 mm. The annual average value was 68 mm. The soil moisture utilisation values were noted in the months of November, December, January and February **(Fig. 4.5)**.

In Phek rain-gauge station, the month of July recorded maximum mean precipitation value of 286 mm. The annual average was shown 116 mm. The average value of Potential Evapotranspiration and Actual Evapotranspiration was 117 mm each which were recorded in the month of July. The average values of PE and AE were 80 mm and 75 mm respectively. The water deficit prevailed in the months of November, December and from January to March. The month of February shows highest value of water deficit with 21 mm. The average value was 5 mm. The water surplus values were accounted from the months of April to October. In the month of July, it received maximum value of 169 mm. The annual average value was 49 mm. The soil moisture utilisation operates in the months of November, December and from January to March **(Fig 4.5)**.



MON
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Aug.
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Nov.
Dec.
LEGEND (in mm)
P
PE
AE
WD
WS
SMU

Fig. 4.5

The rain-gauge station of Sechu accounted 284 mm of maximum mean precipitation in the month of July. The annual average was 110 mm. The month of July represented maximum Potential Evapotranspiration and Actual Evapotranspiration value of 126 mm each. The average values of PE and AE recorded 90 mm and 83 mm respectively. The values show the prevalence of water deficit during November, December and from January to April with an annual average of 7 mm. The maximum value of water deficit concentrated in the months of February and March with 20 mm. The annual average was 7 mm. The water surplus periods were experienced from the months of May to October in this station, of which July month recorded maximum value of 158 mm. The average water surplus shows 39 mm. Soil moisture utilisation was observed during November, December and from January to April **(Fig 4.6)**.

The Tseminyu station received maximum mean precipitation value of 363 mm in the month of July. The mean annual precipitation was 122 mm. The value of Potential Evapotranspiration and Actual Evapotranspiration shows 127 mm each during the month of July. The average value shows 92 mm and 81 mm respectively. The prevalence of water deficit months was found out during November, December and from January to April with an annual average value of 11 mm. The month of March observed maximum value of 39 mm. The water surplus values were observed from the month of May to October, during which the month of July reported 236 mm of maximum value. The annual average was 56 mm. Soil moisture utilisation was highly concentrated during November, December and from January to April **(Fig. 4.6)**.

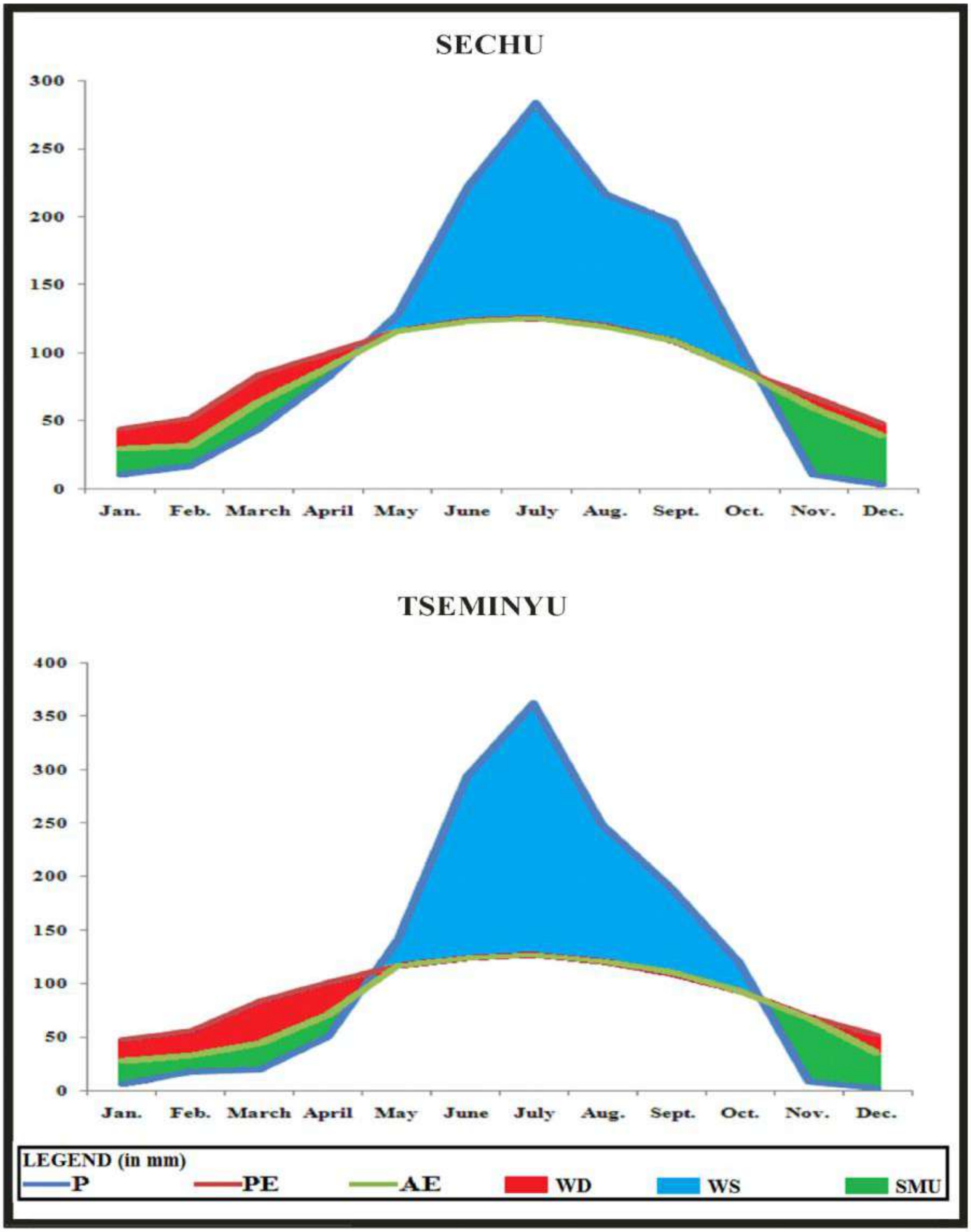
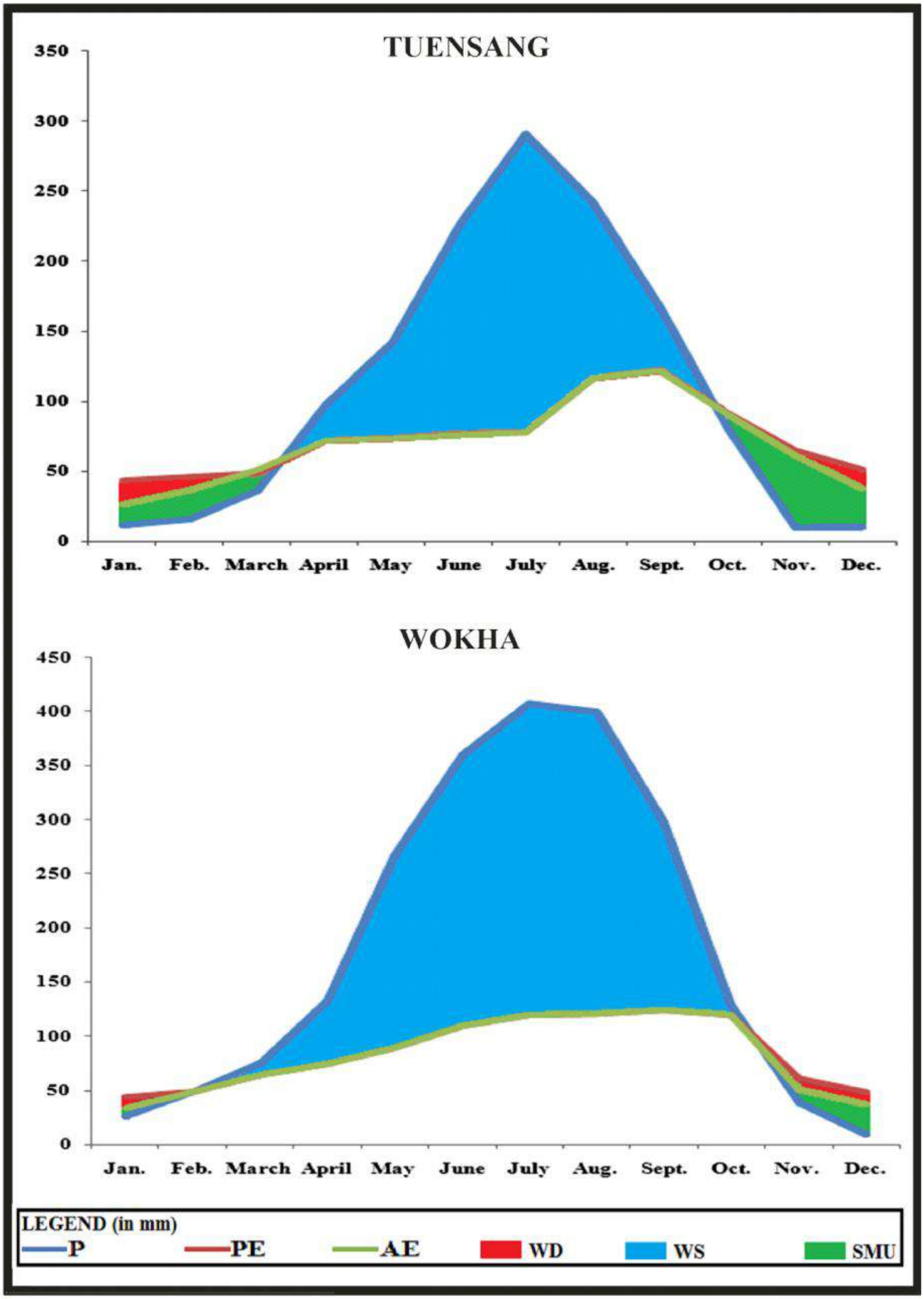


Fig. 4.6

At Tuensang rain-gauge station, the maximum mean precipitation value was shown in the month of July with 290 mm. The average value was 109 mm annually. The value of maximum Potential Evapotranspiration and Actual Evapotranspiration was 120 mm each in the month of September. The average value of PE and AE was recorded 72 mm and 69 mm respectively. The water deficit values were recorded in the months of January, February and from October to December. The maximum value was recorded 17 mm in the month of January. The average water deficit value shows 4 mm. The water surplus values were concentrated from April to September. The month of July highlighted high value of water surplus with 214 mm. The soil moisture utilisation prevailed in the months of November, December, January and February **(Fig 4.7)**.

The maximum mean rainfall of 409 mm was received at Wokha station in the month of July. The annual mean average rainfall was 184 mm. The Potential Evapotranspiration and Actual Evapotranspiration values were recorded maximum in the month September with 125 mm each. The average value was 86 mm and 84 mm respectively. The water deficit values were shown in the months of November, December and January where December recorded maximum value of 12 mm. This station shows average water deficit value of 3 mm. The period of water surplus was reported from March to October. The maximum water surplus was reported during the month of July with 289 mm. The average water surplus value was 104 mm. The soil moisture utility value was prevalent during the months of November, December and January **(Fig. 4.7)**.



TUENSANG
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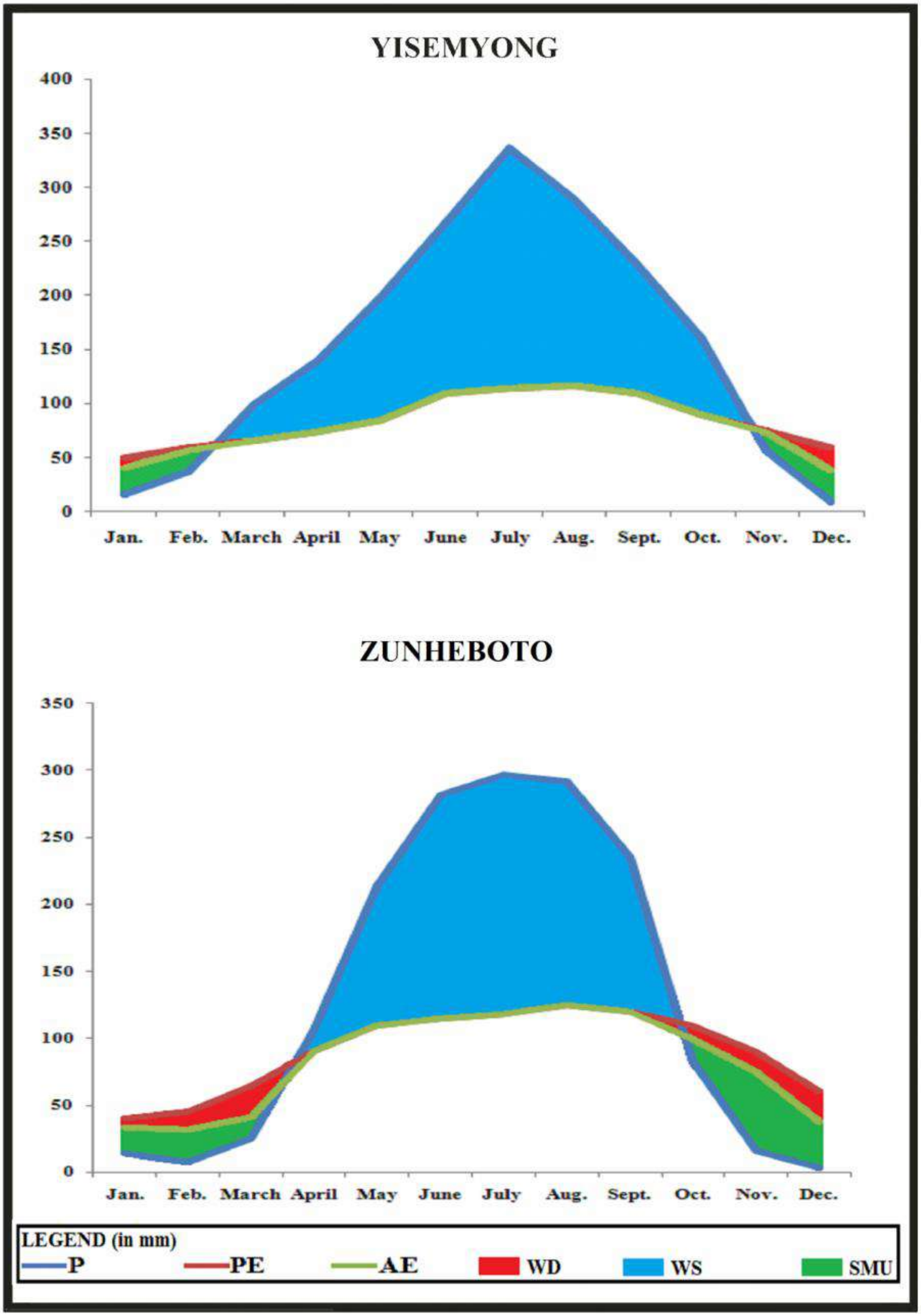
LEGEND (in mm)
P
PE
AE
WD
WS
SMU

Fig. 4.7

At Yisemyong rain-gauge station, the month of July received highest value of mean precipitation with 339 mm. The average annual mean precipitation was 153 mm. The maximum value of the Potential Evapotranspiration and Actual Evapotranspiration was 117 mm each in the month of August with an average value of 84 mm and 81 mm respectively. The water deficit values were concentrated in the months of November, December, January and February. The month of December show highest concentrated value of 22 mm. The annual average of water deficit value was 3 mm. The months of water surplus were recorded from April to October. The month of July recorded maximum value of 222 mm with an annual average value of 80 mm. Soil moisture utilisation existed in November, December, January and February **(Fig. 4.8)**.

The Zunheboto rain-gauge station received maximum mean rainfall of 297 mm during the month of July. The average annual value was 131 mm. In the month of August, the maximum value of Potential Evapotranspiration and Actual Evapotranspiration were shown 125 mm each. The average value was 91 mm and 83 mm respectively. The water deficit periods were experienced from the month of January to March and from October to December. The maximum value of water deficit was exhibited in the month of March with 24 mm. The annual average water deficit value was 8 mm. The water surplus values were noted from April to September. The maximum value of water surplus was observed in the month of July with 179 mm. The soil moisture utilisation operated from January to March and October to December **(Fig 4.8)**.


YISEMYONG
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Oct.
Nov.
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ZUNHEBOTO
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300
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200
150
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June
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Sept.
Oct.
Nov.
Dec.
LEGEND (in mm)
P
PE
AE
WD
WS
SMU

Fig. 4.8

4.8 Water Balance Estimation of Nagaland

1. Total surface of the water resources: 25,465,344,000 m^3.
2. Surface water resources recharged to ground water: 13,561,622,000 m^3.
3. Water lost in the form of evaporation and evapotranspiration**:** 16,827,685,000 m^3
4. Water surplus : 7,991,078,000 m^3
5. Surface run-off : 17,825,740,800 m^3

From the rain-gauge station-wise analysis, it is summarized that the study area is depicted as water surplus area. However, due to hilly terrain surface run-off accounts 70 percent. About 30 percent of water surplus period prevailed in monsoon season but during winter, pre-monsoon and post-monsoon seasons, 70 percent of the water was lost owing to dry condition, evaporation and evapotranspiration. As such, very less percentage of water was stored in surface lake, ponds, beels, etc. Therefore, the water lost in the form of run-off has to be stored adopting watershed management programme in the study area by constructing check dams, percolating ponds and water harvesting structures.

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Chapter 5

Land Utilisation and Irrigation of

5.1 Land Utilisation

Land utilisation of any region is the interaction of the operation of the whole range of environmental factors modified by socio-economic and historical elements. It is a complex diversified and dynamic concept. It is a functional concept because transformation of land cover is always meant for specific purposes like agriculture, pasture, forest, settlement, industry and communication. Land uses are distributed in interactive mixtures. The concept of land use in considered as relatively stable subject, related mainly to the use to which the land in certain season is put use at a certain period of time.

Land utilisation is defined as the use of the land that the entire surface is put to use. It is concerned with the type of land use which man carries out at a certain period of time over an area. It is a dynamic one where transformation of land cover or conversion of land uses type to another for specific purpose to meet timely needs and necessity of mankind. The landscape ecology is inter-disciplinary approach where geographical and biological out looks are involved. Land use ecology forms a central theme in biogeography. Land use studies are of paramount importance where and when resources base of any regions is under evaluation. 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 utilisation 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 organisations like National Atlas and Thematic Mapping Organisation, All India Soil and Land use Survey, Directorate of Economics and Statistics, 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, forestland, 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.

These are forest cover, area put under non agricultural use, barren lands, permanent pastures and other grazing land, land under miscellaneous tree crops and groves, culturable waste land, current fallow land, other fallow land and net area sown.

The land utilisation data has been collected from 1993-94, 1998-99, 2003-04, 2008-09, and 2013-14 at district level and calculated adopting Bhatia's (1965) statistical method for analysis of land utilisation categories for a period five years, decadal-wise and finally computed land utilisation changes for about 20 years. Analysis of irrigation sources to estimate net sown area, district-wise percentage of total irrigated area, net irrigation area, net cultivated area and intensity of irrigation on standard deviation method.

For example:

To compute land utilisation categories of Dimapur forest area

$$= \frac{\text{(Forest area of Dimapur district / total area of Dimapur district)}}{\text{Total forest area of all districts / total net area of all districts}}$$

5.1.1 District-wise Percentage of Land Utilisation

The district-wise percentage of land utilisation ranges from a minimum of 3.5 percent in Longleng district to a maximum of 15 percent in Tuensang district. More than 10 percent of land utilisation was shown in four districts, these were in Mon, Peren, Phek, and Tuensang, while the rest districts land utilisation remain below 10 percent **(Table 5.1 & Fig. 5.1)**.

Table 5.1: District-wise percentage of Land Utilisation (Average of Preceding 5 years)

Sl. No.	Districts	District wise % of Land Utilisation
1	Dimapur	5.6
2	Kiphire	7.0
3	Kohima	8.0
4	Longleng	3.5
5	Mokokchung	9.7
6	Mon	10.8
7	Peren	10.8
8	Phek	12.2
9	Tuensang	15.0
10	Wokha	9.8
11	Zunheboto	7.6

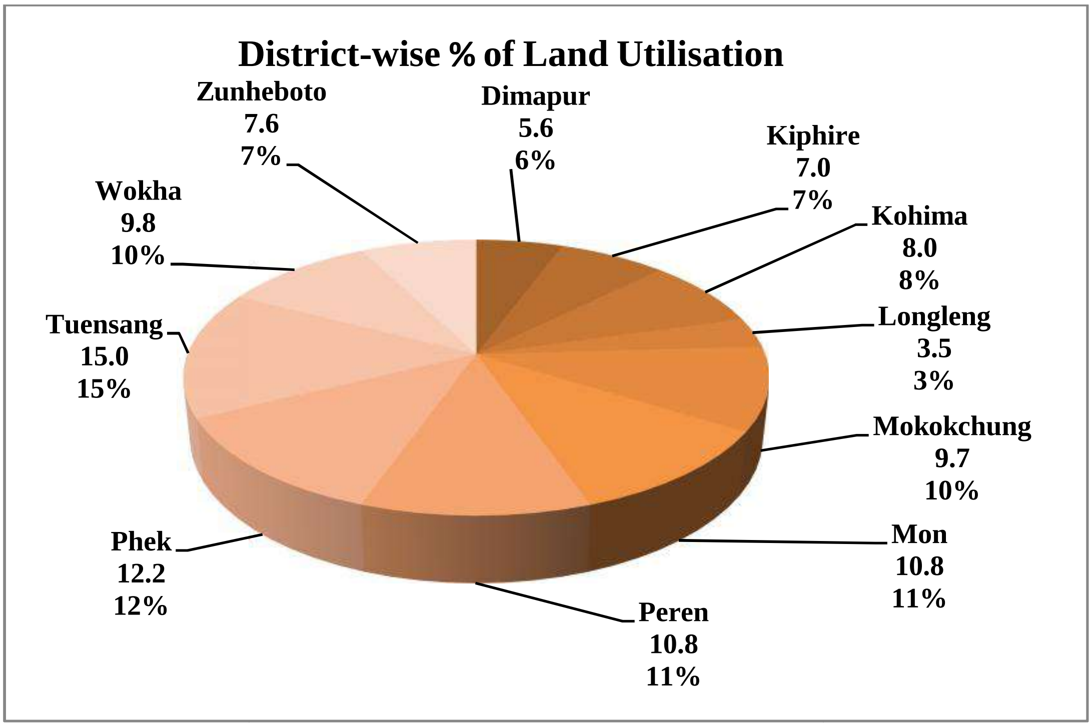

Fig. 5.1

5.1.2 The Land Utilisation (Category-wise)

The analysis of land utilisation category-wise, such as forest area, barren and uncultivable land, land put to non-agricultural use, land under miscellaneous tree crops, grooves etc., current fallow land, other fallow land and net sown area average preceding of five years were worked out according to Bhatia’s (1965) method.

The total forest area is about 767,733 hectares of land which accounted to 46.31 percent of total geographical area. The total area of other land utilisation were, under barren and uncultivable land 201,874 hectares (12.18%), land put non-agricultural use 56,022 hectares (3.38%), land under miscellaneous tree crops and grooves etc., 8,227 hectares (0.50%), current fallow land 124,360 hectares (7.50%), other fallow land 322,737 hectares (19.47%) and net sown area 176,949 hectares (10.67%).

As per Bhatia’s (1965) method the forest area above one were found in Kiphire, Mon, Peren, Tuensang and Wokha districts while the other districts falls less than one. The barren and uncultivable land above one were noticed in five districts only, namely, Dimapur, Kohima, Mokokchung, Mon, and Phek districts **(Table 5.2 & Fig. 5.2)**. Dimapur district revealed land put to non-agricultural use above two, followed by above one in Kohima, Longleng, Mokokchung, Mon, Wokha and Zunheboto districts. The districts of Kiphire, Peren, Phek and Tuensang were indicated below one. Land under miscellaneous tree crops and grooves etc., value was highest in Dimapur district which shows nearly 13. The current fallow land value above one were shown in Kiphire, Longleng, Mokokchung and Zunheboto districts while the rest districts were projected with low values. Under the category of ‘other fallow land’, the districts of Dimapur, Mokokchung and Mon districts presents below the value of one, while the rest districts exhibited above the value. The net sown area above the value one were revealed in Dimapur, Longleng, Mon and Zunheboto district only.

Table 5.2: Land Utilisation (Average of preceding 5 years)

Sl. No.	Districts	Forest	Barren and Uncultivable	Land put to Non-Agri. use	Land under miscellaneous tree crops and grooves	Current fallow	Other fallow	Net sown area
1	Dimapur	0.99	1.25	2.95	12.62	0.23	0.14	1.81
2	Kiphire	1.07	0.11	0.76	DNA	1.86	1.29	0.70
3	Kohima	0.94	1.42	1.25	0.15	0.53	1.14	0.92
4	Longleng	0.88	0.55	1.44	DNA	1.66	1.06	1.38
5	Mokokchung	0.77	1.63	1.86	DNA	1.76	0.93	0.71
6	Mon	1.11	1.99	1.03	DNA	0.28	0.09	1.66
7	Peren	1.08	0.79	0.70	2.48	0.61	1.30	0.73
8	Phek	0.98	1.17	0.90	0.06	0.88	1.19	0.78
9	Tuensang	1.10	0.66	0.54	DNA	0.66	1.33	0.84
10	Wokha	1.11	0.48	1.00	DNA	0.85	1.34	0.73
11	Zunheboto	0.88	0.77	1.33	DNA	1.81	1.07	1.03

Source: Nagaland Science & Technology Council (NASTEC), DNA= Data Not Available.

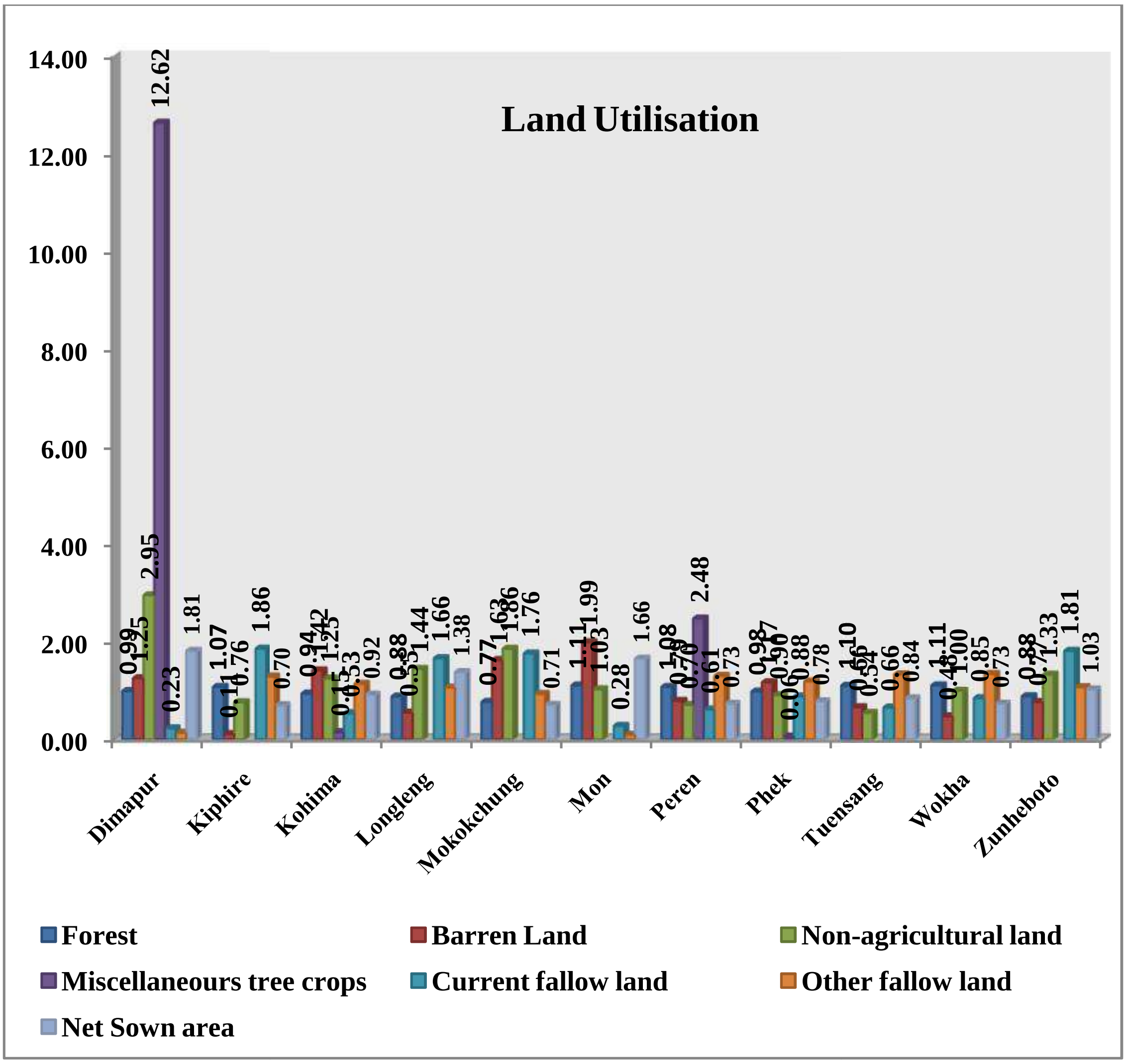

Fig. 5.2

5.1.3 Temporal Variation of Land Utilisation (1993-94, 1998-99, 2003-04, 2008-09 and 2013-14)

The analysis of temporal variation of land utilisation revealed that the forest area of Nagaland decreased drastically (**Table 5.3**). In the year 1993-94, the area of forest cover accounted 56.16 percent of the total geographical area which decreased to 55.75 percent (1993-94), 53.85 percent (2003-04), 53.26 percent (2008-09) and 52.54 percent (2013-14). Land put to non-agricultural use increased from 2.86 percent (1993-94) to 5.59 percent (2013-14). The land under miscellaneous tree crops, grooves etc., cover area declined from 8.59 percent (1993-94) to 5.64 percent (2013-14). The area under culturable wasteland and current fallow land decreased from 5.77 percent (1993-94) to 4.18 percent (2013-04) and 7.83 percent (1993-94) to 3.01 percent (2013-14) respectively. The land use under fallow land and other than current fallow area declined from 6.46 percent (1993-94) to 5.99 percent (2013-14). The net sown area (agricultural land use) increased from 12.34 percent (1993-94) to 22.90 percent (2013-14).

