RAINFALL VARIABILITY AND ENVIRONMENT IN MYANMAR:

A SPATIAL ANALYSIS

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Declaration

I hereby declare that the work in this thesis entitled **"Rainfall Variability and Environment in Myanmar: A Spatial Analysis"** has been carried out by me under the supervision of Dr. Sheela Prasad, Reader, Centre for Regional Studies, School of Social Science, University of Hyderabad and this work has not been submitted for a degree or diploma of any other University or Institute.

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CHAPTER -1

INTRODUCTION

The impact of weather and climate on human communities is so varied and all pervading that they naturally become the most important components of our physical environment. The welfare, safety, and quality of human society are subject to the profound effects of the vagaries of weather and climate. In developing countries the effects ma)- be calamitous. In highly industrialized countries the effect tends to be neutralized by complex socio-economic systems, but even in these countries there are certain climaiic phenomena such as droughts, floods, violent tropical storms of hurricane intensity, heat and cold waves which may endanger lives and property and disrupt even the most sophisticated systems. Moreover, human society has developed to such an extent that its activities unintentionally produce weather and climate modification on a large scale. Besides modification of local climate, highly sophisticated human activities have the potential to modify global climate, and there is no denying that our present technology is in a position to bring about short-term changes in some areas of weather and climate. There are of course, two long-term effects of climate modification that are causing grave concern. One is the increase of carbon dioxide in the atmosphere and the resultant increase in global temperature expected by the middle of the next century. The other is the prediction of changes in the ozone shield, which may give rise to the penetration of more and more harmful ultra-violet rays of the sun.

Man's efforts towards weather modification may lead to serious meteorological consequences. Large-scale activities such as crop production, artificial precipitation, hail suppression, and long dissemination are some of the efforts directed towards weather modification of our environment. Today, man is seriously speculating on the future possibilities of climate control on a global scale. Thus, deliberate weather modification on the micro and macro scale has been in progress for the past few decades. However, any fair measure of success in large-scale weather modification will ultimately depend on how much more we know and understand the mechanisms of the general circulation, the terrestrial heat budget, boundary layer exchange systems and cloud physics. Even if our science and technology are capable of modifyino the weather and climate to a certain desired level, we should not forget about a number of international implications and the possible consequence. It is because of the ever-growing awareness of climate and its vagaries that under the leadership of the World Meteorological Organization (WMO) and with the active participation of the International Council of Scientific Union (ICSU), the United Nations Environmental Programme (UNEP), the Food and Agricultural Organization (FAO), the UNESCO and other organizations, a number of programmes have been launched to meet the new challenges. These include the World Climate Programme (WCP). which has been decided into four components; the World Climate Research Programme (WCRP). the World Climate Applications Programme (WCAP), the World Climate Impact Studies Programme (WCIP) and the World Climate Date Programme (WCDP). (Lai. 1999).

1.1 Definitions and Importance of Climate

1.1.1 Definitions of Climate

Some definitions of climate enunciated by eminent climatologists are given below:

Trewatha: "Climate represents a composite of the day to day weather conditions and of the atmospheric elements, within a specified area over a long period of time. It is more than "average weather" for no uniform definition of climate is possible without appreciation of seasonal and diurnal change and of the succession of weather episode generated by mobile atmospheric disturbances. While in a study of climate emphasis may be given to the average, still departures, variations, and extreme are also important".

According to Critchfield: "the process of exchange of heat and moisture between the earth and atmosphere over a long period of time result in conditions which are called "climate". Climate is more than a statistical average, it is the aggregate of atmospheric conditions involving heat, moisture, and air movement, extremes must always be considered in any climatic description in addition to means. trends, and probabilities".

Koeppe and De Long define "Climate as a summary, a composite of weather conditions over a long period of time, truly portrayed: it includes details of variations - extremes frequencies, sequences of the weather elements which occur from year to year. Particularly, in temperature and precipitation, climate is the aggregate of the weather".

Kendrew opines that "'Climate is a composite idea, a generalization of the manifold weather conditions from day to day throughout the year - certainly no picture of it is at all real unless it is painted of the seasons which are the really prominent features. It is inadequate to give merely the mean state of any element".

G.F.Taylor states that "Climate is the integration of weather, and weather is the differentiation of climate. The distinction between weather and climate is. therefore, mainly of time".