5.1.4 Decadal Variation of Land Utilisation (1993-94, 2003-04 and 2013-14)

The decadal analysis of land utilisation from 1993-04 to 2013-14 (20 years) revealed that the forest area of Nagaland decreased by –3.62 percent while the land put to non agricultural use increased to 2.73 percent. The landuse under miscellaneous tree crops, grooves etc., culturable waste land, current fallow and, fallow land and other current fallow land revealed decrease in land utilisation percentage by –2.95 percent, –1.58 percent, –4.82 percent and –0.47 percent respectively. The net sown area (agricultural land use) increased to 10.56 percent **(Table 5.4 & Fig. 5.3)**.

Table 5.3: Temporal Variation of Land Utilisation (1993-94, 1998-99, 2003-04, 2008-09 and 2013-14)

Sl. No.	Landuse Categories	1993-94		1998-99		2003-04		2008-09		2013-14	
		Area in (ha)	Area in %	Area in (ha)	%	Area in (ha)	%	Area in (ha)	%	Area in (ha)	%
1	Forest	862532	56.16	862532	55.75	862930	53.85	862930	53.26	872930	52.54
2	Barren and uncultivable land	DNA	DNA	DNA	DNA	DNA	DNA	3442	0.21	2496	0.15
3	Land put to non agricultural use	43890	2.86	65140	4.21	94893	5.92	94732	5.85	92862	5.59
4	Land under misc. Tree crops, grooves etc	131910	8.59	123953	8.01	121600	7.59	121176	7.48	93642	5.64
5	Culturable waste land	88560	5.77	65357	4.22	57750	3.60	59588	3.68	69525	4.18
6	Current fallow	120250	7.83	91979	5.94	84013	5.24	73415	4.53	50078	3.01
7	Fallow land and other than current fallow	99280	6.46	76889	4.97	76210	4.76	89477	5.52	99529	5.99
8	Net sown area (agricultural land use)	189473	12.34	261409	16.89	305138	19.04	315570	19.48	380468	22.90

Source: Statistical Handbook of Nagaland; DNA= Data Not Available.

Table 5.4: Decadal Variation of Land Utilisation (1993-94 to 2003-04 and 2013-14)

Sl. No.	Landuse Categories	Decadal variation of Land utilisation Changes in %		Land utilisation changes in % (20 years)
		1993-94 to 2003-04	2003-04 to 2013-14	1993-94 to 2013-14
1	Forest	-2.31	-1.31	-3.62
2	Barren and uncultivable land	DNA	DNA	DNA
3	Land put to non agricultural use	3.06	-0.33	2.73
4	Land under misc. Tree crops, grooves etc	-1.00	-1.95	-2.95
5	Culturable waste land	-2.16	0.58	-1.58
6	Current fallow	-2.59	-2.23	-4.82
7	Fallow land and other than current fallow	-1.71	1.23	-0.47
8	Net sown area (agricultural land use)	6.70	3.86	10.56

Source: Statistical Handbook of Nagaland; DNA= Data Not Available.

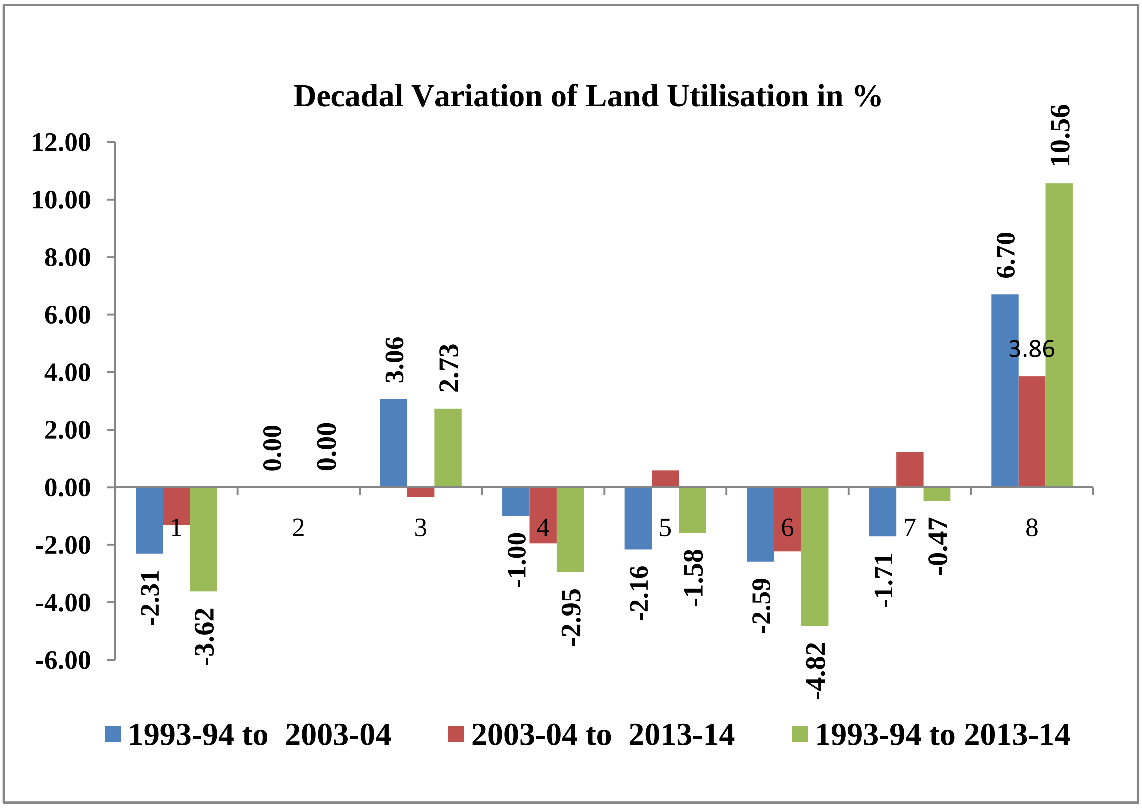

Fig. 5.3

5.2 Irrigation

The concept of irrigation is an artificial application of water to land which is essential for food supply and sustenance, profitable and marketable farming, and optimum use of land. It plays an important role and is a basic ingredient in the process of transforming agriculture. The main sources of irrigation are surface water and ground water. Irrigation facilitates agricultural innovations and development which maintains storage of water in the soil required for plant growth at times and places during deficiency of water supply. Proper management and appropriate maintenance of irrigational sources not only supplements rainfall but also corrects inequalities in the distribution of rainfall. In rainfed and water deficient regions, irrigational facilities provide alternate means of water sources to sustain growth of crops. This maintains soil moisture imbalances required for crops to grow. From time immemorial, irrigational engineering has sustained millions of population as it aid in increase of yield and ensures food supply.

The irrigation data at district level for the year 2000-01 and 2007-08 has been collected, calculated average and analysed source-wise irrigated area (in ha), district-wise irrigation percentage and intensity of irrigation. Bhatia’s (1965) method has been used for the analysis of Irrigation concentration, and intensity of irrigation.

To compute:

Sources of irrigation =

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

$$\textbf{District-wise \% of irrigation} = \frac{\text{Total irrigated area of district}}{\text{Net irrigated area of district}} \times 100$$

$$\textbf{Intensity of irrigation} = \frac{\text{Total irrigated area of district}}{\text{Net area sown}} \times 100$$

The total irrigated area under various sources of irrigation in Nagaland during 2000-01 and 2007-08 was 51,509 hectares of land. It accounted to 3.10 percent of the total geographical area. Out of the 51,509 hectares of total irrigated area, the area under canal irrigation was 51,361 hectares (99.71%), the area under tube well irrigation was 2 hectares (0.0003%), the area under other wells was 70 hectares (0.13%) and the area under other sources of irrigation was about 76 hectares of land (0.14%).

5.2.1 Sources of Irrigation

The analysis of concentration of irrigation during the year 2000-01 and 2007- 08 noted that the canal irrigation was found in all districts. The tube well and other wells sources of irrigation were found only in Dimapur district and other sources of irrigation were noticed in districts of Dimapur, Mokokchung, Phek and Wokha **(Table 5.5)**.

Table 5.5: Irrigation concentration of Nagaland (2000-01 and 2007-08)

Sl. No.	Districts	Area Irrigated (in Hectare)				
		Canals	Tanks	Tube Wells	Other Wells	Other Sources
1	Dimapur	0.99	DNA	4.78	4.18	2.70
2	Kiphire	1.00	DNA	DNA	DNA	DNA
3	Kohima	1.00	DNA	DNA	DNA	DNA
4	Longleng	1.00	DNA	DNA	DNA	DNA
5	Mokokchung	1.00	DNA	DNA	DNA	2.91
6	Mon	1.00	DNA	DNA	DNA	DNA
7	Peren	1.00	DNA	DNA	DNA	DNA
8	Phek	1.00	DNA	DNA	DNA	0.83
9	Tuensang	1.00	DNA	DNA	DNA	DNA
10	Wokha	1.00	DNA	DNA	DNA	2.03
11	Zunheboto	1.00	DNA	DNA	DNA	DNA

Source: Minor Irrigation Scheme, Nagaland, DNA= Data Not Available.

5.2.2 District-wise Source of Irrigation

The district-wise source of irrigation varies from a minimum of 1.6 percent in Longleng district to a maximum of 27.1 percent in Dimapur district. The percentage of irrigation was less than 10 in Kiphire, Mokokchung, Mon, Peren, Tuensang, Wokha and Zunheboto districts **(Table 5.6 & Fig. 5.4, 5.5)**, which are spatially distributed in eastern, northern and tip of south-western (Peren) parts of the study area. The percentage of irrigation ranges from 10 percent to 20 percent in Phek and Kohima districts which are located in the southern parts of the region. The maximum percentage was noticed in Dimapur district which is spatially distributed in south-western part of the state and more over plain area.

Table 5.6: District-wise percentage of Irrigation Pattern (2000-01 and 2007-08)

Sl. No.	Districts	District-wise % of Irrigation
1	Dimapur	27.1
2	Kiphire	1.7
3	Kohima	12.7
4	Longleng	1.6
5	Mokokchung	6.9
6	Mon	4.1
7	Peren	7.1
8	Phek	14.9
9	Tuensang	8.2
10	Wokha	6.1
11	Zunheboto	9.6

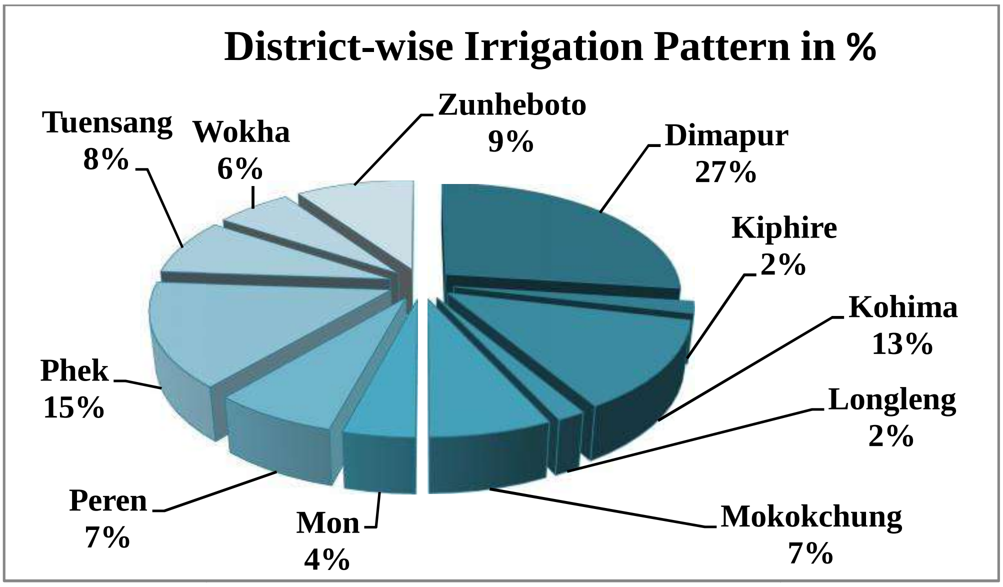

Fig. 5.4

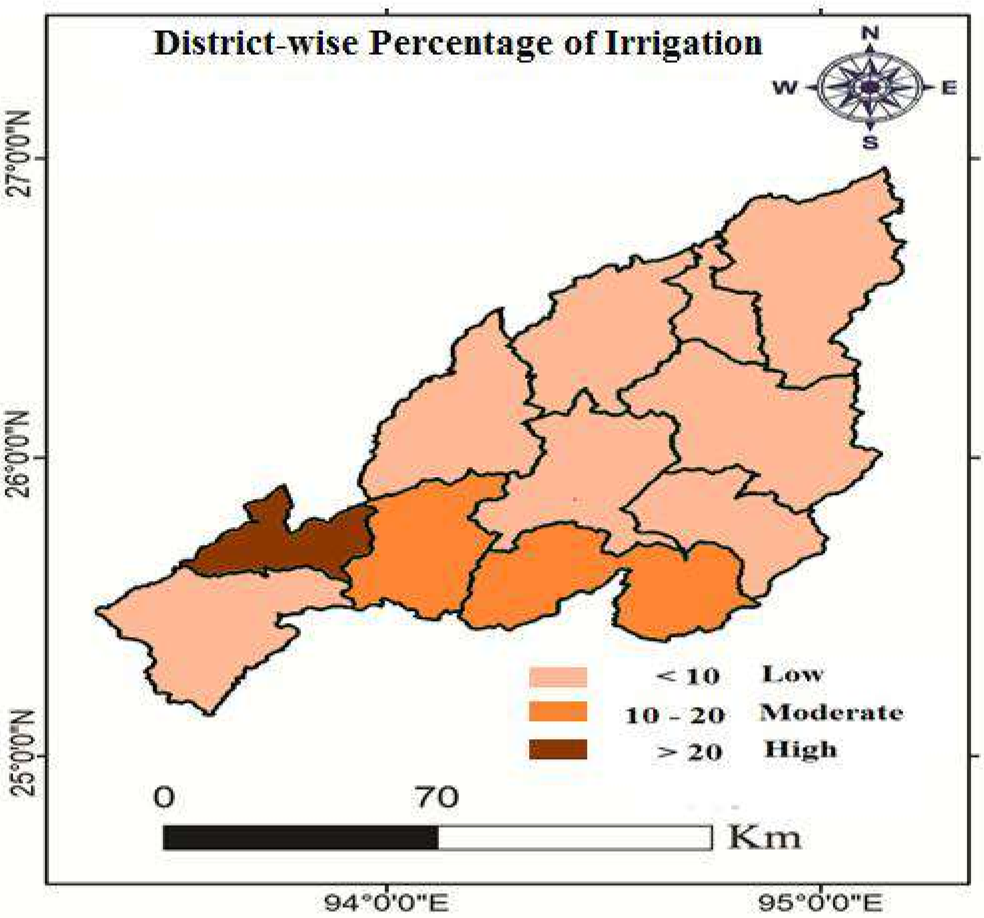

Fig 5.5

5.2.3 Intensity of Irrigation

The intensity of irrigation during 2007-08 varies from a minimum of 62.82 percent in Longleng district to a maximum of 103.82 percent in Kohima district. The average intensity of irrigation was 93.92 percent. The intensity of irrigation exceeded 100 percent in Kohima district only and noticed 100 percent in Kiphire and Wokha districts. The intensity of irrigation less than 100 percent were revealed in districts of Dimapur, Mokokchung, Mon, Phek, tuensang and Zunheboto. The spatial distribution of intensity of irrigation shows all districts under 100 percent except southern part of the study area (Kohima) which shows more than 100 percent **(Table: 5.7 & Fig.: 5.6)**.

Table 5.7: Intensity of Irrigation, Nagaland

Sl. No.	Districts	Intensity of Irrigation
1	Dimapur	88.93
2	Kiphire	100
3	Kohima	103.82
4	Longleng	62.75
5	Mokokchung	95.91
6	Mon	84.56
7	Peren	100
8	Phek	97.41
9	Tuensang	99.98
10	Wokha	100
11	Zunheboto	99.77

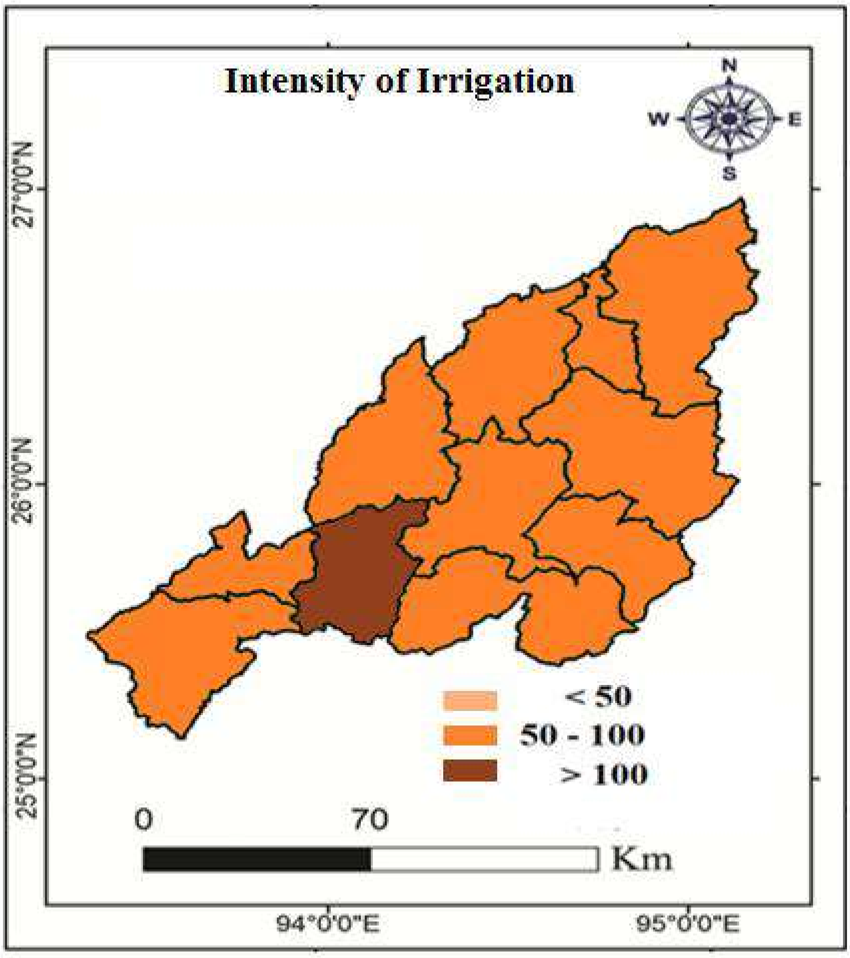

Fig 5.6

5.2.4 Net Irrigated Area and Net Cultivated Area in % (2007-08)

Net irrigated area varies from a minimum of 56 percent in Mon district to a maximum of 95 percent in Dimapur district. The average net irrigated area was 82 percent. The districts of Mokokchung, Peren, Phek, Tuensang and Zunheboto were shown above the average while the net irrigated area of other districts revealed less than average percentage **(Table 5.8)**.

Net cultivated area ranges from a minimum of 29 percent in Mokokchung district to a maximum of 86 percent in Kiphire district. The average percentage of net cultivated area was 47 percent. The districts of Dimapur, Longleng, Tuensang, Wokha and Zunheboto shows more than average (47%) net cultivated area while the net cultivated area of other districts revealed less than average percentage **(Table 5.8).**

Table 5.8: Irrigation Status (Area in Ha.) 2007-08

Sl. No.	Districts	Gross irrigated area	Net irrigated area	% Net irrigated area	Net cultivated area	Rainfed area	% of Net cultivated area
1	Dimapur	15400	14635	95	18470	32380	57
2	Kiphire	2087	1500	72	8960	10474	86
3	Kohima	11957	7057	59	13347	35791	37
4	Longleng	1897	1337	70	8908	12777	70
5	Mokokchung	6154	5602	91	12598	44157	29
6	Mon	4183	2332	56	32519	75196	43
7	Peren	5240	4381	84	14400	31366	46
8	Phek	10162	9442	93	17397	45815	38
9	Tuensang	7200	6476	90	23037	42700	54
10	Wokha	3550	2269	64	13134	22426	59
11	Zunheboto	7050	6121	87	14179	25740	55
	Nagaland	**74880**	**61152**	**82**	**176949**	**378822**	**47**

Source: Nagaland Basic Facts-2008, Directorate of Agriculture Department, Nagaland and NASTEC.

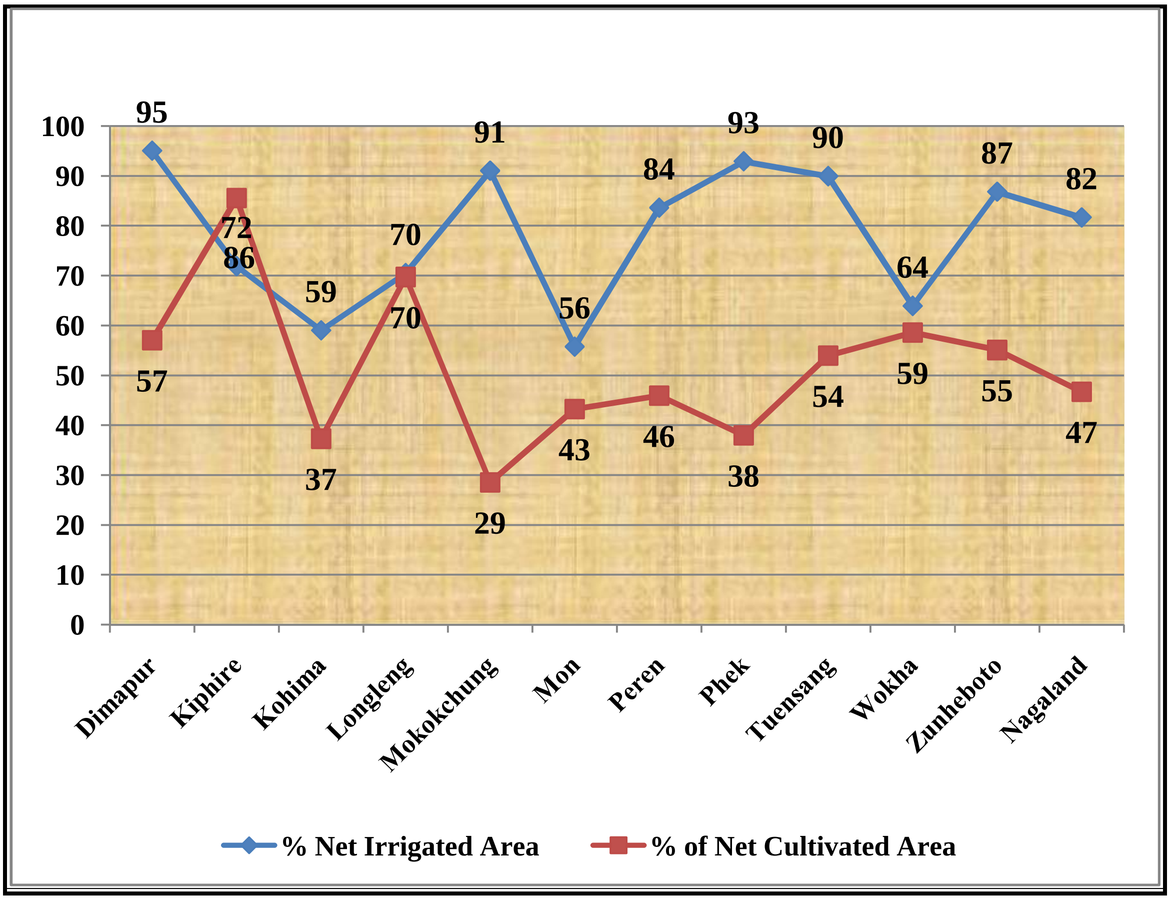

Fig. 5.7

The graph shows that only the district of Kiphire revealed net cultivated area more than net irrigated area. In Longleng district, net cultivated area equals net cultivated area **(Fig.5.7)**. A cursory observation at the graph reveals high percentage of net irrigated area by 90 percent and above was indicated in four districts. These were in Dimapur (95%), Mokokchung (91%), Phek (93%) and Tuensang (90%) districts. The correlation coefficient between net irrigated area to net cultivated area was found out positive (0.18), then variables are associated directly.

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Chapter 6

Agriculture Development of Nagaland

Agriculture is a key sector in most of the developing countries. It plays a pivotal role enabling farmers to accomplish developmental goals, including self-reliance and employment guarantee, growth and equity. Bhatt (2006) highlighted that this agriculture system supports about 2.3 to 2.6 billion people around the third world countries through application of modern technologies. It is characterized by utilisation of good soils and supported by reliable access to water. In contrast, such systems are not applicable in mountainous region with high terrain, steep slopes and narrow valleys with fast flowing runoff.

The agricultural system in Nagaland is traditional and culturally integrated form as most farmers are subsistence in nature or in other words, marginal producers. Geographically, Nagaland has vast area potential for agro-product, yet threatens by food security problems now and then. Such problems are related to traditional practices, small holdings, improper land-use, lack of institutional aid, etc. The agricultural produce are confined to consumption, in other words for self sustenance. However, due to time factor of population and to balance food security, agricultural pattern can be examined by environmental conditions such as temperature, moisture, soil tillage, etc., which are required for cultivation. Subsequently, the areal distribution, concentration, production, productivity, marketing, processing, distribution and consumption are important indicators for trend of agricultural activities.

The concept of Agricultural development is considered as multi-faceted, mainly focused on cropped land development, improvement in farming practices and systems, enhance farm implements, irrigation facilities and irrigated area, intensity of cropping and specialisation, commercialisation, etc. Besides, crop productivity which is the main aspects of agricultural development, it has to be judged equally on quantity of produce and variety of quality of produce. The crop productivity is measured by yield per hectares per crop where variety of agricultural produce can be noted from the crop diversification index. Diversification of cropping elements support not only on economic grounds but also accounted to self-reliance in production and soil fertility maintenance. Igbozurike (1971) opined that ‘Specialization in cropping, including mono-culture, may yield rich dividends for a while but mono-culture is inimical to nature order, deleterious to ecospheric safety and lethal to men's long term interest'.

About twenty selected crops data in district level were collected during 2002-04 and 2012-14, after which three years average were taken and computed differences decadal wise changes of cropping pattern, crop diversification, crop combination and agricultural production of Nagaland. The total cropped area of the state during 2002-04 was 3,19,824 hectares (19.29%) and 2012-14 was 3,83,757 hectares (23.14%) of the total geographical area of the state. The change in cropping pattern shows decadal variation of 2002-04 and 2012-14 was 3.85 percent. The district-wise percentage of total cropping area, percentages of cropping pattern, index of crop concentration and crop diversification index were computed adopting Bhatia's (1965) method. The intensity of cropping pattern, ranking of crops and crop combination were worked out through Rafiullah's (1956) and Doi's (1957) methods.

District wise percentage of total cropping area =

$$\frac{\text{Total cropped area of Districts}}{\text{Net cropped area}} \times 100$$

Crop concentration =

$$\frac{\text{Crop area of District}}{\text{Total cropped area of District}} \div \frac{\text{Total Cropped area of Districts}}{\text{Net cropped area}}$$

Crop diversification = $$\frac{\text{\% of all sown area of all crops}}{\text{No. of crops}} \times 100$$

$$\textbf{Intensity of crops} = \frac{\text{Total cropped area}}{\text{Net sown area}} \times 100$$

Crop Combination

The crop combinations of Nagaland at district wise were computed 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's is 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 is expressed as: $(\Sigma\ d^2)$

The combinations that have the lowest (Σ d^2) will be concentration. In Doi's technique it is not required to calculate (Σ d^2) for each combination but the combination 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 tables required only the summing of actual percentages under different crops instead of finding differences between actual percentage and theoretical distribution.

The total cropped area of the state during 2002-04 was 3,19,824 hectares (19.29%) and 2012-14 was 3,83,757 hectares (23.14%) of the total geographical area of the state. The cropping pattern change in decadal wise from 2002-04 and 2012-14 was 3.85 percent.

6.1 Cropping Pattern in % (2012-14)

The total cropped area of Nagaland during 2012-14 was 3,83,757 hectares of the land which accounted to 23.14 percent of the total geographical area. Out of 3,83,757 hectares of total cropping area, the area under different crop cultivation were as follows **(Fig. 6.1)**; Jhum paddy cultivation 95,680 hectares (24.93%), the area under TRC/WRC paddy cultivation 86,420 hectares (22.52%), the area under Maize cultivation 68,540 hectares (17.86%), the area of Rape seed/ Mustard noticed 27,113 hectares (7.07%), Soyabean cultivation 24,510 hectares (6.39%), Rajmash cultivation 14,390 hectares (3.75%) and Small Millet cultivated under 8,530 hectares (2.22%) of the land. The other crops which occupied less than 2 percent of the area were Tea 7,487 hectares (1.95%), Pea 6,953 hectares (1.81%), Potato 6,553 hectares (1.71%), Linseed 5,727 hectares

(1.49%), Colocossia 5,167 hectares (1.35%), Naga Dal 4,553 hectares (1.19%), Sugarcane 4,283 hectares (1.12%), Sesamum 3,503 hectares (0.91%), Ginger 3,370 hectares (0.88%), Wheat 3,153 hectares (0.82%), Jute 2,997 hectares (0.78%), Tur/ Arhar 2,623 hectares (0.68%) and 2,203 hectares (0.57%) of the land under the cultivation of Beans.

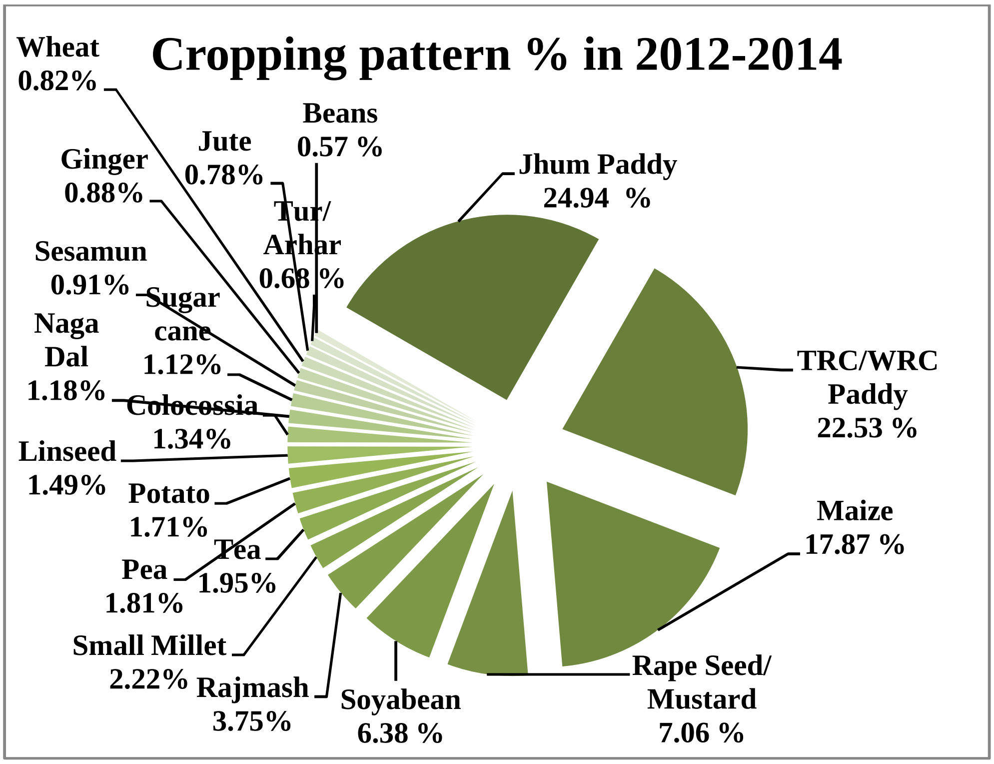


Fig. 6.1

6.2 Decadal Variation of Cropped Area (2002-04 to 2012-14)

The decadal variation of cropping area of twenty crops shows total cropped area of 3,19,824 hectares (2002-04) and 3,83,757 hectares during 2012-2014. This accounted to 19.29 percent and 23.14 percent of the total geographical area respectively. The decadal wise cropping area shows 3.85 percent increased from 2002-04 to 2012-14. Out of twenty crops, only nine crops shows increase in cropping area of Nagaland **(Table 6.1)**. Among these crops, only area of four crops increased more than 1 percent that comprises Maize (4.76%), Rapeseed/ Mustard (1.52%), Rajmash (2.81%) and Tea (1.21%).The decadal variation of cropping area of Naga dal (0.32%), Sugarcane (0.48%), Jute (0.35%), Beans (0.05%) and Colocossia (0.59%) increased less than 1 percent.

Table 6.1: Decadal variation of cropped area (2002-04 to 2012-14)

Sl. No.	Crops	2002-04 Cropping pattern area in %	2012-14 Cropping pattern area in %	Decadal variation of cropping area from 2002-04 to 2012-14
1	Jhum Paddy	28.63	24.93	–3.70
2	TRC/WRC Paddy	24.42	22.52	–1.90
3	Maize	13.10	17.86	4.76
4	Rape Seed/ Mustard	5.54	7.07	1.52
5	Soyabean	6.39	6.39	0.00
6	Rajmash	0.94	3.75	2.81
7	Small Millet	3.02	2.22	–0.79
8	Tea	0.74	1.95	1.21
9	Pea	2.43	1.81	–0.61
10	Potato	1.79	1.71	–0.09
11	Linseed	2.81	1.49	–1.32
12	Naga Dal	0.87	1.19	0.32
13	Sugar cane	0.63	1.12	0.48
14	Sesamun	1.59	0.91	–0.68
15	Wheat	2.41	0.82	–1.59
16	Jute	0.43	0.78	0.35
17	Tur/ Arhar	2.06	0.68	–1.37
18	Beans	0.51	0.57	0.06
19	Colcossia	0.76	1.35	0.59
20	Ginger	0.93	0.88	–0.05

Source: Computed by Scholar.

6.3. Decadal (district-wise) Variation of Cropped Area (2002-04 to 2012-14)

The District-wise percentage of cropping pattern varies from a minimum 10.26 percent in Tuensang district to a maximum of 15.62 percent in Dimapur district during 2002-04 **(Table 6.2).** In 2012-14 the District wise percentage of cropping area varies from a minimum of 4.11 percent at Longleng district to a maximum of 17.66 percent at Dimapur district of the state. The decadal district-wise variation of cropping area from 2002-04 to 2012-14 revealed that only Dimapur and Tuensang districts cropping area were increased by 2.04 percent and 0.48 percent respectively.

Table 6.2: Decadal (district-wise) variation of cropped area in % (2002-2004 to 2012-2014)

Sl.No.	Name of the District	2002-04 (%)	2012-14 (%)
1	Dimapur	15.62	17.66
2	Kiphire	DNA	6.44
3	Kohima	15.54	8.57
4	Longleng	DNA	4.11
5	Mokokchung	11.00	8.23
6	Mon	10.36	9.97
7	Peren	DNA	6.21
8	Phek	13.36	9.57
9	Tuensang	10.26	10.74
10	Wokha	13.10	8.91
11	Zunheboto	10.66	9.60

Source: Compiled by Scholar, DNA= Data Not Available.

The spatial distribution shows that more than 16 percentage of cropping pattern exceeded only in Dimapur district which is located in extreme south-western parts of the state. The moderate cropping pattern which ranges from 8 percent to 16 percent were revealed in Kohima, Mokokchung, Mon, Phek, Tuensang, Wokha and Zunheboto districts which are located mainly on central parts and peak of the north. The low cropping pattern less than 8 percent were observed in Kiphire, Longleng and Peren districts which are located in northern, eastern and extreme tip of south-west of the state **(Fig. 6.2)**.

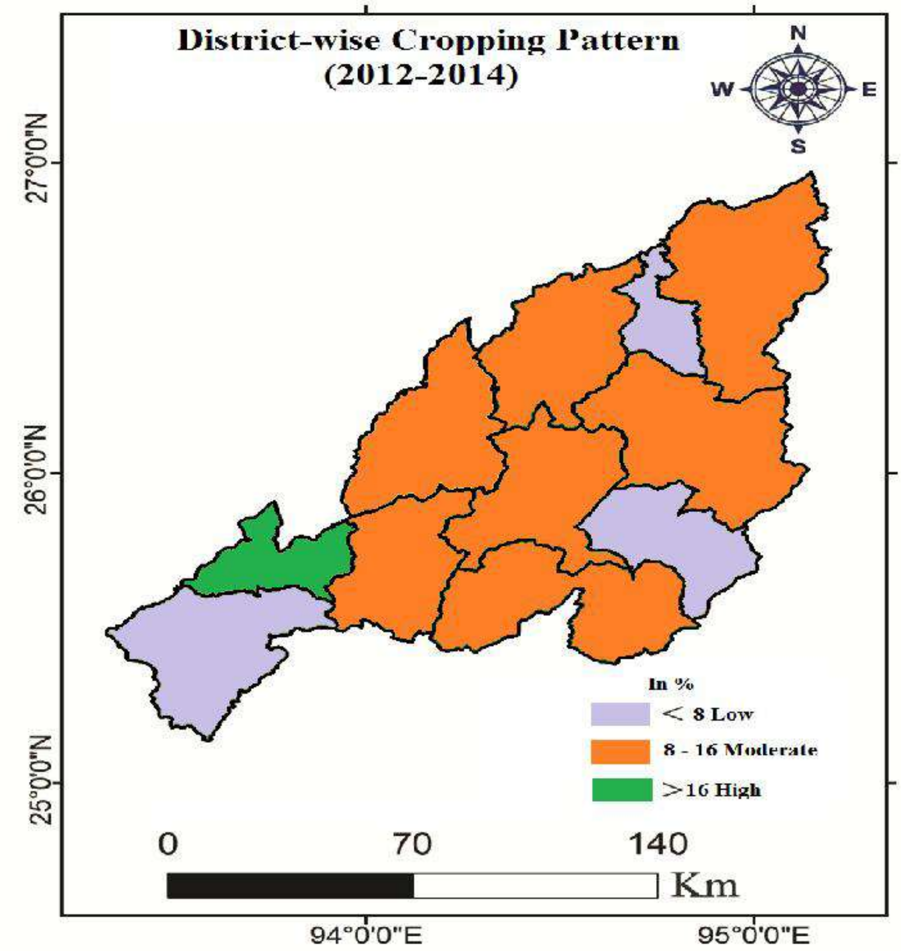


Fig. 6.2

6.4 Crop Concentration (2012-14)

The total cropped area of Nagaland during 2012-2014 was 3,83,757 hectares of the land which accounted 23.14 percent of the total geographical area of Nagaland. About twenty crops data at district level were collected and index of crop concentration were worked out adopting Bhatia's (1965) Method. These crops are Jhum paddy, TRC/WRC paddy, Maize, Rape seed/Mustard, Soyabean, Rajmash, Small millet, Tea, Pea, Potato, Linseed, Colocossia, Naga dal, Sugarcane, Sesamum, Ginger, Wheat, Jute, Tur/Arhar and Beans.

6.4.1 Jhum paddy

The Jhum paddy is an important crop of the state which was cultivated in about 95,680 hectares of the land. It accounted 24.94 percent of the total cropped area **(Table 6.3 & Fig. 6.3)**. The spatial distribution shows low concentration of Jhum paddy in two districts which are distributed in the south and south-western parts of the state. The moderate concentration of Jhum paddy was found in four districts which are located at the tip of south-west to central and eastern parts of the state. The high concentration of Jhum paddy was observed in five districts which are spatially distributed in north and north-western parts of the state. The highest concentration of Jhum paddy was found out in Longleng district with 1.64 percent.

6.4.2 TRC/ WRC paddy

The area under TRC/WRC paddy cultivation was 86,420 (22.52%) hectares of the total cultivated land. The spatial distribution shows low concentration in six districts which are located in the north, in the central and eastern parts **(Table 6.3 & Fig. 6.3)**. The moderate concentration was noticed in four districts, mainly distributed in the west and southern parts of the state. The high concentration of TRC/WRC paddy cultivation was found out only in Dimapur district (2.31%).

6.4.3 Maize

The Maize cultivation was done in 68,540 hectares of the land that accounted to 17.86 percent of total cropped area **(Table 6.3 & Fig. 6.3)**. The spatial distribution shows low concentration of Maize in six districts located along the western corridor and in peak of the north. The moderate concentration of Maize was found only in one district, located in the north. The high concentration of Maize crop was found in four districts which were distributed in the south and eastern parts of the state. The highest Maize crop by 1.69 percent was revealed in Kiphire district.

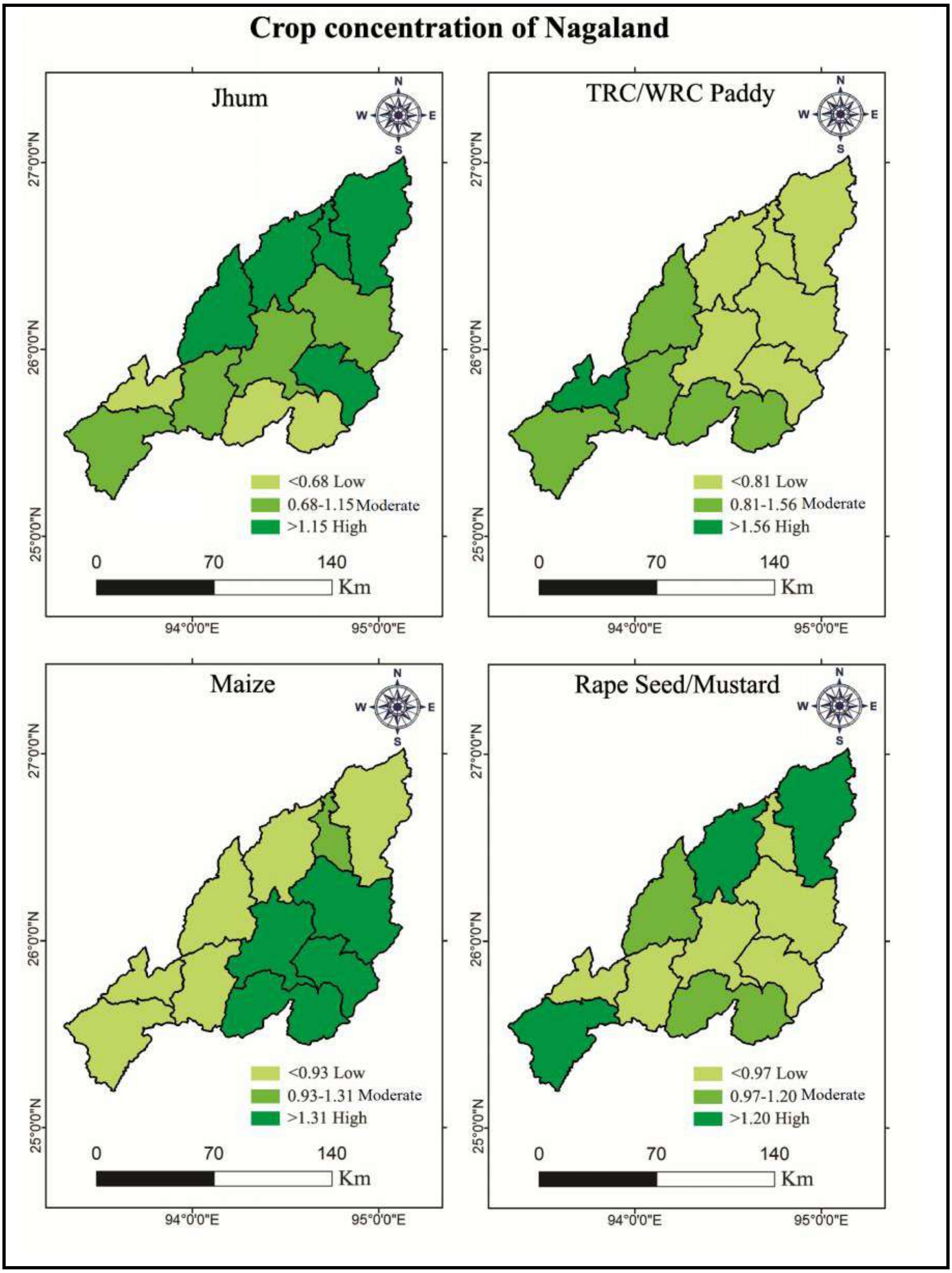
6.4.4 Rape Seed/ Mustard

The area under Rape Seed/Mustard cultivation noticed 27,113 hectares (7.07%) of the total cropped area **(Table 6.3 & Fig. 6.3)**. The spatial distribution shows low concentration in six districts that were distributed in the south-west, central, to the east and parts of the north. The moderate concentration of Rape-Seed/Mustard was found out in two districts, located in south and western parts of the state. The high concentrations were revealed in three districts. These are distributed at the peak of north, west and south-western parts of the state. The highest Rape Seed/Mustard crop was concentrated in Mokokchung district by 1.394 percent.

Table 6.3: Crop concentration of Nagaland (2012-14)

Sl. No.	Districts	Jhum Paddy	TRC/WRC Paddy	Maize	Rape Seed/ Mustard	Soyabean	Rajmash	Small millet	Tea	Pea	Potato	Linseed	Colocossia	Naga Dal	Sugar cane	Sesamum	Ginger	Wheat	Jute	Tur/ Arhar	Beans
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	Dimapur	0.56	2.31	0.55	0.87	0.50	DNA	DNA	2.12	0.53	0.47	1.61	0.35	DNA	1.65	0.92	0.72	0.57	1.15	0.62	DNA
2	Kiphire	1.45	0.15	1.69	0.69	0.71	2.90	0.20	0.04	0.67	0.25	0.81	1.60	1.46	0.65	0.69	0.73	DNA	DNA	0.32	0.66
3	Kohima	0.84	1.07	0.78	0.87	1.02	0.43	2.67	0.51	0.98	2.24	1.43	2.00	2.35	0.64	1.13	1.31	1.08	1.80	0.80	0.97
4	Longleng	1.64	0.06	1.07	0.91	1.11	2.57	0.60	DNA	1.12	0.55	1.46	2.54	2.16	0.76	0.95	1.27	DNA	DNA	0.42	0.95
5	Mokokchung	1.31	0.74	0.69	1.39	0.58	0.79	0.97	1.18	1.15	1.12	2.40	1.39	1.09	1.03	1.43	0.79	1.19	1.74	0.84	0.70
6	Mon	1.48	0.40	0.81	1.35	1.32	0.60	1.04	1.43	1.10	0.62	1.44	2.27	0.86	1.33	0.42	1.05	1.03	1.37	0.75	0.53
7	Peren	1.00	1.39	0.72	1.44	0.73	DNA	DNA	DNA	0.96	0.34	2.34	0.97	1.65	2.08	1.79	1.05	1.36	DNA	0.67	0.94
8	Phek	0.21	1.42	1.32	1.11	0.94	0.32	2.81	0.90	1.24	1.63	1.80	1.52	1.97	0.68	0.82	0.95	0.93	DNA	1.04	0.76
9	Tuensang	1.05	0.38	1.36	0.74	0.85	3.38	0.90	1.87	0.80	1.11	0.87	1.14	1.04	0.85	0.75	0.70	0.81	DNA	0.69	0.49
10	Wokha	1.28	0.82	0.84	1.07	0.73	0.50	2.18	0.20	1.00	0.75	1.73	1.47	1.21	1.52	1.17	0.88	0.98	1.61	0.49	0.75
11	Zunheboto	1.05	0.32	1.52	0.81	3.41	0.48	1.06	0.11	0.84	0.24	0.71	1.10	1.22	0.60	0.38	0.62	0.84	DNA	0.67	0.51

Source: Computed by Scholar. DNA=Data Not Available.



Crop concentration of Nagaland
Jhum
<0.68 Low
0.68-1.15 Moderate
>1.15 High
TRC/WRC Paddy
<0.81 Low
0.81-1.56 Moderate
>1.56 High
Maize
<0.93 Low
0.93-1.31 Moderate
>1.31 High
Rape Seed/Mustard
<0.97 Low
0.97-1.20 Moderate
>1.20 High
0
70
140
Km
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
N
S
E
W

Fig. 6.3

6.4.5 Soyabean

The Soyabean crop was cultivated in 24,510 hectares (6.39%) of the total cropped land **(Table 6.3 & Fig. 6.4)**. The spatial distribution revealed only low and high crop concentration. The cultivation of Soyabean shows low concentration in ten districts except Zunheboto district. The highest crop concentration was recorded in Zunheboto district which is located at the central part of the state by 3.41 percent.

6.4.6 Rajmash

The area under Rajmash cultivation accounted 14,390 hectares (3.75%) of the land **(Table 6.3 & Fig. 6.4)**. The spatial distribution shows only low and high values. The low crop concentrations were spatially located in the north, south, central and western parts of the state. The spatial distributions revealed high crop concentration in three districts (Longleng, Tuensang and Kiphire) which were noticed in eastern and parts of the north. The highest concentration was found in Kiphire district (2.90%).

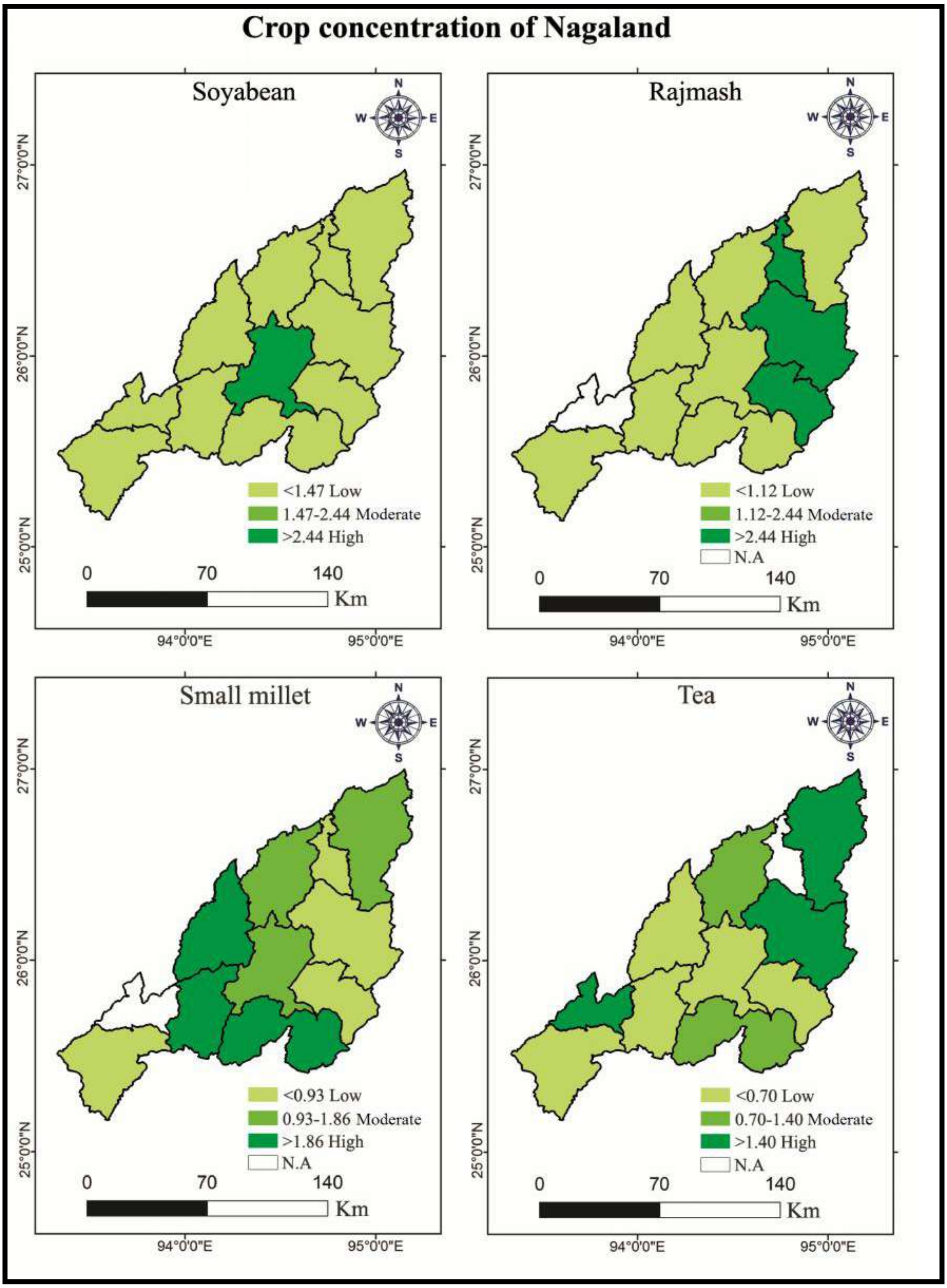

Crop concentration of Nagaland
Soyabean
<1.47 Low
1.47-2.44 Moderate
>2.44 High
Rajmash
<1.12 Low
1.12-2.44 Moderate
>2.44 High
N.A
Small millet
<0.93 Low
0.93-1.86 Moderate
>1.86 High
N.A
Tea
<0.70 Low
0.70-1.40 Moderate
>1.40 High
N.A
0
70
140
Km
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E

Fig. 6.4

6.4.7 Small millet

Small Millet was cultivated under the total cultivated area of 8,530 hectares (2.22%). The spatial distribution shows low crop concentration in four districts, mainly noticed in the east, part of north and tip of the south-west. The moderate crop concentration were found out in three districts and these were spatially concentrated at the peak of north and central parts of the state while high crop concentration were noticed in three districts which are spatially distributed in the west and southern parts of the state. The highest crop concentration of 2.81 percent was noticed in Phek district **(Table 6.3 & Fig. 6.4)**.

6.4.8 Tea

The Tea crop occupied about 7,487 hectares (1.95%) of total cultivated land of the state **(Table 6.3 & Fig. 6.4)**. The spatial distribution shows five districts under low crop concentration and these are spatially found in southern, central and western parts of the state. The moderate crop concentration was observed in two districts that are located in south and north-western parts of the state while high crop concentration were located in three districts, spatially concentrated in the peak of the north, in the east and south-western parts of the state. The highest Tea crop concentration was found in Tuensang district (1.87%).

6.4.9 Pea

The Pea crop was cultivated in about 6,953 hectares (1.81%) of total cultivated land of the state **(Table 6.3 & Fig. 6.5)**. The spatial distribution shows only low and moderate crop concentration. The districts of Dimapur and Kiphire were shown as low crop concentrated areas which are spatially distributed in south-western and south-east part of the state. The moderate concentration of pea crop was found out in all the remaining districts. The highest crop concentration was revealed in Phek (1.24%) district.

6.4.10 Potato

Potato crop was cultivated in about 6,553 hectares (1.71%) of the land **(Table 6.3 & Fig. 6.5)**. There was no low crop concentration. The moderate crop concentrations were observed in nine districts. The high concentration was located in two districts (Phek and Kohima) which were highly concentrated in the southern parts of the state. The highest crop concentration was noticed by 2.24 percent in Kohima district.