C.W.Thomwaite has given a comprehensive and systematic analysis of climate. He broadens the scope of climatology when he suggests that "the study of the atmosphere as well as that of the earth's surface from the case of this discipline. This is so true because each and every characteristic of climate is determined by the exchange of heat, moisture, and momentum between the earth's surface and the atmosphere". (Lai, 1999.pp. 6-7).

1.1.2 The Importance of Climate

1.1.2.1 Climate as the key to regional differentiation

As we are aware, geography is the study of the earth as the home of mankind, the ultimate goal of geography is the scientific analysis of the regional diversities, and the spatial variations found on the earth surface. In other words, geography aims at a correct and systematic appraisal of the inter-relationship between man and his environment. If we discuss the inter-relationship between man and physical environment, we are bound to arrive at the conclusion that human society was shaped by the geographic influences it was exposed to. Moreover, critical analysis of diverse environmental effects makes it clear that climate is the most fundamental and far reaching of the natural elements that control human life.

1.1.2.2 Climate and human affairs

The climatic hypothesis of civilization, as propounded by Ellsworth Huntington. assigns a very high place to climate, which is considered to be most dominant and essential factor in the development of civilization. It is a historical fact that many advanced civilizations in the past have grown up and flourished in different regions of the world having dissimilar climatic regimes ranging from the hot. and ban-en deserts of the Nile Valley to the extremely cold highlands of Sweden. The main factors that determine life are health, climate, food, diseases, and people's cultural level and among all these controlling factors climate occupies the first rank because of its direct control over the quality and quantity of not only man's food, but of most of his other resources. Climate is undoubtedly one of the principal determinants of people's culture through its effects on human occupations as well as modes of living and habits. The climatic influences are three folds. Firstly, climate has a direct bearing on man's health and activity. Secondly, it has a strong indirect but immediate effect through food and other resources. Lastly, climate has been the most dominant factor in causing migrations, racial mixture, and natural selection. In other words, climate may be said to be a determining factor in the geographical distribution of human progress (Lai. 1999. pp. 2-3).

1.2 The Interaction of Climate and Environment:

1.2.1 Some Definitions of Environment

The dictionary meaning of the word environment is "a surrounding of external conditions influencing development or growth of people, animals or plants, living or working conditions".

C.C.Park. (1980): "Environment refers to conditions which surround man at a given point in space and time".

A.Goudie (1984): "The nature of the environment has. in fact, taken environment as the representative of physical components of the earth wherein man is an important factor affecting the environment".

K.R.Dikshit, (1984): "Environment is defined more comprehensively by others as a holistic view of the world as it functions al any point of time, with a multitude of spatial, elemental and socio economic systems distinguished by quality and attributes of space and mode of behaviour of abiotic and biotic forms".

While environment is viewed in different ways with different angles by different groups of people, yet it may be summed up that. "Environment is an inseparable surrounding and is constituted by the interacting systems of physical, biological and cultural elements which are interlinked individually as well as collectively in myriad ways. Physical elements (space, landforms. water bodies, climate, soils, rocks and minerals) determine the variable character of human habitat.

its opportunities as well as limitations. Biological elements (plants, animal's micro-organisms and man) constitute the biosphere. Cultural elements are essentially man-made features which go into the making of cultural milieu"" (Singh and Dubey, 1983).

In another sense, environment is the sum total of the different spheres that exercise its influence upon itself and interact with other spheres of environment. The different spheres of planet Earth's environment are Hydrosphere, Geosphere/Lithosphere. Atmosphere and Biosphere. Nature as such tries to maintain an ecological balance. The phenomenon of maintenance of balance has been identified as Homeostasis. A state of equilibrium is always observed between all the components of environment. In the recent times man has technologically advanced to a great extent, but such a technological advancement has challenged this stage of equilibrium of nature.

In this context, man's role has been critical because he has in the name of technological development exploited the resources and damaged the environment at the alarming rates. Thus there has been much disruption of the functioning of natural environment. Such an influence has been greatly observed in developed world where people have begun to realise and correct the side effects of their wrong policies. While in the developing world people have started thinlang on this line and there has been growing concern of such harmful effects.

1.2.2 The Impact of climate on Environment

1.2.2.1 Effect of individual climatic elements on human life

As we know, climate is the summary on the resultant of all the manifold weather influences. The air temperature, pressure, direction and velocity of wind, humidity, the amount of cloudiness and precipitation are some of the most important weather elements. Each of these elements affects human activities in its own way. It would be worthwhile to focus attention on some of these elements which are directly related to our physical and mental energy, and which largely determine our health and happiness.