6.4.11 Linseed

Linseed was cultivated in about 5,727 hectares (1.49%) of the total crop cultivated area **(Table 6.3 & Fig. 6.5)**. The low crop concentration of linseed was shown in three districts (Kiphire, Tuensang and Zunheboto) and these are spatially located in central and eastern parts of the state. The moderate crop concentrations were found in six districts, these are spatially distributed in the north, south and western parts of the state. The high crop concentrations were located in Mokokchung and Peren districts and these are spatially located in the west and south-western parts of the state. The highest crop concentration was noticed by 2.40 percent in Mokokchung district.

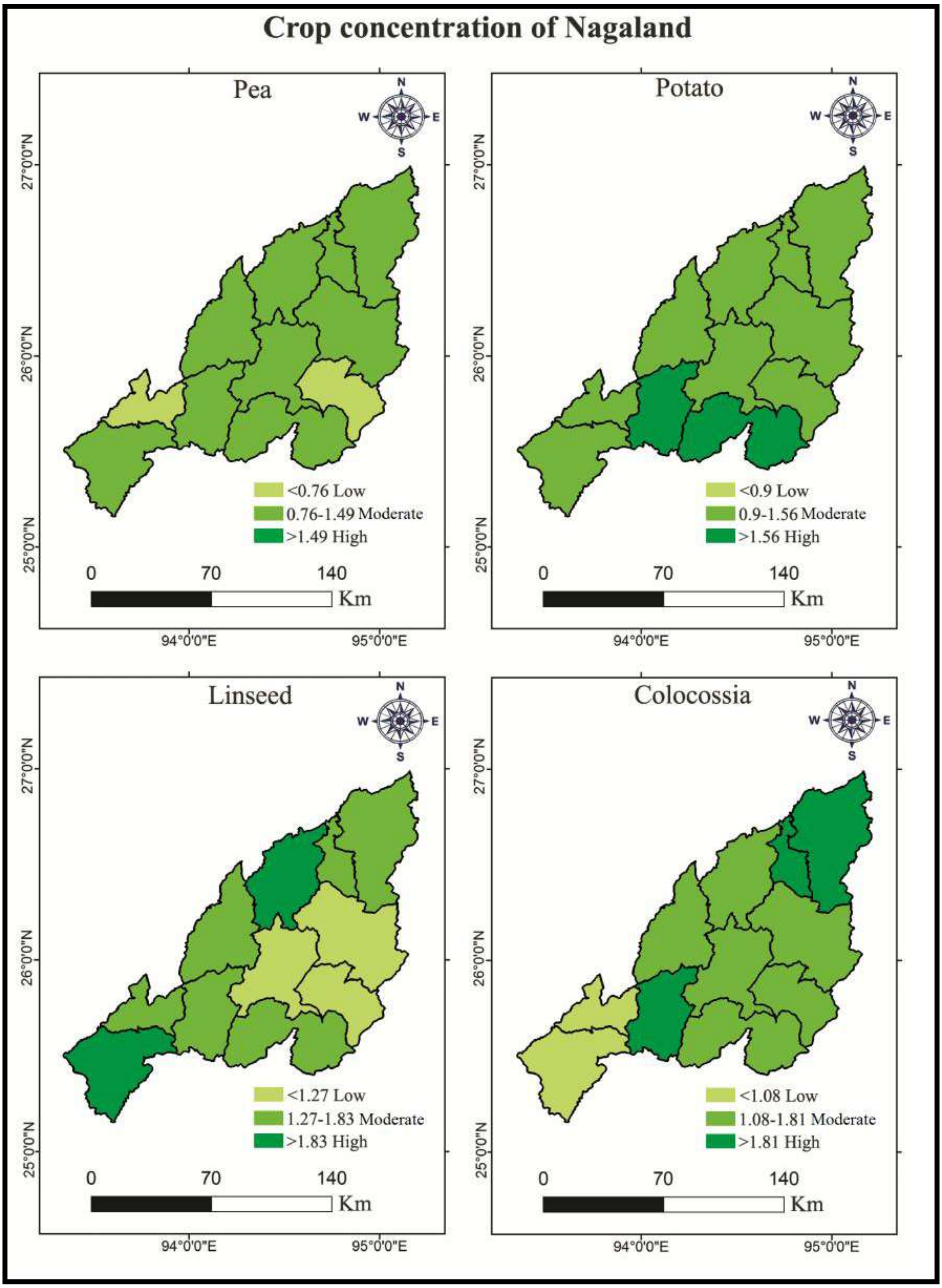

Crop concentration of Nagaland
Pea
<0.76 Low
0.76-1.49 Moderate
>1.49 High
Potato
<0.9 Low
0.9-1.56 Moderate
>1.56 High
Linseed
<1.27 Low
1.27-1.83 Moderate
>1.83 High
Colocossia
<1.08 Low
1.08-1.81 Moderate
>1.81 High
0 70 140
Km
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
N
S
E
W

Fig. 6.5

6.4.12 Colocossia

The Colocossia crop was cultivated in about 5,167 hectares of the land, which accounted 1.35 percent of total cropped area **(Table 6.3 & Fig. 6.5)**. The low crop concentration was observed in Peren and Dimapur districts which are spatially located in tip of south-west part of the state. The moderate crop concentration was observed in six districts spatially distributed in western, central, southern and eastern parts of the state while the high crop concentration were found in Kohima, Mon and Longleng districts, located in the southern and northern parts of the state. The highest crop concentration was noticed in Mon district (2.27%).

6.4.13 Naga Dal

The Naga dal accounted about 4,553 hectares (1.19%) of total cultivated land **(Table 6.3 & Fig. 6.6)**. The spatial distribution shows that there was no low crop concentration in this study area. The moderate crop concentration was observed in six districts which are spatially distributed in the north, central and eastern parts. The high crop concentration was found in four districts, these are spatially distributed in parts of the north and southern parts of the state. The highest crop concentration was found in Kohima (2.35%) district.

6.4.14 Sugarcane

The Sugarcane crop was cultivated in about 4,283 hectares (1.12%) of the total crop cultivated area of Nagaland **(Table 6.3 & Fig. 6.6)**. The low crop concentration was observed in seven districts which are spatially located in the south, eastern, central and north-western parts of the state. The moderate crop concentration was observed in Mon and Wokha districts, spatially distributed in the north and western parts. The high crop concentration of sugarcane was distributed in two districts (Dimapur and Peren), spatially located in the south-western part of the state. The highest crop concentration was noticed by 2.08 percent in Peren district.

6.4.15 Sesamum

The Sesamum crop accounted about 3,503 hectares (0.91%) of the total cropped area **(Table 6.3 & Fig. 6.6)**. The low crop concentration was noticed in five districts, spatially located in the north-eastern, central and south-east of the study area. The moderate crop concentration was found in four districts, these are located in western and in part of the north. The crop concentration in Mokokchung and Peren districts were spatially shown high crop concentration, located in the north-west and in the south-western parts of the state. The highest crop concentration was noticed by 1.79 percent in Peren district.

6.4.16 Ginger

The cultivation of Ginger crop was done in about 3,370 hectares (0.88%) of the total cultivated land **(Table 6.3 & Fig. 6.6)**. The low crop concentration was noticed in five districts, spatially confined in the east, central and extreme south-western parts of the state. The moderate ginger crop concentration was revealed in four districts spatially concentrated in the north, south and in parts of the west. The high crop concentration was observed in Kohima and Longleng districts that were concentrated in the south and northern parts of the state. The highest crop concentration was noticed by 1.31 percent in Kohima district.

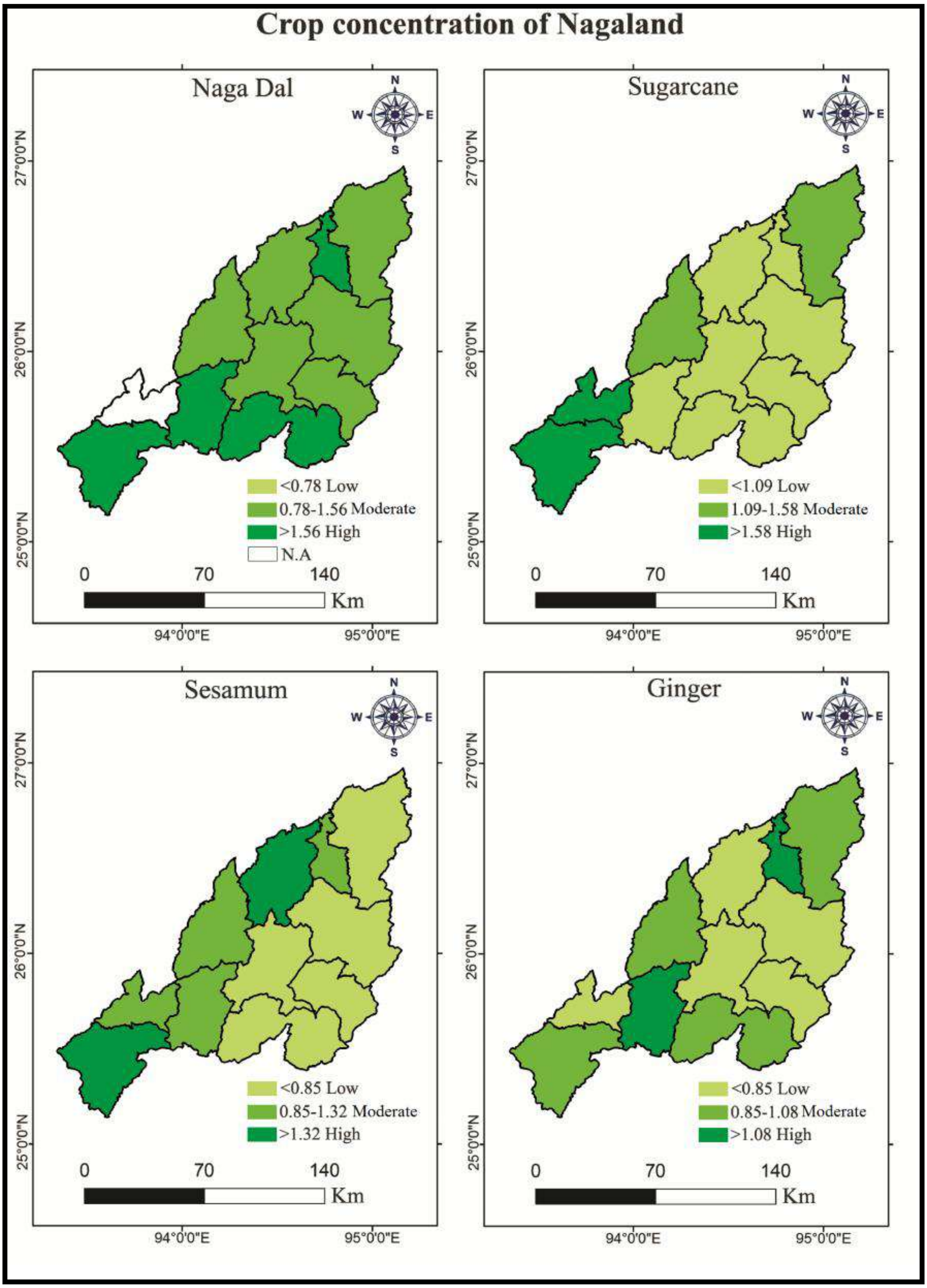

Crop concentration of Nagaland
Naga Dal
<0.78 Low
0.78-1.56 Moderate
>1.56 High
N.A
Sugarcane
<1.09 Low
1.09-1.58 Moderate
>1.58 High
Sesamum
<0.85 Low
0.85-1.32 Moderate
>1.32 High
Ginger
<0.85 Low
0.85-1.08 Moderate
>1.08 High
0
70
140
Km
94°0'0"E
95°0'0"E
27°0'0"N
26°0'0"N
25°0'0"N
N
S
E
W

Fig. 6.6

6.4.17 Wheat

The Wheat cultivation concentrated in about 3,153 hectares (0.82%) of total cropped area **(Table 6.3 & Fig. 6.7)**. There was no low crop concentration. The moderate crop concentration was observed in Tuensang, Zunheboto and Dimapur districts, these are spatially located in the east, central and south-western parts of the state, while high crop concentration were located in six districts, spatially distributed in the north, west and southern parts of the state. The highest crop concentration was found with 1.36 percent in Peren district.

6.4.18 Jute

The Jute crop was cultivated in about 2,997 hectares (0.78%) of the total cropped area **(Table 6.3 & Fig. 6.7)**. The cultivation of Jute crop was found out in only five districts that revealed high crop concentration which are spatially distributed along the western corridor. The highest crop concentration shows 1.80 percent in Kohima district.

6.4.19 Tur/ Arhar

Tur/ Arhar crop occupied about 2,623 hectares (0.68%) of the total cropped area **(Table 6.3 & Fig. 6.7)**. The low crop concentrations were located in three districts and these are spatially concentrated in the north, south-east and in parts of the west. The moderate crop concentrations were observed in six districts. These are spatially distributed in the north-east, central and south-western parts of the state. The high crop concentration were found in Phek and Mokokchung districts and are spatially located in the extreme south and western parts of the state. The highest crop concentration with 1.04 percent was noticed in Peren district.

6.4.20 Beans

The Beans crop cultivation was noticed in about 2,203 hectares (0.57%) of the total cropped area **(Table 6.3 & Fig. 6.7)**. The low crop concentrations were observed in three districts which are spatially located in the north and eastern parts. The moderate crop concentration was observed in four districts which are spatially distributed in the southern and western parts of the study area. The high crop concentrations of beans were experienced in three districts that are spatially located in the south-west and in the northern parts of the state. The highest crop concentration was noticed in Kohima district (0.97%).

From the analysis of cropping pattern of Nagaland, it reveals that the major crop cultivated was Jhum paddy which accounted 24.94 percent of the total cropped area, followed by TRC/WRC paddy in second (22.53%), Maize crop (17.87%) in third, Rape seed/ Mustard in fourth (7.06%) and Soyabean in fifth (6.38%). Other than these crop, all the crops revealed below 5 percent of the total cropped area.

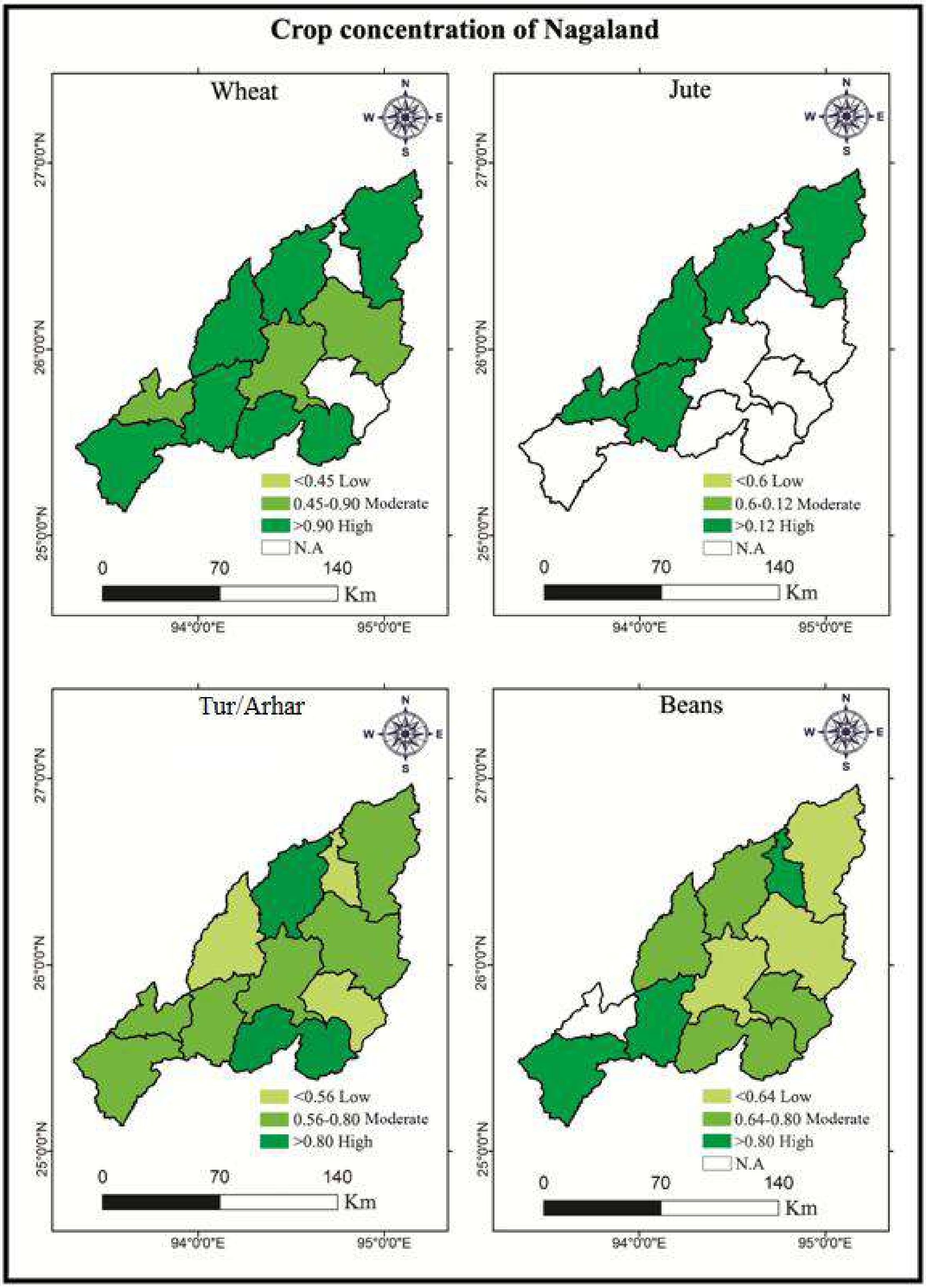

Crop concentration of Nagaland
Wheat
<0.45 Low
0.45-0.90 Moderate
>0.90 High
N.A
Jute
<0.6 Low
0.6-0.12 Moderate
>0.12 High
N.A
Tur/Arhar
<0.56 Low
0.56-0.80 Moderate
>0.80 High
Beans
<0.64 Low
0.64-0.80 Moderate
>0.80 High
N.A
0 70 140 Km
94°0'0"E 95°0'0"E
25°0'0"N 26°0'0"N 27°0'0"N

Fig. 6.7

6.5 Intensity of Cropping Pattern

The intensity of cropping pattern during 2012-14 of the study area vary from a minimum of 396 percent in Dimapur district to a maximum of 1695 percent in Kiphire district **(Table 6.4 & Fig. 6.8)**. The average intensity of cropping pattern was 847 percent. The spatial distribution shows that intensity of cropping pattern was very high in Kiphire and Wokha districts which exceeded 1500 percentage. The intensity of cropping pattern was found high in Longleng and Mon districts with the intensity of cropping pattern ranges from 1000 percent to 1500 percent. The intensity of cropping patter was moderate in Mokokchung, Tuensang, Zunheboto districts with the intensity between 500 percent and 1000 percent, and less than 500 percent exhibited in Dimapur, Kohima, Peren and Phek districts.

Table 6.4: Intensity of cropping pattern

Sl. No.	Districts	Intensity of Cropping pattern in %
1	Dimapur	396
2	Kiphire	1695
3	Kohima	471
4	Longleng	1130
5	Mokokchung	578
6	Mon	1359
7	Peren	492
8	Phek	397
9	Tuensang	689
10	Wokha	1524
11	Zunheboto	582

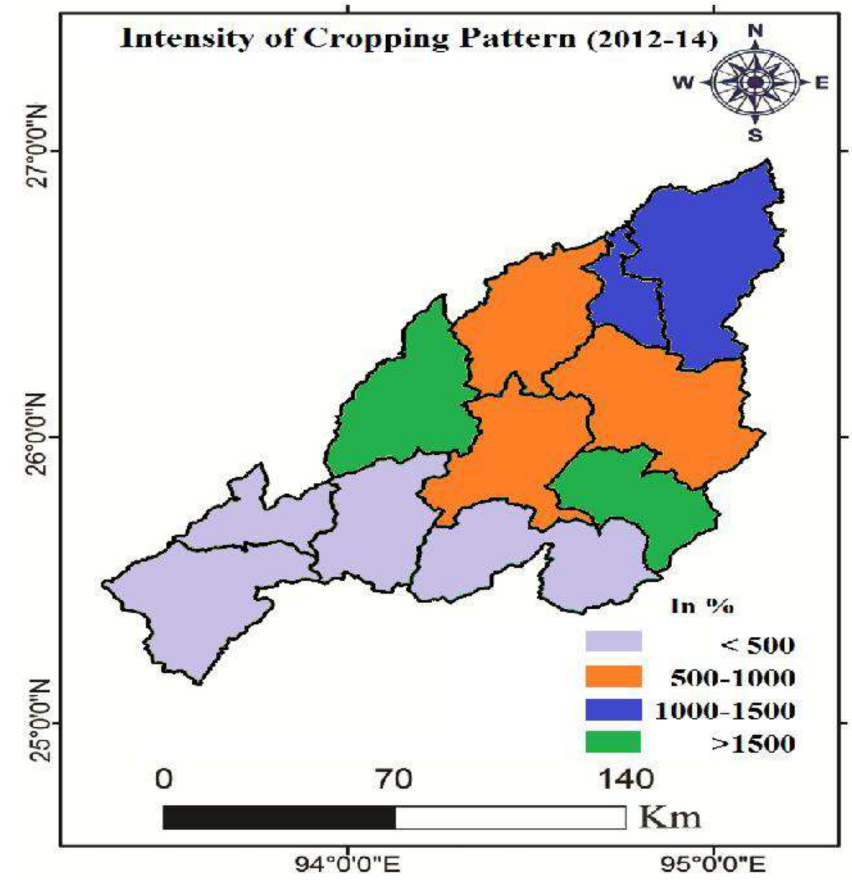


Fig. 6.8

6.6 Crop Diversification (2002-04 to 2012-14)

The crop diversification index of Nagaland was worked out adopting Bhatia's (1965) modified method. According to this method, it considers that those crops which individually occupy 10 percent or more of the gross cropped area in the study area denote very high degree of crop diversification. In other words, lower the crop diversification index then signify more diversification and higher the index more specialisation or monoculture.

The temporal data of district-wise crop diversifications index were computed from 2002-04 and 2012-14 **(Table 6.5, 6.6 & Fig. 6.9 & 6.10)**. During 2002-04, Crop diversification index shows minimum index in Tuensang district (51.33%)

and maximum in Dimapur district (78.18%). In 2012-14, the crop diversification varies from a minimum of 20.55 percent in Longleng to a maximum of 88.32 percent in Dimapur district. The prevalence of very high crop diversification (less than 15%) was not found in any districts for the years 2002-04 and 2012-14 of the state. The high crop diversification (15% to 30%) was noticed only in Longleng district during 2012-14 which is spatially distributed in the north bordering the state of Assam. The moderate crop diversification (30% to 45%) during 2012-14 was observed in five districts. These were revealed in Kiphire, Kohima, Mokokchung, Peren and Wokha which are spatially located in the east, west, at the central and tip of south-western of the study area. The low crop diversification (more than 45%) was found in all districts during 2002-04 but it was noticed only in five districts during 2012-14 (Dimapur, Mon, Phek, Tuensang and Zunheboto). These are located in the south-west, north, south, east and central parts of the state. The magnitude of crop diversification was shown positive crop diversification in two districts out of eight districts while the data were not available (2002-04 to 2012-14) for three districts (Kiphire, Longleng and Peren).

Table 6.5: Index of Crop Diversification of Nagaland

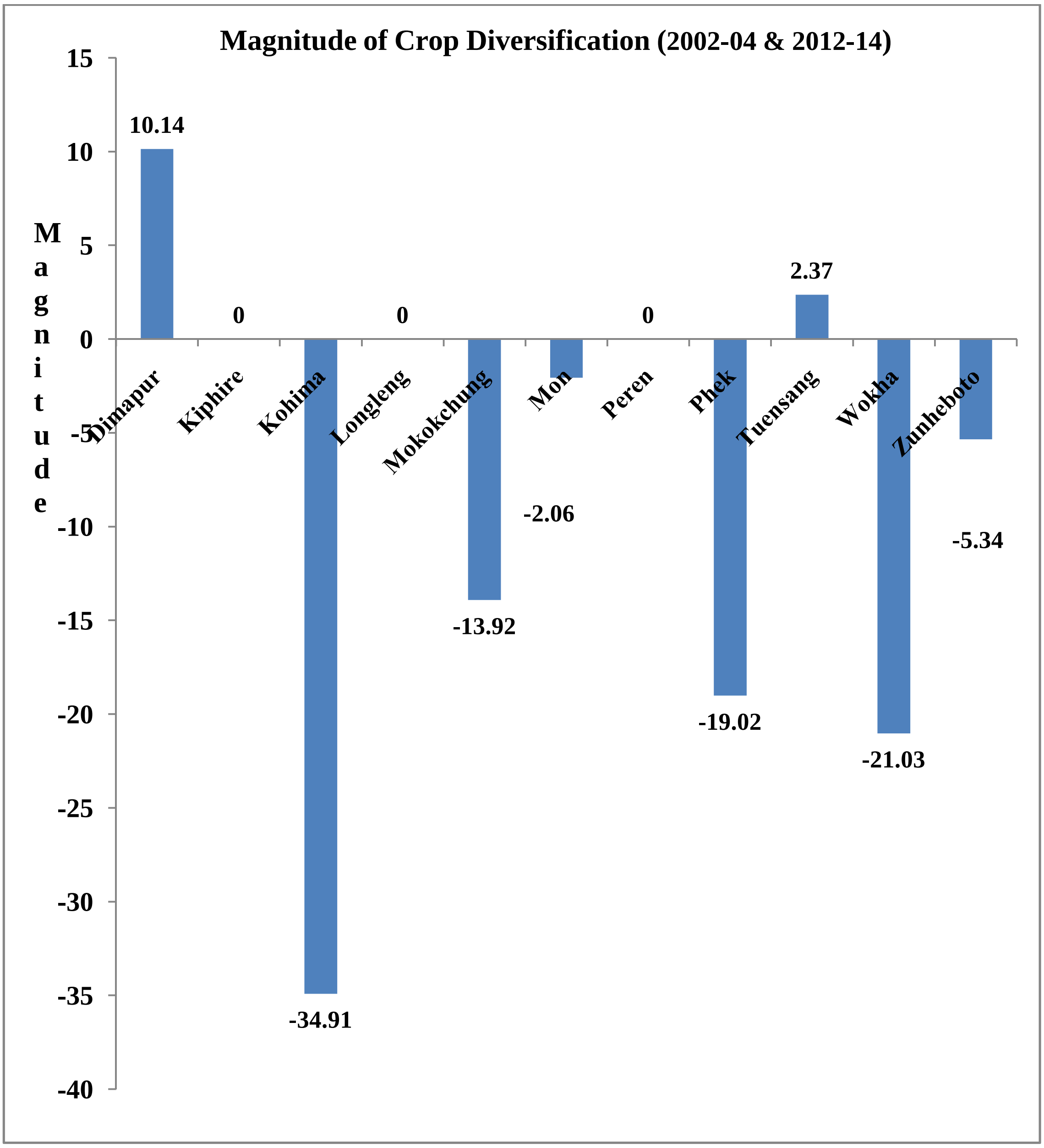
Sl. No.	Name of the District	2002-04	2012-14	Magnitude of Crop Diversification (2002-04 to 2012-14)
		Index of Crop Diversification in %	Index of Crop Diversification in %	
1	Dimapur	78.18	88.32	10.14
2	Kiphire	DNA	32.21	DNA
3	Kohima	77.76	42.85	-34.91
4	Longleng	DNA	20.55	DNA
5	Mokokchung	55.05	41.13	-13.92
6	Mon	51.89	49.83	-2.06
7	Peren	DNA	31.04	DNA
8	Phek	66.88	47.86	-19.02
9	Tuensang	51.33	53.70	2.37
10	Wokha	65.57	44.54	-21.03
11	Zunheboto	53.33	47.99	-5.34

Source: Computed by Scholar. DNA= Data Not Available.

Table 6.6: District-wise Crop Diversification, Nagaland

Sl. No.	Categories of Crop Diversification	Index of Crop Diversification	Name of the District, 2002-04	Name of the District, 2012-14
1	Very High	Less than15	-----	-----
2	High	15 – 30	-----	Longleng
3	Moderate	30 – 45	-----	Kiphire, Kohima, Mokokchung, Peren and Wokha
4	Low	More than 45	Dimapur, Kiphire, Kohima, Longleng, Mokokchung, Mon, Peren, Phek Tuensang, Wokha and Zunheboto	Dimapur, Mon, Phek, Tuensang, and Zunheboto

Source: Computed by Scholar.



'**0**' =*Data Not Available.*

Fig. 6.9

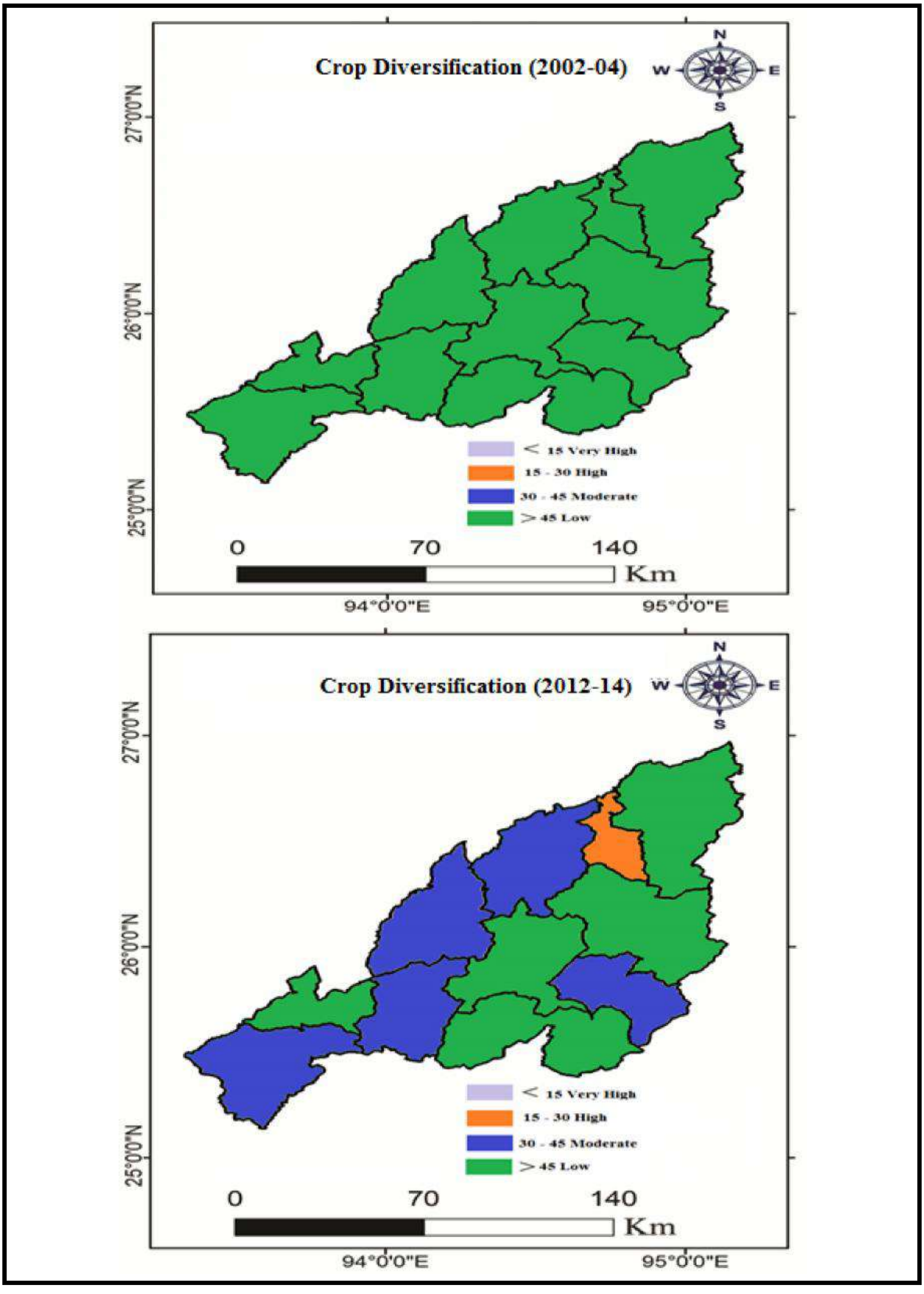

Crop Diversification (2002-04)
N
S
W
E
27°0'0"N
26°0'0"N
25°0'0"N
< 15 Very High
15 - 30 High
30 - 45 Moderate
> 45 Low
0
70
140
Km
94°0'0"E
95°0'0"E
Crop Diversification (2012-14)
N
S
W
E
27°0'0"N
26°0'0"N
25°0'0"N
< 15 Very High
15 - 30 High
30 - 45 Moderate
> 45 Low
0
70
140
Km
94°0'0"E
95°0'0"E

Fig. 6.10

6.7 Crop Combination

According to Rafiullah's (1956) method (maximum positive deviation method), in three different years does calculated an average (2002-04 to 2012-14) and worked out the crop combination. In 2002-04 over all mono culture dominated all districts in the study area but during 2012-14, two crop combination was revealed in Dimapur district while the other districts shows only mono culture **(Table 6.7, 6.8, & Fig. 6.11)**.

During the period 2002-04, Jhum paddy and Wet paddy were noticed under mono culture practiced in different district. Jhum paddy as mono crop dominated five districts (Mokokchung, Mon, Tuensang, Wokha and Zunheboto) while Wet paddy was found in three districts namely Dimapur, Kohima and Phek. The spatial distribution shows whole state practiced mono culture either Jhum paddy or Wet paddy.

During the period 2012-14, the mono crop was cultivated in ten districts and two crop combinations (Jhum and Wet paddy) was cultivated only in Dimapur district. The Jhum paddy as mono crop dominated six districts which were revealed in Kiphire, Longleng, Mokokchung, Mon, Tuensang and Wokha. The Wet paddy as mono crop occupied three districts (Kohima, Peren and Phek) and Maize crop as mono crop was noticed only Zunheboto district. The two crop combination was found out only in Dimapur district, located at the south-western part of the state **(Table 6.7)**. Other than Dimapur district, the whole state spatially practiced mono culture (Jhum paddy/Wet paddy / Maize).

Table 6.7: Crop Combination types and crops, Nagaland

(Rafiullah's method)

Sl. No.	Name of the District	2002-04		2012-14	
		Crop Combination type	Crop in Combination	Crop Combination types	Crop in Combination
1	Dimapur	Mono culture	Wet-Paddy	Two crop combination	Wet-paddy + Jhum-paddy
2	Kiphire	DNA	DNA	Mono culture	Jhum-Paddy
3	Kohima	Mono culture	Wet-Paddy	Mono culture	Wet-Paddy
4	Longleng	DNA	DNA	Mono culture	Jhum-Paddy
5	Mokokchung	Mono culture	Jhum-Paddy	Mono culture	Jhum-Paddy
6	Mon	Mono culture	Jhum-Paddy	Mono culture	Jhum-Paddy
7	Peren	DNA	DNA	Mono culture	Wet-Paddy
8	Phek	Mono culture	Wet-Paddy	Mono culture	Wet-Paddy
9	Tuensang	Mono culture	Jhum-Paddy	Mono culture	Jhum-Paddy
10	Wokha	Mono culture	Jhum-Paddy	Mono culture	Jhum-Paddy
11	Zunheboto	Mono culture	Jhum-Paddy	Mono culture	Maize

Source: Computed by Scholar. DNA=Data Not Available.

Table 6.8: Crop combination of Nagaland by Rafiullah's Method (2012-14)

S.No.	Districts	Mono crop	Two crops	Three crops	Four crops	Five crops	Six crops	Seven crops	Eight crops	Nine crops	Ten crops	Eleven crops	Twelve crops	Thirteen crops	Fourteen crops	Fifteen crops	Sixteen crops	Seventeen crops	Eighteen crops	Nineteen crops	Twenty crops
1	Dimapur	9.50	167.22	142.68	100.10	71.00	55.18	42.74	34.12	27.75	23.11	19.55	16.64	14.45	12.55	11.09	9.82	8.77	7.89	7.10	6.43
2	Kiphire	192.27	23.54	60.09	51.32	39.88	33.43	26.68	21.76	17.98	15.16	12.96	11.08	9.70	8.46	7.52	6.69	6.00	5.42	4.88	4.43
3	Kohima	642.07	-3.75	8.40	11.18	10.80	10.58	9.03	7.51	6.27	5.37	4.64	3.99	3.52	3.07	2.74	2.44	2.19	1.98	1.79	1.62
4	Longleng	80.85	55.70	61.77	51.17	38.64	31.81	25.24	20.52	16.86	14.19	12.10	10.34	9.04	7.87	6.99	6.21	5.56	5.00	4.50	4.08
5	Mokokchung	293.51	-0.65	26.97	26.70	19.04	16.94	13.72	11.34	9.47	8.08	6.96	5.97	5.25	4.58	4.08	3.63	3.26	2.94	2.65	2.40
6	Mon	168.52	8.93	40.55	36.59	27.78	23.11	18.30	14.87	12.27	10.35	8.82	7.54	6.59	5.74	5.09	4.52	4.05	3.65	3.29	2.98
7	Peren	325.62	12.09	32.19	33.20	24.43	21.27	17.12	14.07	11.69	9.93	8.53	7.30	6.41	5.59	4.97	4.42	3.96	3.57	3.21	2.91
8	Phek	300.58	14.34	25.19	29.15	25.54	22.52	18.50	15.31	12.74	10.83	9.31	7.99	7.01	6.12	5.44	4.85	4.35	3.93	3.55	3.21
9	Tuensang	560.46	0.38	15.93	19.96	16.63	15.01	12.39	10.20	8.46	7.18	6.15	5.26	4.61	4.02	3.58	3.19	2.86	2.59	2.33	2.11
10	Wokha	326.66	2.80	26.06	24.17	18.56	16.45	13.20	10.87	9.03	7.68	6.61	5.68	5.00	4.36	3.89	3.46	3.11	2.81	2.53	2.30
11	Zunheboto	515.49	0.97	20.90	19.73	14.56	13.53	10.96	9.07	7.54	6.43	5.54	4.74	4.18	3.65	3.26	2.91	2.62	2.37	2.14	1.94

Source: Computed by Scholar.

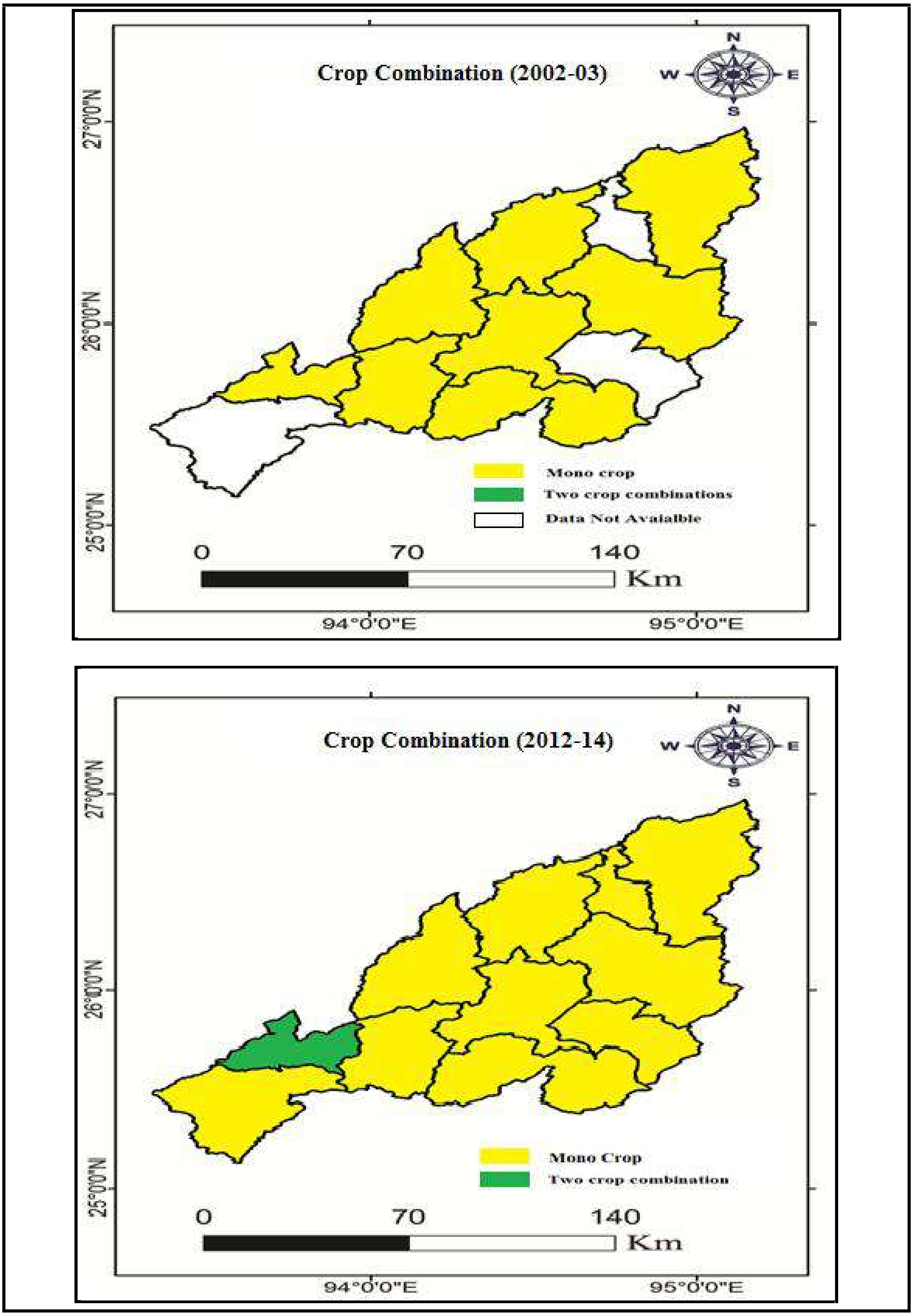

Crop Combination (2002-03)
Mono crop
Two crop combinations
Data Not Avaialble
0
70
140
Km
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
N
S
W
E
Crop Combination (2012-14)
Mono Crop
Two crop combination
0
70
140
Km
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
N
S
W
E

Fig. 6.11

According to Doi's method, during 2002-04 four types crop combination (Wet paddy, Jhum paddy, Maize and Rape seed/ Mustard) were found out in Dimapur, Wokha and Zunheboto districts. The three types of crop combination were noticed in Kohima, Mokokchung, Phek and Tuensang districts, mono culture was noticed in Mon district only while two types of crop combination was not revealed.

During the period 2012-14, the highest five crops cultivation was found in Mon district whereas mono crop was observed in two districts, these were in Kohima and Mokokchung districts. The four crop combinations were noticed in Peren, Phek, Tuensang and Wokha districts which comprises of Jhum paddy, Wet paddy, Maize and Rape seed/ Mustard crops. The highest five crop cultivation comprised of Jhum paddy, Wet paddy, Maize, Rape seed/ Mustard and Soyabean crops **(Table 6.9)**.

Table 6.9: Crop Combination types and crops, Nagaland

(Doi's method)

Sl. No	**Name of the District**	**2002-04** Crop Combination type	**2012-14** Crop Combination types
1	Dimapur	4-crops	2-crops
2	Kiphire	DNA	3-crops
3	Kohima	3-crops	Mono culture
4	Longleng	DNA	3-crops
5	Mokokchung	3-crops	Mono culture
6	Mon	Mono culture	5-crops
7	Peren	DNA	4-crops
8	Phek	3-crops	4-crops
9	Tuensang	3-crops	4-crops
10	Wokha	4-crops	4-crops
11	Zunheboto	4-crops	3-crops

Source: Computed by Scholar; DNA=Data Not Available.

6.8 District-wise Ranking of Crops (2012-14)

The major first ranking crops in Nagaland during 2012-14 comprises Jhum paddy, Wet paddy and Maize crops **(Table 6.10 & 6.14)**. The Jhum paddy was found in six districts (Kiphire, Longleng, Mokokchung, Mon, Tuensang and Wokha), whereas Wet paddy was found in four districts (Dimapur, Kohima, Peren and Phek). Maize crop was only observed in Zunheboto district.

Table 6.10: 1st Ranking crops

Crop	No. of Districts	Name of Districts
Jhum paddy	6	Kiphire, Longleng, Mokokchung, Mon Tuensang and Wokha
Wet paddy	4	Dimapur, Kohima, Peren and Phek
Maize	1	Zunheboto

The second ranking crops of the state also comprise Jhum paddy, Wet paddy and Maize with different occupied areas. The Maize crop was noticed in five districts of Kiphire, Longleng, Mon, Phek and Tuensang. The Jhum paddy was noticed in four districts (Dimapur, Kohima, Peren and Zunheboto), while Wet paddy was observed in Mokokchung and Wokha districts **(Table 6.11 & 6.14)**

Table 6.11: 2nd Ranking of crops

Crop	No. of Districts	Name of Districts
Maize	5	Kiphire, Longleng, Mon, Phek and Tuensang
Jhum paddy	4	Dimapur, Kohima, Peren, and Zunheboto
Wet paddy	2	Mokokchung and Wokha

The third ranking comprises four crops in this study area; these are Maize, Rajmash, Rapeseed and Soyabean. The Maize was grown in five districts, Rajmash in three districts, Rapeseed in two districts and Soyabean was cultivated in only one district **(Table 6.12 & 6.14)**.

Table 6.12: 3rd Ranking of Crops

Crop	**No. of Districts**	**Name of Districts**
Maize	5	Dimapur, Kohima, Mokokchung, Peren and Wokha
Rajmash	3	Kiphire, Longleng and Tuensang
Rapeseed	2	Mon and Phek
Soyabean	1	Zunheboto

The fourth ranking crops comprise of Rapeseed, Wet paddy and Soyabean crops. The Rapeseed was found in five districts, Wet paddy and Soyabean were grown in three districts each **(Table 6.13 & 6.14)**.

Table 6.13: 4th Ranking of crops

Crop	**No. of Districts**	**Name of Districts**
Rapeseed	5	Dimapur, Kiphire, Mokokchung, Peren and Wokha
Wet paddy	3	Mon, Tuensang and Zunheboto
Soyabean	3	Kohima, Longleng, and Phek

Table 6.14: District-wise Ranking of Crops in % (2012-14)

S.No.	Districts	1st Rank	2nd Rank	3rd Rank	4th Rank	5th Rank	6th Rank	7th Rank	8th Rank	9th Rank	10th Rank	11th Rank	12th Rank	13th Rank	14th Rank	15th Rank	16th Rank	17th Rank	18th Rank	19th Rank	20th Rank
1	**Dimapur**	53.08	14.06	9.87	6.10	4.24	2.98	1.65	1.61	1.15	1.07	0.99	0.92	0.72	0.62	0.57	0.35	0.00	0.00	0.00	0.00
2	**Kiphire**	36.13	30.46	11.58	4.81	4.28	3.49	1.61	1.46	1.35	0.81	0.73	0.69	0.66	0.65	0.50	0.40	0.32	0.08	0.00	0.00
3	**Kohima**	24.66	21.11	14.01	6.10	6.09	5.33	4.48	2.35	2.00	1.96	1.80	1.72	1.43	1.31	1.13	1.09	1.02	0.97	0.80	0.64
4	**Longleng**	41.01	19.21	10.27	6.66	6.34	2.54	2.24	2.16	1.46	1.46	1.27	1.20	1.10	0.95	0.95	0.76	0.42	0.00	0.00	0.00
5	**Mokokchung**	32.87	16.97	12.37	9.76	3.45	3.15	2.40	2.35	2.30	2.24	1.93	1.74	1.43	1.39	1.19	1.09	1.04	0.85	0.79	0.70
6	**Mon**	37.02	14.57	9.46	9.22	7.90	2.85	2.41	2.27	2.20	2.07	1.44	1.37	1.33	1.25	1.05	1.03	0.86	0.75	0.53	0.42
7	**Peren**	31.96	25.10	13.01	10.10	4.39	2.34	2.09	1.92	1.79	1.65	1.36	1.05	0.97	0.94	0.67	0.67	0.00	0.00	0.00	0.00
8	**Phek**	32.66	23.84	7.81	5.66	5.62	5.13	3.27	2.48	1.97	1.81	1.80	1.52	1.27	1.04	0.95	0.93	0.82	0.76	0.68	0.00
9	**Tuensang**	26.33	24.50	13.51	8.65	5.19	5.12	3.74	2.22	1.80	1.59	1.14	1.04	0.87	0.85	0.81	0.75	0.70	0.69	0.49	0.00
10	**Wokha**	31.93	18.94	15.18	7.52	4.37	4.36	2.01	2.00	1.73	1.61	1.52	1.49	1.47	1.21	1.17	0.97	0.88	0.75	0.49	0.41
11	**Zunheboto**	27.30	26.18	20.45	7.28	5.70	2.13	1.92	1.68	1.22	1.11	0.84	0.71	0.67	0.62	0.60	0.51	0.48	0.38	0.22	0.00

Source: Computed by Scholar.

The fifth ranking crops comprise of Soyabean, Rapeseed, Small millet and Tea **(Table 6.15 & 6.14)**. The Soyabean crop was found in five districts, Rapeseed in four districts, Small millet and Tea were grown in one district each.

Table 6.15: 5th Ranking of crops

Crop	**No. of Districts**	**Name of Districts**
Soyabean	5	Kiphire, Mokokchung, Mon, Peren and Wokha
Rapeseed	4	Kohima, Longleng, Tuensang and Zunheboto
Small millet	1	Phek
Tea	1	Dimapur

The sixth ranking crops were Soyabean, Small millet, Jhum paddy, Wet-paddy, Rajmash, Colocossia, Linseed and Tea **(Table 6.16 & 6.14)**. The Soyabean was found in three districts, Small millet in two districts, and Jhum paddy, Wet paddy, Rajmash, Colocossia, Linseed and Tea were found in one district each. These crops were observed as seventh to twentieth ranking of crops which fall under below 5 percent of the total cropped area.

Table 6.16: 6th Ranking of crops

Crop	No. of Districts	Name of Districts
Soyabean	3	Dimapur, Tuensang and Wokha
Small millet	2	Kohima and Zunheboto
Jhum paddy	1	Phek
Wet paddy	1	Kiphire
Rajmash	1	Mokokchung
Colocossia	1	Longleng
Linseed	1	Peren
Tea	1	Mon

6.9 Decadal Variation of Crop Production (in M.T.), (2002-04 to 2012-14)

During 2002-04 and 2012-14, the production of TRC/WRC paddy dominated the crop production. The decadal variation of total crop production of the twenty crops (in Metric tons) during 2002-2004 was 5,83,240 M.T., and in 2012-2014 it was 10,27,033 M.T. **(Table 6.17)**. These accounted to 35.17 percent and 61.94 percent of the total geographical area of Nagaland respectively. The decadal-wise production in metric tons was 26.77 percent that increased from 2002-04 to 2012-14. Out of twenty crops, five crops shows production wise positive values, these were Sugarcane (5.15%), Tea (2.63%), Maize (1.27%), Rajmash (1.35%) and Beans (0.03%).

Table 6.17: Crop Production (in M.T.) from 2002-04 to 2012-14

Sl. No.	Crops	2002-04 Production in M.T. in %	2012-14 Production in M.T. in %	Decadal Changes of crop production from 2002-04 to 2012-14
1	Jhum Paddy	21.03	17.09	-3.94
2	TRC/WRC Paddy	23.67	20.85	-2.82
3	Maize	11.81	13.08	1.27
4	Rape Seed/ Mustard	3.24	2.65	-0.59
5	Soyabean	4.83	2.99	-1.84
6	Rajmash	0.39	1.73	1.35
7	Small Millet	1.75	0.83	-0.91
8	Tea	0.62	3.24	2.63
9	Pea	1.27	0.64	-0.63
10	Potato	10.81	6.69	-4.12
11	Linseed	1.32	0.45	-0.87
12	Naga Dal	0.50	0.46	-0.04
13	Sugarcane	13.09	18.15	5.05
14	Sesamum	0.72	0.20	-0.52
15	Wheat	2.95	0.54	-2.41
16	Jute	0.78	0.53	-0.25
17	Tur/ Arhar	0.98	0.22	-0.76
18	Beans	0.24	0.27	0.03
19	Colocossia	DNA	4.78	DNA
20	Ginger	DNA	4.59	DNA

Source: Statistical Handbook of Nagaland, M.T.= Metric Ton; DNA=Data Not Available.

6.10 Decadal Variation of Crop yield in M.T. per hectare (2002-04 to 2012-14)

The decadal changes of crop yield of twenty crops during 2002-04 was 5,83,240 in M.T. of the total copping area of 3,14,443 hectares and in 2012-14 the yield of crops in metric tons was 10,27,033 of the total copping area in 3,83,755 hectares of the land. It accounted 1.85 percent and 2.68 percent crop yield per hectares respectively. The decadal-wise crop yield per hectare was increased by 0.83 percent from 2002-04 to 2012-14. The crop yield per hectare during 2002-04 to

2012-14 shows that seven crops comprises of Sugarcane (5.71%), Tea (2.93%), Wet paddy (0.71%), Jhum paddy (0.50%), Rajmash (0.49%), Beans (0.40%), and Maize (0.31%) revealed positive values (Table 6.16).

Table 6.18: Crop yield in M.T. per hectare during 2002-04 and 2012-14

Sl. No.	Crops	Crop yield in M.T. for hectare (2002-04)	Crop yield in M.T. per hectare (2012-14)	Changes crop yield per hectare from 2002-04 to 2012-14
1	Jhum Paddy	1.34	1.83	0.50
2	TRC/WRC Paddy	1.77	2.48	0.71
3	Maize	1.64	1.96	0.31
4	Rape Seed/ Mustard	1.07	1.01	-0.06
5	Soyabean	1.38	1.25	-0.13
6	Rajmash	0.75	1.24	0.49
7	Small Millet	1.06	1.00	-0.05
8	Tea	1.52	4.45	2.93
9	Pea	0.96	0.95	0.00
10	Potato	10.98	10.49	-0.49
11	Linseed	0.86	0.81	-0.05
12	Naga Dal	1.04	1.03	-0.01
13	Sugar cane	37.80	43.52	5.71
14	Sesamun	0.82	0.60	-0.22
15	Wheat	2.23	1.76	-0.47
16	Jute	3.29	1.83	-1.47
17	Tur/ Arhar	0.87	0.87	0.00
18	Beans	0.87	1.27	0.40
19	Colocossia	DNA	9.51	DNA
20	Ginger	DNA	13.98	DNA

Source: Computed by Scholar; M.T.= Metric Ton; DNA=Data Not Available.

6.11 Correlation coefficient between Crop Intensity and Irrigation Intensity

The correlation coefficient is in between intensity of irrigation and intensity of crops is negative (-0.22), then variables are not associated directly.

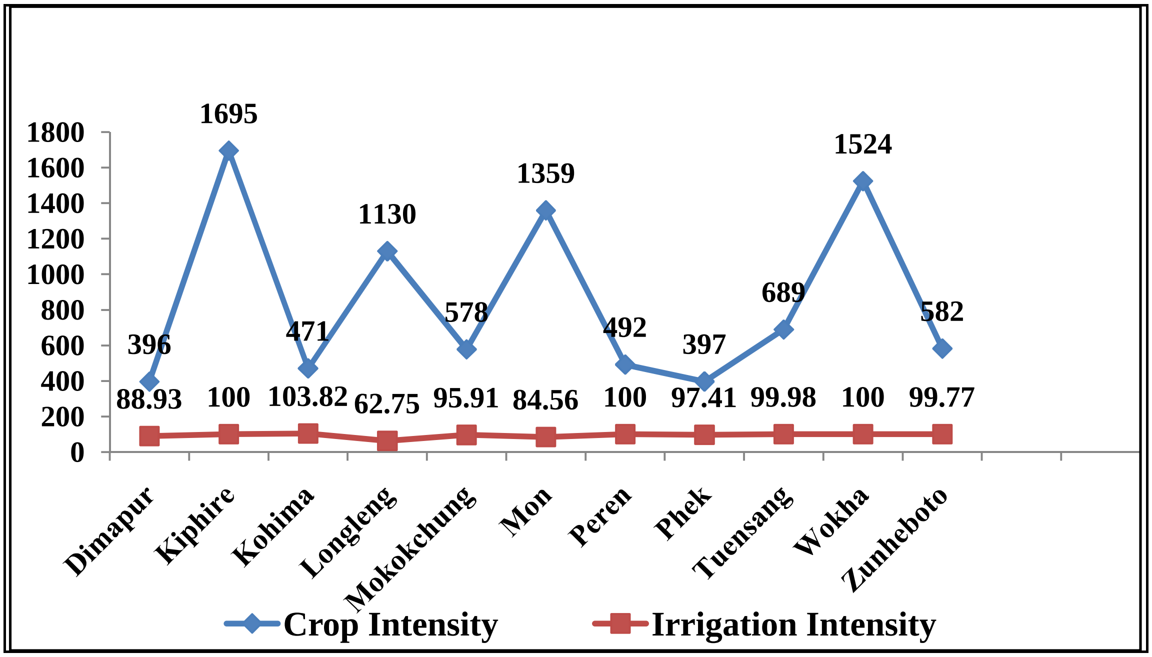


Fig. 6.12

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Chapter 7

Water Availability and Crop Suitability of Nagaland

The water availability days and months of Nagaland has been worked out from sixteen rain-gauge stations taking monthly ratio of the Actual Evapotranspiration (AE) and Potential Evapotranspiration (PE) using the Raman and Srinivasa Murthy (1971) method. They are humid (when AE = PE), wet (when AE = ½th of the PE or more than ½th of the PE), moderately dry period (when AE = ¼th of the PE or more than ¼th of the AE) and dry period (when AE = 1/8th of the PE or more than 1/8th of the PE). The whole year has been divided into four periods but in this study area or state, revealed only humid and wet periods.

7.1 The Water Availability Days

The analysis of water availability days of Nagaland revealed only humid and wet periods, in other words moderately dry and dry period do not prevail in the study area.

7.1.1 Humid Period

The water availability days during humid period vary from a minimum of 183 days at Tuensang station to a maximum of 245 days at Mangkolemba, Wokha and Yisemyong rain-gauge stations. Water availability days vary from 183 days to 184 days at Kiphire, Meluri, Sechu, Tseminyu and Tuensang rain-gauge stations. The water availability for 214 days were experienced at Bhandari, Dimapur, Jalukie, Kohima, Mokokchung, Mon, Phek, and Zunheboto rain-gauge stations **(Table 7.1)**. The spatial distribution shows that the water availability days vary from 180 days to 220 days experienced in the south and south-east, and above 220 days concentrated in the north and north-western parts of the region **(Fig. 7.1)**.

7.1.2 Wet Period

The water availability days of wet period vary from a minimum 120 days in Mangkolemba, Wokha and Yisemyong rain-gauge stations to a maximum of 182 days in Tuensang rain-gauge station **(Table 7.1)**. The water availability vary from 151 to 181 days were observed at Bhandari, Dimapur, Jalukie, Kohima, Mokokchung, Mon, Phek, Zunheboto, Kiphire, Meluri, Sechu, and Tseminyu rain-gauge stations. The spatial distribution of water availability days shows 120 to 160 days distributed along the western corridor which increases to 160 days in the central and 180 days to the south, and to the eastern flank it increase from 160 to above 180 days **(Fig. 7.1)**.

Table 7.1: Water availability days

Sl. No	Rain-gauge station	Dry Period	Moderately Dry Period	Wet period	Humid Period
1	Bhandari	0	0	151	214
2	Dimapur	0	0	151	214
3	Jalukie	0	0	151	214
4	Kiphire	0	0	181	184
5	Kohima	0	0	151	214
6	Mangkolemba	0	0	120	245
7	Meluri	0	0	181	184
8	Mokokchung	0	0	151	214
9	Mon	0	0	151	214
10	Phek	0	0	151	214
11	Sechu	0	0	181	184
12	Tseminyu	0	0	181	184
13	Tuensang	0	0	182	183
14	Wokha	0	0	120	245
15	Yisemyong	0	0	120	245
16	Zunheboto	0	0	151	214

Source: Computed by the Scholar.

The Water Availability Days in Various Periods

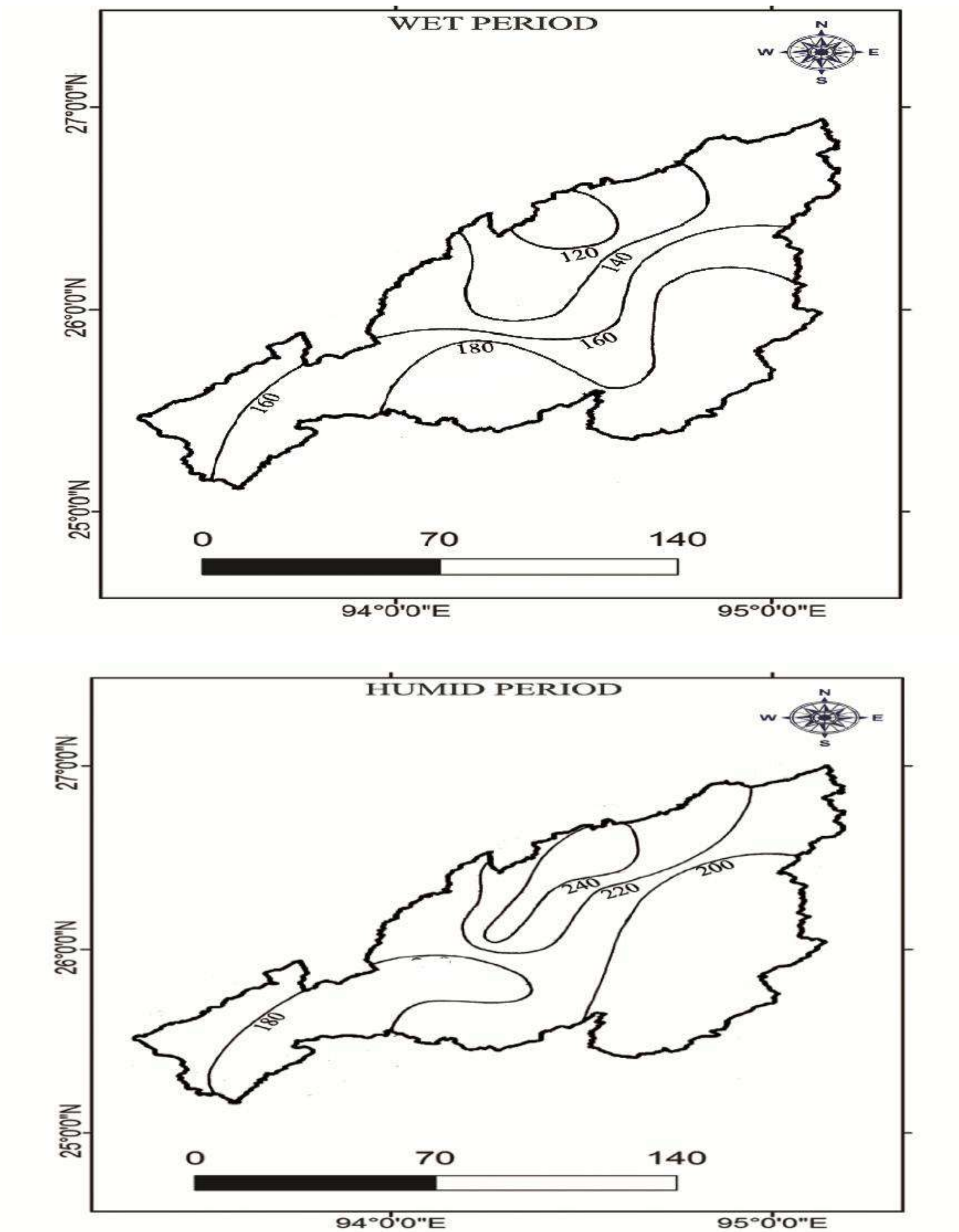

Fig. 7.1

7.2 Monthly Water Availability

The analysis of monthly water availability in the study area exhibits only two periods, these are humid and wet period.

7.2.1 Humid Period

The analysis of monthly water availability in each stations revealed that the distribution of humid period was concentrated in different periodic months. The monthly water availability shows prevalence of humid period for six months at five rain-gauge stations in which at Kiphire, Meluri, Sechu and Tseminyu stations, it prevailed from the month of May to October while at Tuensang it experienced from the month of April to September. This period of monthly water availability was experienced for seven months at eight rain-gauge stations where Bhandari, Jalukie, Kohima, Mokokchung, Mon, Phek and Zunheboto experienced from the month of April to October while Dimapur station experienced from the month of May to November. The stations of Mangkolemba, Wokha and Yisemyong experienced eight months humid period from the month of March to October **(Table 7.2)**.

7.2.2 Wet Period

The wet period existed for four months (November, December, January, and February) at Mangkolemba, Wokha and Yisemyong stations. It prevailed for five months (November, December, January, February and March) at Bhandari, Dimapur, Jalukie, Kohima, Mokokchung, Mon, Phek and Zunheboto rain-gauge stations while at five rain-gauge stations the wet period prevailed for six months in which the stations of Kiphire, Meluri, Sechu and Tseminyu experienced in the month of January, February, March, April, November and December whereas the station of Tuensang experienced during the month of January, February, March, October, November and December **(Table 7.2)**.

The monthly analysis of water availability calendar identified only two periods that are humid and wet period in Nagaland. It was revealed that the rain-gauge stations of Mangkolemba, Wokha and Yisemyong experienced 245 days of water availability during humid periods in the months of March, April, May, June, July, August, September and October (8 months) which are highly favorable for two crop cultivation under normal condition. In wet period single crop can be cultivated under normal climatic conditions.

Table 7.2: Water availability calendar in different periods

Sl. No	Rain-gauge station	Humid Period	Wet period	Moderately Dry Period	Dry Period
1	Bhandari	April, May, June, July, August, September and October	January, February, March, November and December		
2	Dimapur	May, June, July, August, September, October and November	January, February, March, April, and December		
3	Jalukie	April, May, June, July, August, September and October	January, February, March, November and December		
4	Kiphire	May, June, July, August, September and October	January, February, March, April, November and December		
5	Kohima	April, May, June, July, August, September and October	January, February, March, November and December		
6	Mangkolemba	March, April, May, June, July, August, September and October	January, February, November and December		
7	Meluri	May, June, July, August, September and October	January, February, March, April, November and December		
8	Mokokchung	April, May, June, July, August, September and October	January, February, March, November and December		
9	Mon	April, May, June, July, August, September and October	January, February, March, November and December		
10	Phek	April, May, June, July, August, September and October	January, February, March, November and December		
11	Sechu	May, June, July, August, September and October	January, February, March, April, November and December		
12	Tseminyu	May, June, July, August, September and October	January, February, March, April, November and December		
13	Tuensang	April, May, June, July, August and September	January, February, March, October, November and December		
14	Wokha	March, April, May, June, July, August, September and October	January, February, November and December		
15	Yisemyong	March, April, May, June, July, August, September and October	January, February, November and December		
16	Zunheboto	April, May, June, July, August, September and October	January, February, March, November and December		

Source: Computed by the Scholar.

7.3 Crop Suitability of Nagaland

The water availability days and months of different periods were analysed and suggest the crop suitability of Nagaland. In all stations, only humid and wet period prevails therefore, during humid period it is highly favorable for cultivation of two crops during the months of April, May, June, July, August, September and October. These crops which were found suitable during this period are jhum paddy, wet paddy, maize, rapeseed/ mustard, small millet, soyabean, tea, pea, colocossia, sugarcane, ginger, wheat, and tur/arhar. During wet period months of January, February, November and December single crop comprises of ginger, small millet, pea, beans, vegetable and maize could be cultivated.

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Chapter 8

Summary and Conclusion

The mean monthly rainfall analysis of Nagaland shows that the mean rainfall less than 100 mm were recorded during the months of November, December, January, February and March (five months). Out of which, the month of December shows less value of 6 mm, where the rain-gauge station of Tseminyu recorded the lowest value of 2 mm. The months of April, May, June, July, August, September and October recorded mean monthly rainfall above 100 mm. The maximum monthly mean rainfall of 314 mm was recorded in the month of August, where the rain-gauge station of Mokokchung received the highest value of 454 mm. The monthly mean rainfall intensity of less than 10 mm/ a rainy day were found out in the months of November, December, January, February and March. The lowest intensity was recorded in December by 5 mm/ a rainy day, where Tseminyu station recorded less intensity of 2 mm/ a rainy day. The months of April, May, June, July, August, September and October recorded 10 mm/ a rainy day and above. The maximum intensity of 15 mm/ a rainy day was recorded during the months of July and August, where Mokokchung station recorded the highest intensity during these two months by 20 mm/ a rainy day and 19 mm/ a rainy day respectively. The mean rainfall variability above 100 percent were recorded during the months of November, December, January and February, where the maximum mean variability of 162 percent was recorded in December. The rain-gauge station of Yisemyong shows the highest mean variability of 238 percent. The months of March, April, May and October recorded above 50 percent while the months of June, July, August and September recorded less than 50 percent of rainfall variability, where July revealed the lowest variability by 35 percent on which the rain-gauge station of Mangkolemba recorded less variability by 15 percent. The monthly mean rainfall ratio above 400 percent was recorded in the months of November, December, January and February. The month of December shows the highest mean ratio of 596 percent where Yisemyong station was shown with highest ratio of 969 percent. The mean ratio above 200 percent was concentrated in the months of March and April. The months of May, June, July, August, September and October revealed below 200 percent, where July recorded less ratio of 128 percent in which Mangkolemba rain-gauge station recorded lowest mean rainfall ratio of 51 percent.

The analyses of seasonal mean rainfall shows that the study area received maximum rainfall during monsoon season which recorded 847 mm. The seasons of pre-monsoon and post-monsoon received mean rainfall of 315 mm and 336 mm respectively. The winter season recorded minimum mean rainfall of 38 mm. The analysis of rainfall intensity indicates that monsoon season shows maximum intensity of 14 mm/ a rainy day while winter season recorded minimum intensity of 6 mm/ a rainy day. The seasons of pre-monsoon and post-monsoon recorded intensity value of 10 mm/ a rainy day and 12 mm/ a rainy day respectively. The rainfall variability was highest during post-monsoon season by 70 percent. The seasons of winter and pre-monsoon recorded 51 percent each. The rainfall variability of less value was shown in monsoon season by 10 percent. The concentration of rainfall ratio reveals that the post-monsoon season recorded high ratio of 169 percent. The rainfall ratio of winter was shown 119 percent and pre-monsoon by 135 percent. The lowest ratio was shown in monsoon season by 23 percent.

The annual mean rainfall widely varies from a minimum of 886 mm at Kiphire to a maximum of 2206 mm at Wokha rain-gauge station. The average mean rainfall was 1536 mm. The rain-gauge stations of Bhandari, Kohima, Mangkolemba, Mokokchung, Mon, Yisemyong and Zunheboto recorded above the average mean rainfall. The spatial distribution varies from 900 mm to 1300 mm in the eastern and south-western parts, 1300 mm to 1700 mm in the tip of the south and in the central part, high concentration above 2100 mm was observed. The rainfall intensity varies from 23 mm/ a rainy day at Kiphire to 56 mm/ a rainy day at Wokha station. The average rainfall intensity was 42 mm/ a rainy day. The spatial distribution of annual rainfall intensity shows that less than 30 mm/ a rainy day were concentrated in the east and above 40 mm/ a rainy day in the south, to the north and western parts. The highest concentration above 50 mm/ a rainy day was observed in central and south-western parts of the study area. The annual rainfall variability varies from 71 percent at Yisemyong to 99 percent at Tseminyu station with an average of 86 percent. The spatial distribution of rainfall variability revealed minimum concentration less than 75 percent observed around Yisemyong rain-gauge station and less than 85 percent in the eastern flank. In the southern and western parts it ranges from 85 percent to 95 percent where maximum concentration above 95 percent was observed around Tseminyu station. The rainfall ratio recorded a minimum of 150 percent at Yisemyong while Tseminyu station recorded a maximum value of 296 percent. The annual rainfall ratio average was 238 percent. The rainfall ratio was spatially distributed that varies from 200 percent to 240 percent in the east, central and south-west, and above 240 percent in the west and northern parts of the study area. The minimum rainfall ratio was observed in parts of north-west around Yisemyong station with less than 160 percent and maximum recorded in the south-west above 280 percent around Tseminyu station.

According to Radhakrishna *et al.* (1974), U.S. Geological (1962), Seghal's (1973) and Krishna Rao (1970) methods, the estimation of all the available rain-gauge stations of Nagaland shows that the average annual recharge varies from a minimum of 413 mm at Kiphire station to a maximum of 1247 mm at Wokha station. The average groundwater recharge was 818 mm. The total groundwater resources have been estimated to be (Total geographical area X mean groundwater recharge) 13,561,622,000 m^3.

The analyses of water balance elements shows that the Potential Evapotranspiration (PE) average value below 100 mm was recorded during the months of October, November, December, January, February, March and April. The lowest mean PE value was reported at Mangkolemba, Mokokchung and Phek stations with 35 mm in the month of January and maximum value at Mon rain-gauge station during the month of October with 123 mm. The high concentration of average PE above 100 mm was recorded from the consecutive month of May to September. During these months, the maximum value of 143 mm was recorded at Mon rain-gauge station in the month of August while Tuensang rain-gauge station recorded minimum average PE of 72 mm in the month of May. The total average PE was 1053 mm. The Actual Evapotranspiration (AE) average values were recorded low in the months of October, November, December, January, February, March and April with the value below 100 mm. In the months of May, June, July, August and September, the value of average AE was above 100 mm. The maximum value of AE 143 mm was recorded at Mon rain-gauge station in the month of August while minimum value were shown at Bhandari, Mangkolemba, Mokokchung, Phek and Tuensang rain-gauge stations with 25 mm in the month of January. The water deficit period prevailed during the months of October, November, December, January, February, March and April. The average value shows maximum water deficit in the month of December with 21 mm where Dimapur station recorded maximum value of 39 mm during this month. The water surplus analyses determine that there is no value of surplus during the months of November, December, January and February. The water surplus value was above 100 mm during the months of June, July and August. The average maximum value of water surplus during the month of July was 193 mm where the rain-gauge of Mokokchung recorded maximum of 334 mm. The Moisture Adequacy Index value records 100 percent during the months of May, June, July, August and September. The minimum average Moisture Adequacy was recorded 64 percent in the month of December.

The values of Aridity Index prevailed during the months of October, November, December, January, February, March and April. The maximum Aridity Index value with an average of 36 percent was revealed in the month of December where Dimapur station recorded highest Aridity Index with an average value of 55.71 percent. Climatologically, the analyses of Moisture Index reveal Dry subhumid type of climate during the months of November, December, January and February. In the month of December, the Moisture Index indicates prevalence of semiarid type of climate in Dimapur station. In the month of March and April, climatic condition varies from Dry subhumid to Moist subhumid. From the month of May to September, Humid type of climate was prevailed in the entire study area of Nagaland.

The analysis of water balance elements concludes that from the month of March to September there was prevalence of water surplus. However, favorable climatic condition to grow crops prevails from the month of May to September.

The months of November, December, January and February are extremely effective from water deficit; therefore, this dry spell will deter the crop to grow, unless the water requirements are irrigated.

The seasonal analyses of water elements reveal that the study area received maximum mean average precipitation value of 847 mm during monsoon period. The minimum average precipitation of 38 mm was observed in winter season. During pre-monsoon and post-monsoon period, the average mean values were recorded 315 mm and 336 mm respectively. The Potential Evapotranspiration of maximum value was observed in monsoon by 361 mm and minimum value of 148 mm in the winter season. The Actual Evapotranspiration of maximum value prevailed during monsoon period with an average of 361 mm. The minimum AE mean value was recorded during winter period with 97 mm. The prevalence of water deficit value was very high in winter season with an average of 47 mm. The water deficit values do not exist in monsoon but during pre-monsoon and post-monsoon prevalence of water deficit with an average were recorded 32 mm and 16 mm respectively. The water surplus values were remarkably observed during monsoon season with an average of 486 mm. The water surplus values were also identified during pre-monsoon and post-monsoon with 128 mm and 113 mm respectively. In winter there was no water surplus. The Moisture Adequacy Index was noticed minimum in winter period with 66 percent. In the pre-monsoon it was reported 93 percent and 96 percent during post-monsoon period. The maximum Moisture Adequacy Index value was 100 percent in monsoon period. The Aridity Index values were highly concentrated in winter season with 34 percent. During the seasons of pre-monsoon and post-monsoon, the values of Aridity Index were recorded 14 percent and 7 percent respectively, hence, there was no Aridity Index observed during monsoon season. The analysis of water balance elements concludes that the study area received high amount of rainfall during monsoon and moderate during pre-monsoon and post-monsoon. During monsoon, the water surplus and Moisture Adequacy Index value was high, thereby no water deficit prevail in this season. In winter season, there was high value of water deficit, therefore Moisture Index values were recorded low, wherein Aridity Index was very high. Finally, the seasonal analysis of water balance elements conclude that crop cultivation is highly favourable during monsoonal period. The climatic classification from Moisture Index value identifies Dry Subhumid type of climate in winter, Moist subhumid and Dry subhumid in pre-monsoon and post-monsoon, and pre-humid type of climate during monsoon season.

The analyses of annual water balance elements determine that the entire study area received an average mean rainfall of 1536 mm, mean annual Potential Evapotranspiration of 1054 mm and the mean Actual evapotranspiration average value of 976 mm. The annual water deficit analyses identified 75 mm of water deficit at Meluri rain-gauge station only. Meanwhile, the average annual water surplus was recorded 483 mm. The Moisture Adequacy Index revealed 93 percent and Aridity Index observed 6.87 percent at Meluri station only. Climatologically, overall analyses of annual water balance elements shows that the area experience humid type of climate.

Water Balance Estimation of Nagaland

1. Total surface of the water resources: 25,465,344,000 m^3.
2. Surface water resources recharged to ground water: 13,561,622,000 m^3.
3. Water lost in the form of evaporation and evapotranspiration**:** 16,827,685,000 m^3
4. Water surplus : 7,991,078,000 m^3
5. Surface run-off : 17,825,740,800 m^3

From the rain-gauge station-wise analysis, it is summarized that the study area is depicted as water surplus area. However, due to hilly terrain, surface run-off accounts 70 percent. About 30 percent of water surplus period prevailed in monsoon season but during winter, pre-monsoon and post-monsoon seasons, 70 percent of the water was lost owing to dry condition, evaporation and evapotranspiration. As such, very less percentage of water was stored in surface lake, ponds, beels, etc. Therefore, the water lost in the form of run-off has to be stored adopting watershed management programme in the study area by constructing check dams, percolating ponds and water harvesting structures.

The total forest area is about 767,733 hectares of land which accounted to 46.31 percent of total geographical area. The total area of other land utilisation were, under barren and uncultivable land 201,874 hectares (12.18%), land put non-agricultural use 56,022 hectares (3.38%), land under miscellaneous tree crops and grooves etc., 8,227 hectares (0.50%), current fallow land 124,360 hectares (7.50%), other fallow land 322,737 hectares (19.47%) and net sown area 176,949 hectares (10.67%).

The analysis of temporal variation of land utilisation revealed that the forest area of Nagaland decreased drastically. In the year 1993-94, the area of forest cover accounted 56.16 percent of the total geographical area which decreased to 55.75 percent (1993-94), 53.85 percent (2003-04), 53.26 percent (2008-09) and 52.54 percent (2013-14). Land put to non-agricultural use increased from 2.86 percent (1993-94) to 5.59 percent (2013-14). The land under miscellaneous tree crops grooves etc., cover area declined from 8.59 percent (1993-94) to 5.64 percent (2013-14). The area under culturable wasteland and current fallow land decreased from 5.77 percent (1993-94) to 4.18 percent (2013-04) and 7.83 percent (1993-94) to 3.01 percent (2013-14) respectively. The land use under fallow land and other than current fallow area declined from 6.46 percent (1993-94) to 5.99 percent (2013-14). The net sown area (agricultural land use) increased from 12.34 percent (1993-94) to 22.90 percent (2013-14).

The decadal analysis of land utilisation from 1993-04 to 2013-14 (20 years) revealed that the forest area of Nagaland decreased by –3.62 percent while the land put to non agricultural use increased to 2.73 percent. The landuse under miscellaneous tree crops, grooves etc., culturable waste land, current fallow and, fallow land and other current fallow land revealed decrease in land utilisation percentage by –2.95 percent, –1.58 percent, –4.82 percent and –0.47 percent respectively. The net sown area (agricultural land use) increased to 10.56 percent. The total irrigated area under various sources of irrigation in Nagaland during 2000-01 and 2007-08 was 51,509 hectares of land. It accounted to 3.10 percent of the total geographical area. Out of the 51,509 hectares of total irrigated area, the area under canal irrigation was 51,361 hectares (99.71%), the area under tube well irrigation was 2 hectares (0.0003%), the area under other wells was 70 hectares (0.13%) and the area under other sources of irrigation was about 76 hectares (0.14%) of the land.

The district-wise sources of irrigation also shows maximum of 27.1percent in Dimapur district. The intensity of irrigation was found maximum in Kohima district by 103.82 percent. During the period 2007-08, the average intensity of irrigation was 93.92 percent in the study area. The total net irrigated during 2007-08 was 61,152 hectares of the land, it account to 3.68 percent of the total geographical area. The total net cultivated area during 2007-08 was 176,949 hectare of the land which accounts 10.67 percent of the total geographical area of Nagaland. The district of Kiphire only shows net cultivated area more than net irrigated area. In Longleng district percentage of net irrigated area and percentage of net cultivated area were found out 70 percent each. The districts of Dimapur, Mokokchung, Phek and Tuensang revealed maximum percentage of net irrigated area by above 90 percent. During the period of 2007-08, the percentage of net irrigated area was 82 percent which was more than the net cultivated area (47%). The correlation coefficient is in between net irrigated area to net cultivated area is positive (0.18), then variables are associated directly.

The total cropped area (twenty crops) of the state during 2002-04 was 3,19,824 hectares (19.29%) and 2012-14 was 3,83,757 hectares (23.14%) of the total geographical area of the state. The change in cropping pattern shows decadal variation of 2002-04 and 2012-14 was 3.85 percent. The total cropped area of during 2012-14 was 3,83,757 hectares of the land which accounted to 23.14 percent of the total geographical area. Out of the total cropping area, the area under different crop cultivation accounted; Jhum paddy cultivation 24.93 percent, TRC/WRC paddy 22.52 percent, Maize cultivation 17.86 percent, Rape seed/ Mustard 7.07 percent, Soyabean 6.39 percent, Rajmash 3.75 percent and Small Millet 2.22 percent of the land. The other crops which occupied less than 2 percent of the area were Tea (1.95%), pea (1.81%), Potato (1.71%), Linseed (1.49%), Colocossia (1.35%), Naga Dal (1.19%), Sugarcane (1.12%), Sesamum (0.91%), Ginger (0.88%), Wheat (0.82%), Jute (0.78%), Tur/ Arhar (0.68%) and Beans (0.57%). The decadal district-wise variation of cropping area from 2002-04 to 2012-14 revealed that only Dimapur and Tuensang district cropping area were increased by 2.04 percent and 0.48 percent respectively.

From the analysis of cropping pattern of Nagaland, it was found out that the major cultivated crops were Jhum paddy, followed by TRC/WRC paddy, Maize, Rape seed/ Mustard, Soyabean while other crops accounts below 5 percent of the total cropped area. The intensity of cropping pattern was very high in Kiphire and Wokha districts. Decadal-wise crop diversification from 2002-04 to 2012-14 revealed that during 2002-04 low crop diversification (specialised or monoculture) dominated all the districts but in the year 2012-14, high level of crop diversification was noticed in Longleng district which means more diversification of crops. Moderate crop diversification was noticed in five districts, these were in Kiphire, Kohima, Mokokchung, Peren and Wokha. The district-wise ranking of crops identified Jhum paddy, Wet paddy and Maize in first and second rankings of crops in all districts. The third ranking crops were Maize, Rajmash, Rape seed and Soyabean. The study on crop combination adopting Rafiullah’s method during the year 2002-04 revealed that mono culture (Jhum paddy/ Wet paddy) dominated all the districts, but during 2012-14, the district of Dimapur shows two crop combination (Wet paddy + Jhum paddy) while the other districts reveals only mono culture (Jhum paddy/ Wet paddy/Maize). The crop combination of 2002-04 by Doi’s method reveals three districts with four crop combination, these were Wet paddy, Jhum paddy, Maize and Rape seed/ Mustard, four districts under three crop combinations and one district under mono culture. During the period of 2012-14, one district (Mon) shows five crop combination (Jhum paddy, Wet paddy, Maize, Rape seed/ Mustard and Soyabean), four districts under four crop combination (Jhum paddy, Wet paddy, Maize and Rape seed/ Mustard), three districts with three crop combination, two crop combination noticed in one district and two districts under mono crop combination. The crop production (in M.T.) during 2002-04 and 2012-14 shows that production of Jhum paddy and TRC/WRC paddy were high but decadal changes of production revealed that the production of Jhum paddy and TRC/WRC declined from 2002-04 to 2012-14 by –3.94 percent, and –2.82 percent respectively. The production of Maize, Rajmash, Tea, and Sugarcane increased during the decade. The crop yield among the twenty crops from 2002-04 and 2012-14 shows that the crop of sugarcane attainted maximum yield (5.71

M.T per hectare). The correlation coefficient is in between intensity of irrigation and intensity of crops is negative (-0.22), then variables are not associated directly.

The analysis of water availability identified only humid and wet period in the study area. During humid period the rain-gauge stations of Mangkolemba, Wokha and Yisemyong experienced maximum water availability days of 245 days which was recorded in the months of March to October (eight months). These rain-gauge stations are highly favorable for two crops cultivation under normal conditions. At the stations of Kiphire, Meluri, Sechu, Tseminyu and Tuensang, it varies from 183 days to 184 days (six months). The rain-gauge stations of Bhandari, Dimapur, Jalukie, Kohima, Mokokchung, Mon, Phek and Zunheboto experienced 214 days during 7 months which are also highly favorable for two crops cultivation under normal conditions. During wet period, Tuensang rain-gauge station experienced the maximum water availability days with 182 days during six months (October, November, December, January, February and March). The stations of Kiphire, Meluri, Sechu and Tseminyu experienced 181 days in the months of November, December, January, February, March and April (six months). At Dimapur, Jalukie, Kohima, Mokokchung, Mon, Phek and Zunheboto rain-gauge stations, it was recorded 151 days of water availability during five months while the stations of Mangkolemba, Wokha and Yisemyong experienced minimum days of water availability during wet period with 120 days during four months (November, December, January and February).

The water availability days and months were analysed on period-wise and finally observed that at all the rain-gauge stations only humid and wet period were experienced. During humid period, it is highly favourable for two crops cultivation during the months of April, May, June, July, August September and October. In this period, suggested crops are jhum paddy, wet paddy, maize, rapeseed/mustard, small millet, soyabean, tea, pea, colocossia, sugarcane, ginger, wheat and tur/arhar. During the wet period of November, December, January, February and March, single crop is suggested for cultivation, these are ginger, small millet, pea, beans and maize.

Finally, it is remarked that the Nagas strived from ages purely on interaction with nature for survival. The land and forest were accepted as the main economic assets for sustenance; as a result, they worshipped the elements of nature. The celebration of age-old festival during the time of sowing of seeds, pre-harvest, etc, signifies true essence that agriculture is not new to the native population; hence, the socio-economic of Nagas were accentuated on traditional cultivation. The art of songs/music, folk-lore, dance, etc, were composed and skilled in reverie to nature and its blessings. It is evident that agricultural forms of activities nurture the people. Though it may be argued that agricultural practice is traditional and un-scientific, however, this sector still played a vital role as it provide basic requirements, employment and additional income. Meantime, this traditional form of agriculture faces a challenging order as this attributes to climatic change and environmental degradation.

The agricultural system in regions like Nagaland needs to be addressed through Neo-traditional implementation incorporating socio-cultural factors with scientific innovation so that food security, livelihood and welfare of the people do compromise with the management of the environment. Agricultural trend is a dynamic process which demands appropriate initiative so as to cope man-nature relationship. This can be achieved through imparting education on farming, providing financial aid, initiative through government agencies, institutional and farm scientist involvement, dissemination of research findings and above all respecting mutual co-operation. This will aid the agrarian society to progress in understanding all the factors that determines agricultural development.

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Alam, K. (1993): 'Agriculture Development in North East India- Constraints and Prospect', Deep and Deep Publishing, New Delhi, pp. 3-15.

Alansi, A.W., Almin, M.S.M., Halim, Abdul., Dhafri, H.Z.M., Thamer, A.M., Waleed, A.R.M., Aimrun, W. and Ezrin, M.H. (2009): 'The Effect of Development and Land Use Change on Rainfall-Runoff and Runoff-Sediment Relationships Under Humid Tropical Condition-Case Study of Bernam Watershed Malaysia', *European Journal of Scientific Research*, Vol. 31(1), pp. 88-105.

Bairagya, Ramsundar. and Bairagya, Haraprasad. (2011): 'Water Scarcity a Global Problem-An Economic Analysis', *Indian Journal of Landscape Systems and Ecological Studies*. Vol. 34(1), pp. 127-132.

Ballukraya, P.N. (2012); 'Resistivity Investigations for Groundwater Exploration in Hard Rock Areas-A Review', *Journal of Applied Hydrology*, Vol. XXV(3&4), pp. 38-54.

Banerjee, S.K. (1958): 'Computation of Groundwater Potential', Publication. No. 4, Central Board of Geophysics, New Delhi, pp. 380-392.

Banerjee, Tapati., Duttaa, D., Sarkar, Deepak. and Das, Debabrata. (2010): 'Soil Moisture Based Crop Planning for Farmers' Land-A Case Study from Silai Sub-watershed of West Bengal', *Indian Journal of Soil Conservation*, Vol. 38(2), pp. 89-93.

Barghava, P.N. (1977): 'Statistical Studies on the Behavior of Rainfall in a Region in Relation to a Crop ', A Monograph Issued by I.A.R.S of I.C.A.R, New Delhi.

Basu, D.N. and Guha, G.S. (1996): 'Agro-climatic Regional Planning in India', Concept Publishing Company, New Delhi, pp. 178-179.

Bathusha, M. Ibrahim. and Saseetharan, M.K. (2010): 'Assessment of Water Quality Index for Ground Water of Coimbatore City North Zone', *Journal of Applied Hydrology*, Vol. XXIII(1&2), pp. 1-11.

Bhandari, N.K. (2009): ‘Interlinking of Rivers (ILR) with Special Reference to Gujarat’, *Journal of Applied Hydrology*, Vol. XXII(1), pp. 68-83.

Bhalla, G.S. and Singh, Gurmail. (2001): ‘Indian Agriculture- Four Decades of Development’, Sage Publication India Pvt. Ltd, p. 3.

Bhatia, Shyam S. (1965): ‘Patterns of Crop Concentration and Diversification in India’, Economic Geography, Vol. 41(1), pp. 39-56.

Bhaskar, K.S., Galikawad, S.T. and Madavi, S.H. (1988): ‘Evaluation of Soil Based Crop Yield Efficiency of Vertisols for Land Use Planning’, *J. Maharastra Agric. Uni*., Vol.13, pp. 325-360.

Bhatt, B.P. (2006): ‘Role of Agriculture in the Economic Development of Nagaland- Issues, Challenges and Opportunities’, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, pp. 55-72.

Bhattarcharjee, Niranjann. and Bora, Rana. (2012): ‘Selecting of Potential Sites for Integrated Watershed Management Programmes in Noa Basin, Assam Using Remote Sensing and GIS Technique’, *Hill Geographer,* Vol. XXVII(1), pp. 32-40.

Bora, Rana. and Krishnaiah, Y.V. (2015): ‘Temperature, Rainfall and Rainfall Recharge of the Kakodonga River Basin, India’, *International Journal of Science and Research*, Vol. 4(2), pp. 170-182.

Bublaku, Skender S. and Begiraj, Aryan. (2015): ‘Water Balance and Water Loss Implication in Badovc Lake, Kosovo’, *Journal of Geography and Earth Science*, Vol. 3(1), pp**.** 87-97.

Chackacherry, George., Nandeshwar, M. D. and Jayakumar, K. V. (2013): ‘Implementation of Participatory Irrigation Management in Kerala State, India-Challenges’, (Ed) Madhav D. Nandeshwar, K.V. Jayakumar, Girish Gopinath and G.K. Ambili, Sustainable Natural Resources Management under Changing Climatic Scenerios.International Geography Congress, Allied Publishers PVT. LTD., pp. 71-73.

Chakraborth, Ananya. (2012); ‘Crop Diversification in Murshidabad District, West Bengal-A Spatio-Temporal Analysis’, *International Journal of Physical and Social Sciences*, Vol. 2(7), pp. 393-403.

Chand, Mukesh., Kumar, Deshyant., Singh, Dhananjai., Roy, Nitish. and Singh, D.K. (2011): ‘Analysis of Rainfall for Crop Planning in Jhansi District of Bundelkhand Zone of Uttar Pradesh’, *Indian Journal of soil Conservation*, Vol. 39(1), pp. 20-26.

Chaturvedi, Rajani. and Thakur, G. Lalitkumar. (2012): ‘Levels of Agricultural Performance in Vidarbha Region (2001-2006)’, *The Goa Geographer*, Vol. IX(1), pp.50-54.

Chattopadyyay, Srikumar. (2015): ‘Human Dimension of Environmental Change with Special Reference to Water System and River Restoration’, *Trans. Inst. Indian Geographers*, Vol. 37(2), pp. 155-171.

Chauhan, R.N. (2007): ‘Basic Principles of Economic Geography’, ABD Publisher, Jaipur, pp. 19-20.

Chibane, B. and Rahmani, S.E. Ali. (2015): ‘Hydrological Based Model to Estimate Groundwater Recharge, Real-Evapotranspiration and Runoff in Semi-Arid Areas’, *Larhyss Journal*, ISSN 1112-3680, n°23, pp. 231-242.

Chopra, Kanchan., Rao, C.H. Hanumantha. and Sengupta, Ramprasad. (2003): ‘Resources, Sustainable Livelihood and Eco-systems Services’, Concept Publishing Company, New Delhi, pp. 53-93.

Chopra, Kusum. (1990): ‘The Emerging Growth, Challenges to Indian Agriculture’, Rawat Publication, New Delhi and Jaipur.

Chopra, Narayan. (2011): ‘Land Use/ Land Cover of a Part of Sonbhadra District, U.P.-A Geographical Analysis Using Remote Sensing Data’, *National Geographical Journal of India*, Vol. 57(3), pp. 67-74.

Dadhwal, K.S., Mandal, D., Srimali, S.S., Mohan, S.C., Raizada, A. and Sankar, M. (2012): 'Impact of Different Land Use Systems on Soil Properties in a Watershed of Lower Himalayan Region', *Indian Journal of Soil Conservation*, Vol. 40(2), pp. 115-121.

Das, Bhaskar. (2013): 'Surface Water Resource Potentials and their Management Strategy at Arsha Block in Peruliya District, West Bengal', *Eastern Geographers,* Vol. XIX(1), pp. 137-148.

Das, Pratibha T. (2010): 'Study of the Soils of Deepor Beel Catchment in Relation to Soil Farming Factors using Remote Sensing and GIS', *Indian Journal of Soil Conservation*, Vol. 39(2), pp. 94-100.

Devi, Lalita. (1992): 'Climatic Characteristics and Water Balance- A Case Study of Uttar Pradesh', Concept Publishing Company, New Delhi, pp. 111-127.

Devi, Laishram Mirana., Naqvi, Hasan Raja., Siddiqui, Lubna. and Siddiqui, Masood Ahsan. (2014): 'Land Use/Land Cover Change Detection Analysis in Manipur, India', *National Geographical Journal of India*, Vol. 60(3), pp. 245-262.

Dhawan, B.D. (1988): 'Role of Irrigation in Raising Intensity of Cropping', *J. Ind. School Political Economy*, Vol. 3(4), pp. 632-671.

Directorate of Agriculture Nagaland: Kohima. (1986): 'Hand Book of Nagaland Agriculture', p. 7&40.

Doi, K. (1957): 'The Industrial Structure of Japan Perfectiveses Proceed', CGU Japan, pp. 310-316.

Farrag, Abd El hay Aly., Sayed, El Sayed Ahmed El., and Megahed, Hanna Ahmed (2016): 'Land Use/ Land Cover Change Detection and Classification Using Remote Sensing and GIS Techniques-A Case Study at Siwa Oasis, Northwestern Desert of Egypt', *International Journal of advanced Remote Sensing and GIS* (Cloud Publication), Vol. 5(3), pp. 1649-1661.

Gautham, N.C. and Narayan, L.R.A. (1982): ‘Suggested Natural Land Use/ Land Cover Classification System for Indian Using Remote Sensing Technique’, Pink Publishing, Mathura, p.23.

Ghosh, P.K., Das, Anup., Saha, R. and Tomas, J.M.S. (2010): ‘Improving Mustard Yield through in-situ Soil Moisture Conservation and Conservation Tillage in Foot Hills of Meghalaya’, *Indian Journal of Soil Conservation*, Vol. 38(3), pp. 184-187.

Giridhar, M.V.S.S. and Vishwanadh, G.K. (2008): ‘Comparison of Temperature Based Reference Evapotranspiration Equation for Palleru Sub Basin, India’, *Journal of Applied Hydrology*, Vol. XXI(3&4), pp. 80-90.

Gole, Uma. (2009): ‘Carrying Capacity of Land in Seonath Basin’, *The Goa Geographer*, Vol. VI(1), pp. 49-53.

Gopalaswamy, N. (1994): ‘Agricultural Meteorology’, Rawat Publications, Jaipur and Delhi, pp. 1-8.

Goswami, S.N., Sarma, B.K. and Singh, S.B. (2002): ‘Food Security of North East India for Twenty First Century’, (Ed) B. Datta Ray, Agenda for North East India, Concept Publishing Company, New Delhi, pp. 31-35.

Hangaragi, S.S. (2010): ‘Measurement of Agricultural Efficiency and Planning for Sustainable Development in Drought Prone Area-A Case Study of Bagalkot District of Karnataka’, *Trans. Inst, Indian Geographers*, Vol. 32(2), pp. 127-136.

Hashmi, N.I. and Gomatee. (2011): ‘Spatio - Temporal Variation of Crop Diversification in Bulandshahr District, U.P.’, *National Geographical Journal of India*, Vol. 57(4), pp. 105-112.

Hussain, Majid. (2006): ‘Systematic Agricultural Geography’, Rawat Publication, Jaipur and New Delhi, pp. 213-273.

Igbozurike, Mathias U. (1971): ‘Against Mono-culture’, *Professional Geography*, Vol. 23, p. 114.

Iyer, R Ramaswamy. (2005): ‘Water - Perspectives, Issues, Concerns’, Sage Publication, New Delhi, p. 80.

Jahan, Nudrat. and Goswami., Kaushalendra Prakesh. (2012): ‘Forest Resources and Environmental Services in Faizabad District’, *National Geographical Journal of India*, Vol. 58(1), pp. 55-62.

Jain, R.C. (2009): ‘Emerging Challenges for Sustainable Groundwater Management in India’, *Journal of Applied Hydrology*, Vol. XXII(1), pp. 93-101.

Jaiswal, Jitendra Kumar. and Verma, Narender. (2013): ‘The Study of the Land Use/ Land Cover in Varanasi District Using Remote Sensing and GIS’, *Trans. Indian Geographers*, Vol. 35(2), pp. 210-212.

Jakhar, Praveen., Gowda H.C. Hombe., Naik, B.S. and Barman, D. (2011): ‘Probability Analysis of Rainfall Characteristics of Semiliguda in Koraput, Orissa’, *Indian Journal of soil Conservation*, Vol. 39(1), pp. 9-13.

Jamir, Tongdi. (2015): ‘Changes in Land Cover/ Land Use Over the North East Region of India’, *J. Geogr. Inst. Cvijic*. Vol. 65(3), pp. 309-322.

Jamir, Wangshimenla. (2014): ‘Mapping of Forest Cover through Remote Sensing and GIS, Wokha District, Nagaland’, IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), Vo. 8(4), pp. 97-102.

Jha, K.K. and Chawang, J.K. (2013): ‘Pattern of Information Sources Utilization among Paddy Cultivators of Dhansiripur R.D. Block of Nagaland’, *Nagaland University Research Journal*, Vol. 66, pp. 46-53.

Jha, R.K. (1999): ‘Deforestation and Village Life’, Mittal Publication, New Delhi, p. 11.

Jyothirmayi, P. and Kumar, R. Anil. (2013): ‘Changing Land Use Pattern and Some Environmental Implications in the Valapattanam River Basin, Kannur District of Kerala State’, (Ed) Madhav D. Nandeshwar, K. V. Jayakumar, Girish Gopinath and G. K. Ambili, Sustainable Natural Resources Management under Changing Climatic Scenarios, Proceedings of the 3rd International Geography Congress, Allied Publishers PVT. LTD., pp. 352-356.

Kalaiselvi, V. (2012): ‘Patterns of Crop Diversification in Indian Scenario’, Scholars Research Library, Vol. 3(4), pp. 1914-1948.

Kalita, D.C. and Bhowmick, B.C. (2008): ‘A Comparative Study of Shifting and Settled Cultivation in the Hill Zone of Assam’, *Nagaland University Research Journal*, Vol. 5(1), pp. 17-28.

Kannan, P., Sankar, M. and Prabhavathi, M. (2010): ‘Remote Sensing and GIS for Land Mapping and Crop Planning in Cauvery Delta Region of Tamil Nadu, India’, *Indian Journal of Soil Conservation*. Vol. 38(30), pp. 199-204.

Kanslime, Monica K., Wambugu, Stephen K. and Shisanya, Chris A. (2013): ‘Perceived and Actual Rainfall Trends and Variability in Eastern Uganda- Implications for Community Preparedness and Response’, *Journal of Natural Science Research*, Vol. 3(8), pp. 179-194.

Karanth, G.K. (1995): ‘Change and Continuity in Agrarian Relations’, Concept Publishing Company, New Delhi.

Khan, A.R. and Singh, R.B. (1992): ‘Micro Level Monitoring of Land Use and Agriculture in Himalayas’, (Ed) Noor Mohammad, Land Use and Agricultural Planning, Concept Publishing Company, New Delhi, Vol. 4, pp. 227-241.

Khan, Mohd. Shahnawaz. and Khan, Mohd. Mazhar Ali. (2012): 'Detection of Land Use/Land Cover Changes Using Remote Sensing and GIS-A Case Study of Bulandshahr District (Uttar Pradesh)', *National Geographical Journal of India*, Vol. 58(3), pp. 81-88.

Krishan, Gopal. (1992): 'The Concept of Agricultural Development', (Ed) Noor Mohammad, Dynamics of Agricultural Development, Concept Publishing Company, New Delhi, Vol. 7, pp. 29-36.

Krishnaiah, Y.V. (2009-10): 'Cropping Pattern of the Papagni River Basin, Andhra Pradesh', *North Eastern Geographer (Refereed Journal),* Gawahati University, Guwahati, Vol. 36(1&2), pp. 132-141.

Krishnaiah, Y.V. (2010a): 'Hydrological Studies of the Papagni River Basin', *The Goa Geographer (Peer-review Journal),* Goa, Vol. VII(1), pp. 19-24.

Krishnaiah, Y.V. (2010b): 'An Integrated Study of Natural Resources Development of the Papagni River Basin Using Remote Sensing Techniques', In: proc. of International Geographic Union (IGU) Commission Seminar on Land use, Biodiversity and Climate Change held on Dec. 11-13, 2010, Organised and Published by Dept. of Geography, Cotton College, Guwahati.

Krishnaiah, Y.V. (2011a): 'Land Capability of the Papagni River Basin, Andhra Pradesh, Using Remote Sensing Technique', *Trans. Inst. Indian Geographers (Refereed Journal)*, Pune, Vol. 33(1&2), pp. 132-141.

Krishnaiah, Y.V. (2012): 'Water Availability Days, Calendar and Crop Suitability of the Papagni River Basin, India', *The Goa Geographer (Peer-Reviewed Journal)*, Goa, Vol. VII(1), pp. 28-35.

Krishnaiah, Y.V. (2013a): 'Irrigation and Agriculture Development of the Papagni River Basin, India', *Journal of Water Research*, Vol.135, pp. 161-174.

Krishnaiah, Y.V. (2013b): 'Water Balance Estimation of the Papagni River Basin, India', *The Indian Journal of Spatial Science* (Reviewed Journal), Vol.5(1), pp. 70-76.

Krishnaiah, Y.V. (2013c): ‘Landuse Pattern and Landuse Efficiency of the Papagni River Basin, India’, *The Indian Journal of Spatial Science (Reviewed Journal)*, Vol. 4(1), pp. 59-68.

Krishnaiah, Y.V. (2014a): A Reference Book of ‘Water Balance and Watershed Development of the Papagni River Basin: Remote Sensing Approach’, Published by LAP LAMBERT Academic Publishing, Heinrich-Blocking-Str.6-8, 66121, Saabrucken, Deutschland/Germany.

Krishnaiah, Y.V. (2014b): ‘Rainfall Analysis and Rainfall Recharge of the Papagni River Basin, Andhra Pradesh’, *National Geographical Journal of India (International peer-reviewed and Referred Journal)*, B.H.U., Varanasi, Vol. 60(1), pp. 83-96.

Krishnaiah, Y.V. and Rao, M Sambasiva. (2005): ‘Land and Water Resources Evaluation and Watershed Develoment of the Papagni Basin Using Remote Sensing Data’, In: proc. of Seminar Book entitle ‘Environmenttal Challenges and Sustainable Development: Remote Sensing and GIS’, Edited by Dr. Vijaya Bhole, Dr. A. Kamalakar Reddy, Dr. S. Padmaja, Published by Universal Scientific Publishers, Jaipur, Vol. 2, pp. 417-422.

Kuba, James. and Jha, K.K. (2008): ‘Attitude of Farmers towards Improved Practiced of Paddy Cultivation’, *Nagaland University Research Journal*, Vol. 5(1), pp. 113-117.

Kumanan, C.J. (2012): ‘Certain Vistas of Geoinformation Technology for Water Resources Management’, *Journal of Applied Hydrology*, Vol. XXV(3&4), pp. 1-8.

Kumar, D. and Kumar, S. (1989): ‘Rainfall Distribution Pattern Using Frequency Analysis’, *Journal Agril. Engg.*, Vol. 26(1), pp. 33-38.

Kumar, Sunil. and Kumar, Surjeet. (2015): 'Rainfall Variability Analysis and its Impact on Crop Production in Bihar', *Africa Journal of Agricultural Research*, Vol. 10(9), pp. 983-989.

Kumar, Vijay., Jain, Sharad K. and Singh, Yatveer. (2010): 'Analysis of Long-Term Rainfall Trends in India', *Hydrological Sciences Journal-Journal des Sciences Hydrologiques*, Vol. 55(4), pp. 484-496.

Kumra, V.K. and Kumar, C.S. (2001): 'Land Use Pattern and its Environmental Consequences', (Ed) Prithvish Nag, Chandra Shekhar Kumar, Smita Sengupta, Environment, Population and Development, Concept Publishing Company, New Delhi, pp. 120-136.

Lakshminarayana, S. and Krishnaiah, Y.V. (2013); 'Climate and Hydrological Characteristics of Anantapur Municipal Corporation, Andhra Pradesh', *The Goa Geographer (Peer-Reviewed), Goa*, Vol. X, pp. 61-70.

Lambin, E.F. (1999): 'Monitoring Forest Degradation in Tropical Regions by Remote Sensing-Some Methodological Issues', *Glob. Ecol. Biogeogr*, Vol. 8(3-4), pp. 191-198.

Let, Surajit. and Pal, Swades. (2013): 'Crop Diversification of Birbhum Diistrict: A Spatio-Temporal Assessment', *Eastern Geographers,* Vol. XIX(1), pp. 49-54.

Mahajan, V.S. (2002): 'Agricultural should Get High Priority in the North-East', (Ed) B. Datta Ray, Agenda for North East India, Concept Publishing Company, New Delhi, pp. 36-39.

Malini, B. Hema. and Endris, Tesfaye Muhiye. (2013): 'Identification of Ideal Length of Growing Period for Rain-fed Crop-A Case Study of Amhara National Regional State-Ethiopia', *Punjab Geographer*, Vol. 9, pp. 7-16.

Majeed, Abdul. (1992): 'Approaches to Land Use Survey', (Ed) Noor Mohammad, Land Use and Agricultural Planning, Concept Publishing Company, New Delhi, Vol. 4, pp. 91-110.

Malhotra, Kirti. and Venugopal, H. (2008): 'Artificial Neural Networks for Estimation of Runoff for Better Watershed Management', *Journal of Applied Hydrology*, Vol. XXI(3&4), pp. 1-7.

Mandal, R.B. (1990): 'Land Utilization- Theory and Practice', Concept Publishing Company, New Delhi, pp. 1-24.

Manna, M.C. Rao., Subha. A. and Mandal, A. (2013): ' Maintenance of Soil Biological Health under Different Crop Production Systems', *Indian Journal of Soil Conservation*, Vol. 4(2), pp. 127-135.

Mukherjee, Anita Roy. (1995): 'Forest Resources Conservation and Regeneration- A Study of West Bengal Plateau', Concept Publishing Company, New Delhi, p. 30.

Murthi, J Dakshina (1964): ' Some Characteristics of Rainfall Distribution in Visakhapatnam District', An Unpublished Monograph Submitted to Andhra University, Visakhapatnam.

Murty, Narasimha, K.L. (2008): 'Loss of Agricultural Land and Changing Utilization of Resource Base-A Case Study of Three selected Villages of Srikakulam District, A.P.', (Ed) Baleshwar Thakur, Perspectives in Resources Management in Developing Countries, Concept Publishing Company, New Delhi, Vol. 3, pp. 362-375.

Naidu, L.G.K., Verma, K.S. and Jain, S.P. (1988): 'Soil Family - A Key in Soil Taxanomy for Agriculture Interpretation', *J. Ind. Soc. Soil Sci*., Vol. 36, pp.192-194.

Narayan, Dev. and Biswas, H. (2001): Augmenting Crop Production through Rainwater Harvesting and Recycle in Red Soils of Central India', *Indian Journal of Soil Conservation,* Vol. 40(1), pp. 52-59.

Nath, V. (2009): 'Regional Development and Planning in India', (Ed) S.K. Aggarval, Concept Publishing Company, New Delhi, pp. 231-263.

Nayal, L.T. (2011): 'Anomalies in the Distribution Pattern of Rainfall in Dharwar District, Karnataka', Vol. 57(2), pp.73-80.

Nonneke, I.L. (1989): 'Vegetable Production', An AVI Book, Publisher van Nostrand Reinhold, pp. 614-623.

O'Callaghan, J.R. (1996): 'Land Use - The Interaction of Economics, Ecology and Hydrology', Published by Chapman & Hall, London, pp. 1-23.

Ogale, S.B., Choudhar, R.H. and Patil, A.S. (2012) 'A Study of Crop Combination and Diversification in Melegaon Suggar Factory Command Area of Baramati Tehsil, Pune District (Maharashtra)', *International Indexed & Referred Research Journal*, Vol. III(34), pp. 57-60.

Ogale, Sunil B. (2014): 'A Study of Crop Combination Region of Baramati Tahsil in Pune District (Maharashtra)', *International Journal of Innovation and Scientific Research*, Vol. 2(2), pp. 329-334.

Ojo, O. (1994): 'Water Balance and Planning Strategies for Agricultural Development- The African Experience', *Indian. Jour. Agricultural Meteorology*, Vol. 2, pp. 117-118.

Pachauri, S.K. (1984): 'Dynamics of Rural Development in Tribal Areas-A Study of Srikakulam District, Andhra Pradesh', Concept Publishing Company, New Delhi, pp. 17-43.

Pandey, Dhirendra Kr., Anil Tiwarari, Kr. and Sharma, V.N. (2013): 'Status of Forest Resources in Saryupar Plain, Uttar Pradesh', *National Geographical Journal of India*, Vol. 59(3), pp. 291-300.

Pandey, N.G., Chakravorty, B., Venkataramana, R. and Mani, P. (2013): 'Soil Water Retention Characteristics of Ajay River Basin', *Journal of Applied Hydrology*, Vol. XXVI(1-4), pp. 73-81.

Pareta, Kuldeep. (2013): 'Assessment of Carbon Stocks in Shifting Cultivation Lands-A Case Study of Nagaland State of India', Esri International User Conference.

Patel, C.C. (2009): 'Water Resources Management Development and Emerging Issues', *Journal of Applied Hydrology*, Vol. XXII(1), pp. 1-17.

Prasad, Nageshwar., Burdwan. and Ghosh, Tanusree. (2013): ' Methods of Land Capability, Capability Classes and their Suitability in the Southwest Birbhum District, West Bengal', *Trans. Inst. Indian Geographers*, Vol. 35(1), pp. 75-88.

Purandeswari, D. (2009): 'Role of Science in Combating Stressed Water Resources', *Journal of Applied Hydrology*, Vol. XXII(3&4), pp. 1-5.

Rafiullah, S.M. (1956): 'A New Approach to Functional Classification of Towns', Geographer, Vol.XII, pp. 40-53.

Raghunath, H.M. (2010): 'Hydrology-Principles, Analysis and Design', New Age International (P) Limited, Second Edition.

Rahman, Hifzur. and Lata, Suman. (2012): 'Comparative Analysis of Irrigation and Cropping Intensity in Uttar Pradesh, India', *National Geographical Journal of India*, Vol. 58(3), pp. 25-34.

Rahmani, S.E., Chibane, Brahin. and Boucefiene, Abdelkader. (2016): 'Groundwater Recharge Estimation in semi-Arid Zone-A Case Study from the Region of Djelfa (Algeria)', *Appl Water Sci, Doi* 10.1007/s 13201-106-0399-y.

Rai, S,N., Thiagarajan, S., Kumari, Y. Ratna. and Kumar, Dewashish. (2012): 'Exploring Deccan Traps for Groundwater in Parts of Kalmeshwar Taluk, Nagpur District, India', *Journal of Applied Hydrology*, Vol. XXV(3&4), pp. 85-94.

Rai, V.K. (2001): 'Irrigational Water Use and Requirements - A Case Study', (Ed) Prithvish Nag, Chandra Shekhar Kumar, Smita Sengupta, Environment, Population and Development, Concept Publishing Company, New Delhi, pp. 170-188.

Raina, J.L. (1997): 'Agricultural Geography', Pointer Publishers, Jaipur, p. 21.

Raju, D.R. Prasada., Alam, Neelima., Bajpal, Sanjay. and Saini. Vineet. (2012): ‘Affordable and Sustainable Technological Solution to Address Varied Water Challenges in India-A Case Study’, *Journal of Applied Hydrology*, Vol. XXV(3&4), pp. 28-37.

Raju, K.N. Prudhvi., Shraban, Sarkar., Pandey, Manish Kumar and Keshari, Shruti (2014): ‘Surface Water Resources and River Systems of Andhra Pradesh’, Geological Society of India, Special Publication, No. 3, pp. 92-98.

Ramdass, G., Laxmi, G Udaya. and Sriramulu. (2016): ‘Application of RS and GIS for Land Use/ Land Cover, Geomorphological Studies in Nalgonda District, Telangana, India’, *International Journal of Advanced Remote Sensing and GIS* (Cloud Publications), Vol. 5(3), pp. 1592-1604.

Ram, Daya. and Yadav, S.S. (2008): ‘Changing Pattern of Crop Failure in Rainfed Agricultural Lands-A Case Study of Hissar Tehsils of Haryana’ (Ed) Baleshwar Thakur, Perspectives in Resources Management in Developing Countries, Concept Publishing Company, New Delhi, Vol. 3, pp. 376-401.

Raman, C.A.V. and Murthy, Srinivasa. (1971): ‘Water Availability Period for Crop Growth’, IMD Publication, No.173.

Rana, Pooja. and Sohal, K.S. (2012): ‘Changes in Extent of Irrigation and its Impacts on Agricultural Landscape and Environment in Punjab’, *National Geographical Journal of India*, Vol. 58(2), pp. 59-68.

Rao, P.R. Khrishna. (1970): ‘Groundwater Potential in Hard Rock Areas in India’, Publication in Government of Karnataka, Bangalore.

Rao, M. Samabasiva. (1984): ‘Water Balance and Development of Surface and Sub-surface Water Resources and Agriculture of Madurai District, Tamil Nadu’, *Indian Journ. of Agril. Meteorology*, Vol. 2(1), pp. 55-63.

Rao, S Venkateswara., Rao, P.H.V. Vasudeva., Rao, G. Krishna. and Rao, N. Subha. (1997): 'Significance of Water Resources Development in the Rural Environment with References to Srikakulam District, Andhra Pradesh', (Ed) Prithvish Nag, V.K. Kumra, Jagdish Singh, Geography and Environment, Concept Publishing Company, New Delhi, Vol. 2, pp. 94-115.

Rao, V.L.S. Prakesh. (1986): 'Land Use Survey of India', (Ed) P.S. Tewari, Agricultural Geography, Vol. VIII, Heritage Publishers, New Delhi, pp. 28-43.

Rawat, M.S. (2014): 'Integrated Watershed Management - An Alternative Approach for Sustainable Development in Nagaland', *Journal of Agriculture and Life Science*, Vol. 1(1), pp, 1-14.

Rawat, M.S.S. and Singh, M.P. (2010): 'Climatic Change and Variability in Dehradun City, Uttarkhand', *National Geographical Journal of India*, Vol. 56(1), pp. 51-60.

Ray, B Datta. (2001): 'Agenda for North East India', Concept Publishing Company, New Delhi, pp. 1-37.

Ray, C.R., Senapati, P.C. and Lal, R. (1980): 'Rainfall Analysis for Crop Planning at Gopalpur, Orissa', *J. Agric. Eng*., Vol. 17, p. 384.

Rayudu, Sanjeeva. and Krishnaiah, Y.V. (2011): 'Impact of Irrigation on Agricultural Production in India', *The Economic Challenger*, Vol. 30(50), pp. 35-38.

Reddy, P. Sanjeeva. (1997): 'Different Sources of Irrigation - A Case Study of the Telangana Region', Manak Publication Pvt. Ltd, pp, 1-24.

Reddy, R. Ramakhrishna. (2013): 'Climate Change Mitigation Measures and Water', *Land and Water-Geographic Challenges and Geospatial Technologies, A Post Volume Conference,* pp. 216-226.

Regar, P.L., Rao. S.S. and Joshi, N.L. (2010): 'In-situ Rainwater Conservation Practices on Productivity of Chickenpea (Cicer arietnum) in the Rainfed conditions of Arid Rajasthan, India', *Indian Journal of Soil Conservation*, Vol. 38(2), pp. 111-115.

Rongsen , M. (2003): 'Land in Travail - A Critique on Development', CTC, Mokokchung, p.47.

Roy, Animesh. (2014): 'Changes in Land Utilization in West Bengal : District and B.D. Block Level Analysis', *Punjab Geographer- A Journal of the Association of Punjab Geographers, India*, Vol.10, pp.23-44.

Roy, P. Basu. and Barman U.K. (2014): 'Crop Concentration and Diversification in Jalpaiguri District of West Bengal-A Case Study', *International Journal of Food, Agriculture and Veterinary Sciences*, Vol. 4(3), pp. 5-9.

Sachchidananda. (1989): 'Shifting Cultivation in India', Concept Publishing Company, New Delhi, pp. 5-12.

Sachan, Shika., Thomas, T. and Singh, R.M. (2014): 'Meteorological and Hydrological Drought Characteristics in Bearma Basin of Bundelkhand Region in Madhya Pradesh', *Indian Journal of Soil Conservation*, Vol. 42(3), pp. 235-242.

Saha, Joydeep. (2013): 'Crop Diversification in Indian Agriculture with Special Reference to Emerging Crops', *Trans. Inst. Indian Geographers*, Vol. 35(1), pp. 139-146.

Saha, Manika. and Sengupta, Sushmita. (2014): 'Symbiotic Relationship between Forest and Tribe-Case Study of Santal Tribe of Jaypur Forest, Bankura District, West Bengal', *Trans. Inst. Indian Geographers*, Vol. 36 (2), pp. 235-246.

Samanta, Gopa. and Sengupta, Shrabana. (2010): 'Gender and Agricultural Work-Livelihood Crises of Women Agricultural Workers in Hoogly District of West Bengal', *Annals.* Vol. XXX(2), pp. 40-54.

Samuel, Manoj P. and Satapathy, K.K. (2008): 'Rainwater Harvesting for Irrigation and Drinking Water Requirements in Hilly Terrains of N-E India', *Journal of Applied Hydrology*, Vol. XXI(3&4), pp. 44-56.

Sandhu, JitDalijit Kaur. and Kaushik, Krishna. (2014): 'Agricultural Perspectives and its Input on Soil and Groundwater-A Case Study of Bibipur Village, Yamunagar, Haryana', Trans. Inst. Indian Geographers, Vol. 36(1), pp. 83-89.

Sardar, Uttam Kumar. (2011): 'Status of Land Use Pattern in the District of South 24 Parganas', *Indian Journal of Landscape Systems and Ecological Studies*, Vol. 34(1), pp. 461-464.

Schneider, H. Stephen., Root, L. Terry. and Mastrandrea, D. Michael. (2011): 'Encyclopedia of Climate and Weather', Published by Oxford University Press, Inc, Second Edition, pp. 378-379.

Sebu, Soyhunlo. (2013): 'Geography of Nagaland', Spectrum Publications, Guwahati, pp. 99-149.

Sebu, Soyhunlo. and Yaden, Sangyu. (2013): 'Population Explosion and its Impact on the Fauna in Nagaland- Issues and Challenges', (Ed) Madhav D. Nandeshwar, K.V. Jayakumar, Girish Gopinath and G.K. Ambili, Sustainable Natural Resources Management under Changing Climatic Scenerios.International Geography Congress, Allied Publishers PVT. LTD., pp. 329-334.

Seghal, S.R. (1970): 'International Hydrological Decade', News Letter, No.5, p. 5.

Sehgal, J. (1991): 'Soil-site Suitability Evaluation for Cotton', *Agropedology*, Vol. 1, pp. 49-63.

Seitinthang, Lh. (2013): 'Cropping Pattern Changes in Manipur', *Hill Geographer*, Vol. XXIX(2), pp. 69-76.

Sharma, B.L. (1991): 'Applied Agricultural Geography', Rawat Publication, Jaipur.

Sharma, K.K. and Dubey, S.K. (2013): 'Probability Analysis of Rainfall for Planning Water Harvesting and Irrigation in Semi-arid Region of Uttar Pradesh', *Indian Journal of Soil Conservation*, Vol. 4(1), pp.14-19.

Sharma, Pooja. and Sohal, K.S. (2013): 'Emerging Cropping Pattern in Punjab- A Debatable Issues', *National Geographical Journal of India*, Vol. 59(2), pp. 19-36.

Sharma, R.R. (2012): 'Impact of Climate change on River Discharge- A Case Study of Birhun Khad, Tawi Basin, Jammu', *Journal of Indian Geomorphology*, Vol. 1. Pp. 26-31.

Sharma, T.C. (1999): 'Technological Change in Indian Agriculture', Rawat Publication, New Delhi and Jaipur.

Shukla, Sarika. (2013): 'Dynamism of Indian Agriculture', (Ed) Madhav D. Nandeshwar, K.V. Jayakumar, Girish Gopinath and G.K. Ambili, Sustainable Natural Resources Management under Changing Climatic Scenerios.International Geography Congress, Allied Publishers PVT. LTD., pp. 57-60.

Siddiqi, Farooq, M. (1992): 'Agricultural Practices and Agricultural Change in Bundelkhand', (Ed) Noor Mohammad, Land Use and Agricultural Planning, Concept Publishing Company, New Delhi, Vol. 4, pp. 313-322.

Siddiqui, Shamsul Haque., Aktar, Nasim. and Ahmad, Mumtaj. (2014): 'Pattern of Crop Concentration in Malda District-A Geographical Analysis', *National Geographical Journal of India,* Vol. 60(3), pp. 235-244.

Singh, A.K., Joshi, G.C. and Pande, P.C. (1997): 'Replacing Agriculture by Horticulture: A Solution to Ecological Problems in Kumaun Himalaya', (Ed) Prithvish Nag, V.K. Kumra, Jagdish Singh, Geography and Environment, Concept Publishing Company, New Delhi, Vol. 2, pp. 147-156.

Singh, Anamika. and Singh, B.N. (2010): 'A Study on Climate Variability Over Varanasi', *National Geographical Journal of India*, Vol. 56(2), pp. 45-52.

Singh, Arun, K. (2014): 'Urban Water Supply in Uttar Pradesh- A Case Study of Varanasi', *National Geographical Journal of India*, Vol. 60(2), pp. 141-156.

Singh, C.P. (1997): 'Effect of Soil Erosion on Arable Land of Vindhyan Plateau: A Case Study, (Ed) Prithvish Nag, V.K. Kumra, Jagdish Singh, Geography and Environment, Concept Publishing Company, New Delhi, Vol. 2, pp. 157-172.

Singh, Gulab Baghel. (1995): 'Geography of Human Resources', Mohit Publication, New Delhi, p. 24.

Singh, J. and Dhillon. (1984): 'Methods of Agriculture Regionalization in Agricultural Geography', New Delhi, India, Tata Mc Graw-Hill, 3rd edition, pp. 213-297.

Singh, Kh. Jugindro. and Singh, L. Jelsyam. (2014): 'Changing Paradigm of Shifting Cultivation in Wangjing River Basin, Manipur', *The Deccan Geograper*, Vol. 52(1), pp. 53-58.

Singh, Mehtab. and Singh, R.B. (2013): 'Land Use and Land Cover Dynamics: A Case of Amri Choe Sub Watershed in Haryana Shiwaliks', *Eastern Geographers.* Vol. XIX(1), pp. 27-34.

Singh, Mridula. (2004): 'Integrated Planning of Land and Water Resources with Special References to U.P.', (Ed) Tapeshwar Singh, Resources Conservation and Food Security, Concept Publishing Company, New Delhi, Vol. 1, pp. 30-37.

Singh, Ranavijai Bahadur. (2010): 'Drinking Water and Urban Poor in Ethiopia', *National Geographical Journal of India*, Vol. 56(3&4), pp.135-142.

Singh, R.P. (1992): ‘Concept of Land Use’, (Ed) Noor Mohammad ‘Land Use and Agricultural Planning’, Concept Publishing Company, New Delhi, Vol. 4, pp. 73-89.

Singh, Sunita. (2011): ‘Land Resources Utilization for Agricultural in Rohtas District Bihar’, *National Geographical Journal of India*, Vol. 57(2), pp. 82-86.

Singh, Surender. (1992): ‘Agricultural Development and Environmental Issues’, (Ed) Noor Mohammad, Dynamics of Agricultural Development, Concept Publishing Company, New Delhi, Vol. 7, pp. 219-241.

Singh, Surjeet., Kumar, C.P., Sharma, Anupma. and Vasta, Rajan. (2012): ‘Water Balance of the Sonar Sub-Basin-A Case Study’, *Journal of Applied Hydrology*, Vol. XXV(1&2), pp. 25-28.

Singh, Usha. and Yadav, Swati. (2010): ‘Condition of Groundwater for Irrigation in U.P. Bundelkhand Region’, *National Geographical Journal of India*, Vol. 56(3-4), pp. 101-108.

Singh, Vibha. and Singh, J. (2012): ‘Levels of Agricultural Development and its Correlates in Chandauli District (Uttar Pradesh)’, *National Geographical Journal of India*, Vol. 58(3), pp.13-24.

Sinha, D.D., Mohapatra, S.N. and Padmini. (2015): ‘Site Selection for Suitable Water Harvesting Structure Using Remote Sensing and GIS’, *Trans. Inst. Indian Geographers*, Vol. 37(2), pp. 223-232.

Sitaram, Korade Mahendra. and Paliwal, Rakesh. (2014): ‘Integrated Land Use/Land Cover Analysis of Surat District, Gujarat by Using Digital Classification Technique’, *The Deccan Geographer*, Vol.52(1), pp. 9-16.

Somasundaram, J., Lakaria, B.L., Saha, R., Sinha, N.K., Jha, P., Chaundhary, R.S., Singh, R.K., Mandal, D., Hati, K.M., Ramesh, K., Coumar, M Vassanda., Biswas, A.K., Dey, P., Reddy, K Sammi. and Rao, A Subba. (2014): 'Management of Stressed Soils of Dry Land Agriculture in Semi-arid Tropics-A Review', *Indian Journal of Soil Conservation*, Vol. 42(2), pp. 178-187.

Sonwane, B.G., Achole, P.B., Hange, A.K., and Nagade, D.S. (2009): 'Transformation in Land Use Efficiency in Latur District 1983-88 to 1998-2003', *The Goa Geographer*, Vol. VI(1), pp. 54-57.

Subbaiah, R. and Prajapathi, G.V. (2013): 'Weekly Rainfall Frequency Analysis for Junagadh of Gujarat State of India-A Case Study', *Indian Journal of Soil Conservation*, Vol. 41(2), pp. 99-106.

Subhas, N. (2014): 'Assessing the Impact of Dry Spell during Monsoon Season on Rice Productivity-A Case Study Over Patna District', *Indian Journal of Soil Conservation,* Vol. 42(3), pp. 255-259.

Subhas, N., Singh, S.S. and Priya, Neha. (2001): 'Rainfall Variability and its Impact on Change of Cropping Systems in Bihar', *Indian Journal of Soil Conservation,* Vol. 40(1), pp. 33-40.

Subrahmanyam, K.V. and Gajanana, T.M. (2000):'Co-operative Marketing of Fruits and Vegetables in India', Concept Publishing Company, New Delhi, pp. 1-30.

Subrahmanyam, V.P. (1983): 'Some Aspect of Hydro-climatology and Water Balance of Chandrapalem Basin', Trans. Inst. Indi. Geographers, Vol.5(1), pp. 11-18.

Subrahmanyam, V.P. and Viswanadham, P. (1979): 'A Study of Rainfall Pattern in Visakhapatnam District', The Indian Geographical Journal. Vol. 54(1), pp. 55-64.

Sukumar, B. and Sukumar, Ahalya. (2013): 'Assessment of Water Resources of Kannur District, Kerala Using Remote Sensing and Well Data in GIS Environment', *Land and water-Geographic Challenges and Geospatial Technologies, A Post Volume Conference*, pp.110-116.

Sundaram, K.V., Moni, M. and Jha, M Mrityunjay. (2004): 'Natural Resources Managementand Livehood Security Survival Strategies and Sustainable Policies', Concept Publishing Company, New Delhi, p.43.

Sundriyal, R.C., Shankar, Uma. and Upreti, T.C. (1999): 'Perspectives for Planning and Development in North East India', Published by Bishen Singh, Dehradun, pp. 78-83.

Suneetha, P. and Babu, Ch. Tala. (2009): 'Analysis of Groundwater Potential through GIS and Remote Sensing', Journal of Applied Hydrology, Vol. XXII(3&4), pp. 91-99.

Surayawanshi, D.S. and Dagu, Pagar Sanjay. (2010): 'A Spatio -Temporal Analysis of Crop Diversification in Nashik District- Maharashtra', *Punjab Geographer*, Vol. 6, pp. 83-89.

Taukdar, Moumita. and Singh, Suredra. (2011): 'Land Use Changes in Tinsukia District, Assam, Annals, Vol. XXXI(1), pp. 81-92.

Tejpal. (2011): 'Impact of Mining Activities of Land Use Land Cover and Surrounding Environment-A case Study of Faridabad Block, Haryana', *Eastern Geographers*, Vol. XIX(1), pp. 127-136.

Thampi, G. Santosh and Raneesh, K.Y. (2013): 'Impact of Land Use/ Land Cover and Climate Change on Groundwater recharge in a Humid Tropical Watershed Using a Simple Hydrologic model', (Ed) Madhav D. Nandeshwar, K.V. Jayakumar, Girish Gopinath and G.K. Ambili, Sustainable Natural Resources Management under Changing Climatic Scenerios.International Geography Congress, Allied Publishers PVT. LTD., pp. 115-128.

Thornthwaite, C.W. and Mather, J.R. (1955): 'The Water Balance, Publication in Climatology', Centerton, (New Jersey), Vol.8 (1), p.104.

Tiwari K. Anil. and Sharma, V.N. (2011): 'Level of Agro-based Industrial Development in Eastern Uttar Pradesh', *National Geographical Journal of India*, Vol. 57(4), pp. 43-52.

Tripathi, S.K. (2009): 'Rainfall Analysis for Crop Planning - A Lesson from Uttarakhand', *Journal of Applied Hydrology*, Vol. XXII(1), pp. 42-54.

Umar, Naima. and Rehman, Hifzur. (2011): 'Crop Productivity Variations in U.P.-A Regional Analysis', *National Geographical Journal of India*, Vol. 57(2), pp. 55-64.

U.S. Geological Survey (1962): 'U.S. Geological-Survey Water Supply Paper', p. 1544.

Vaidya, B.C. and Nannaware, R. Ramesh. (2013): 'Assessment of Land Use/Land Cover Dynamics in Parner Taluka by Using Remote Sensing Technique', The Deccan Geographer, Vol. 51(1&2), pp. 109-115.

Vorosmarty, C.J,. Lettenmaier, D., Leveque, C., Meybech, M., Pahl-wost, C., Alcamo, J., Cogrove, W., Grassi, H., Hoff, H., Kambat, R., Lansigan, F., Lawford R. and Naiman, R. (2014) : 'Human Transforming the Globe Water Systems', *EOS*, *Transactions*, *American Geophysical Union*, Vol.85(48), pp. 509-514.

Vries, de. and Simmers, I. (2012): 'Groundwater Recharge: An Overview of Process and Challenges', *Hydrogeol Journal*, Vol. 10, pp. 5-17.

Wangshimenla and Jungio, N. Renthungo. (2012): 'Utilization Pattern and Management of Forest Resources in Wokha District of Nagaland', *The Goa Geographer*, Vol. IX(1), pp.78-86.

Waylen, Peter. and Owusu, Kwadwo. (2009): 'Trends in Spatio - Temporal Variability in Annual Rainfall in Ghana (1951-2000), RMets (Royal Meteorological Society), Vol. 64(5), pp. 115-120.

Wright, R.L. (1996): ‘An Evaluation of Soil Variability over Single Bedrock Type in Part of Southeast Spain’. *Catena*, Vol.27, pp. 1-24.

Yadav, Rajendra Prasad. (2014): ‘Land Utilization and Nutrition in Chhindwara District, Madhya Pradesh’, *The Deccan Geographer*, Vol. 52(1), pp.87-95.

Zutshi, B. and Kumar, Vinod. (2013): ‘A Social Economic Case Study of Rain Water Harvesting and Water Conservation Measures in Jodhpur/ Jaisalmer, Rajasthan’, (Ed) Madhav D. Nandeshwar, K. V. Jayakumar, Girish Gopinath and G. K. Ambili, Sustainable Natural Resources Management under Changing Climatic Scenarios, Proceedings of the third International Geography Congress, Allied Publishers PVT. LTD., pp. 289-297.

Plate 1: Milak River (Winter Season)

Plate 2: Dikhu River (Pre-monsoon Season)


Plate 3: Doyang River (Monsoon Season)


Plate 4: Tsurang River (Post-monsoon Season)


Plate 5: River-bed of Dikhu


Plate 6: Upland Cultivation in Nagaland

Plate 7: Early Stage of Intercultural Operation (Weeding)

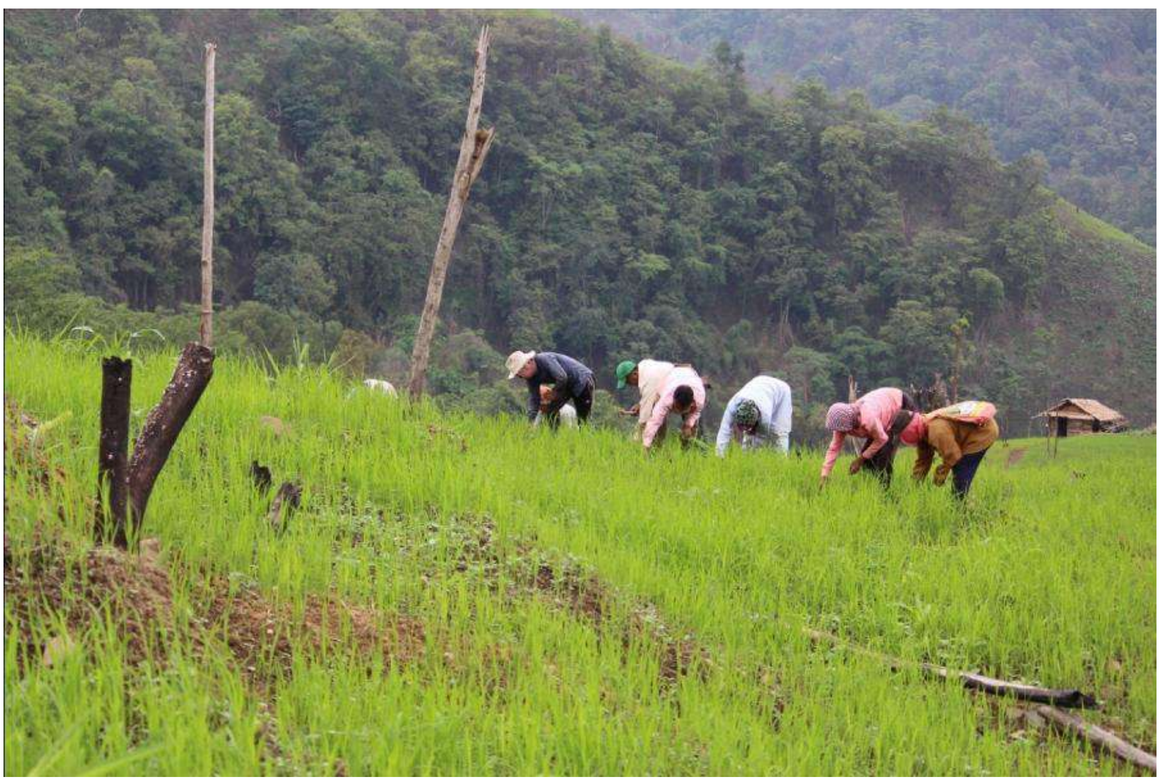

Plate 8: Later Stage of Intercultural Operation (Weeding)


Plate 9: Rice Ripening (maturity stage)


Plate 10: Threshing of Rice


Plate 11: Abandoned Jhum Field


Plate 12: Clearing of New Jhum Field


Plate 13: TRC/WRC Cultivation (Changki Valley)


Plate 14: Sources of Minor Canal Irrigation

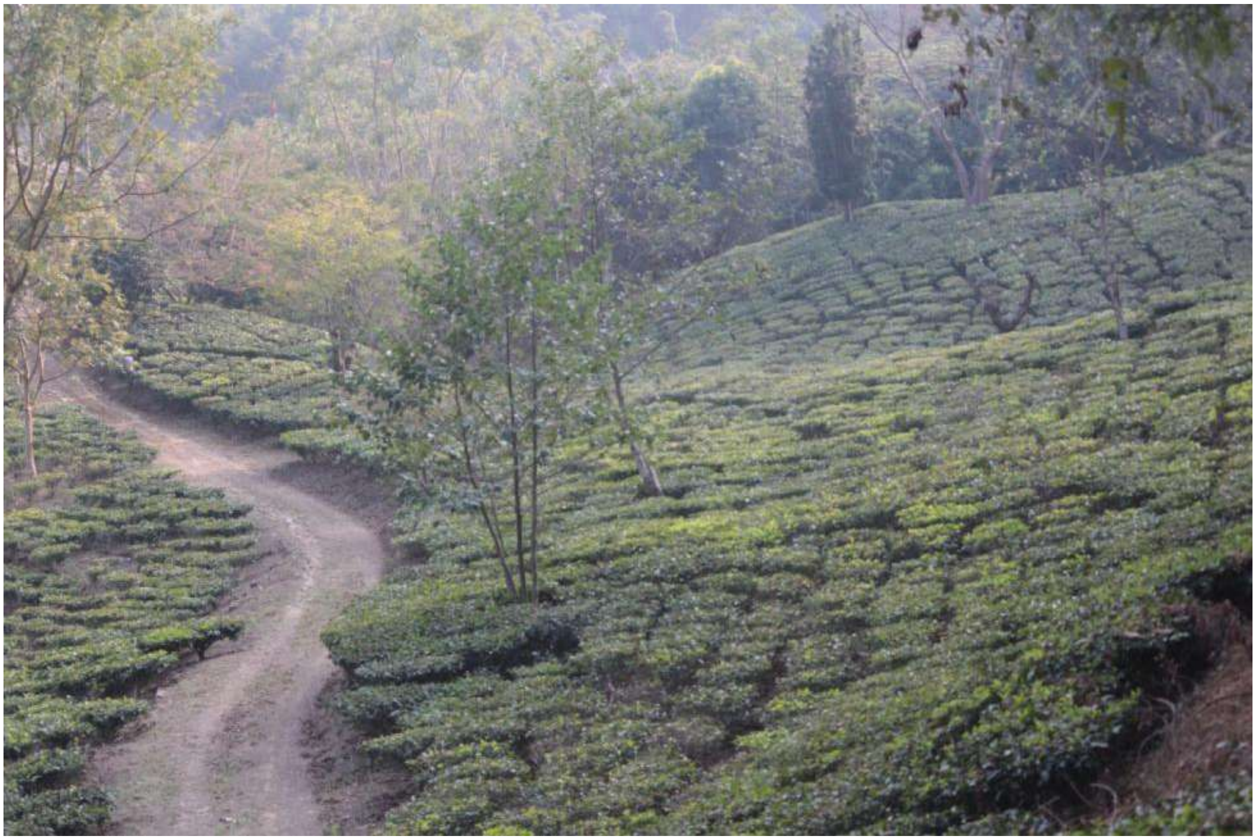

Plate 15: Tea Garden

Plate 16: Weekly Local Market at Mokokchung