From the point of view of both health and work, the best climate would be one in which the mean temperature rarely falls below the mental optimum of 38°F, or rises above the physical optimum of about 64°F.The ideal condition would be found where the mean annual temperature is about 51°F. The great metropolitan cities of London, Paris, New York and Peking do have this mean annual temperature. Almost all the industrially advanced countries of the world have their mean winter temperatures not far from 38° F and the mean summer temperatures near about 64°F.

The relative humidity of air is also an important climatic element. Everybody is familiar with the harmful effects of the dry air during winter. Similarly, hot and humid air is equally harmful. High temperature combined with high relative humidity produces sultry weather, which does not favour either physical or mental labour. Besides, relative humidity and temperature are closely related with our physical comfort and efficiency. The optimum temperature apparently controls the phenomena of life from the lowest activities of protoplasm to the highest activities of the human intellect.

Climatic conditions have complex bearing on soil, crops, vegetation, commerce, plant diseases and above all. human health. Even the surface of the land is modified to a large extent by the action of climatic elements. For example, in hot wet climate regions, humid landforms are different from those arid landforms where a dry hot climatic condition exists. Similarly, the landforms of Polar Regions where climate is extreme will contrast from the landforms of temperature and equatorial regions.

Kendrew. an eminent weather Scientist, has aptly remarked that Climate is the most fundamental and far reacting of the natural elements, which control life. According to him. the vegetation of the earth is closely dependent on it. and the adaptations in the animal kingdom are numerous. Eskimos of the snow bound Arctic region, the white races of the temperate regions, and the Negros of the tropical rain forests are all products of the different climatic conditions. Thus, the effect of climate on human life has been aptly remarked by Pepadakis that climate is the most effective and the most powerful component of our natural environment". (Papadakis, 1975)

1.2.2.2 Effects of Climate on adaptation of ecosystem

The speed and magnitude of climate change affects the success of species, population, and community adaptation. The rate of climatic warming may exceed the rate of shifts in certain range species, these species could be seriously affected or even disappear because they are unable to adapt. Some plant and animal species (such as endangered species generally) and species adapted to narrow niches for which habitat is discontinuous and barriers impede or block migrations and natural systems (such as coral reefs, mangroves, and other coastal wetlands, prairie wetlands, remnant native grasslands; montage eco-systems near ridges and mountain tops; and ecosystems overlying permafrost) could be adversely affected by regional climatic variations.

1.2.2.3 Impact of Oimate on bio geophysical environment

Global climate change will affect the bio-geophysical characteristics of the oceans and coast, modifying their ecological structure and affecting their ability to sustain coastal residents and communities. Impacts in the coastal zone will reflect local geological, ecological, and socio-economic conditions within a broader regional and global context. Some times one inherently respond to short and long term variability and trends in sea level, wave energy, sediment supply, and other forcing. Coastal communities particularly on low lying deltas, atolls and reef islands, face threats of inundation, increased flooding, and salt water intrusion, with impacts on health and safety, water supply. fisheries, agriculture, aquaculture, property, transportation links and other infrastructure.

1.2.2.4 Impact of Climate on Agriculture

All the agricultural activities rely on climate; crops grow best, only when optimum temperature and rainfall are available. And. climate change may increase demands for irrigation from the agricultural sector, and if these extra needs are drawn from rivers or aquifers, there will be an effect on hydrological and ecological regimes. Different kinds of crop patterns can be seen due to the variable climatic pattern, crops from arid regions would not be similar to that of humid climate areas.

Indirectly, ecological disturbances, air pollution, changes in food and water supplies, and coastal flooding are all examples of possible impacts that might affect human health. How people and nature adapt to climatic change will determine how seriously it impacts human health. Some people and places are likely to be affected more than others. Generally, poor people and poor countries are less likely to have the money and resources they need to cope with preventing and treating health problems. Very young children and elderly adults will run the highest risk.

1.3 Environmental impacts on climate

1.3.1 The effect of environmental change on climate can be seen with the Greenhouse effect and Global warming

"Greenhouse Gases" let sunlight through the earth's surface then impede the escape of energy (heat) into space. These gases act in much the same way as glass panels in a greenhouse, which allow sunlight through and trap heat inside, thus the term Greenhouse effect. Without naturally occurring Greenhouse gases it is estimated that the earth's average temperature would be nearly 33°C colder. This would result in a planet much less suitable for human life.

Global wanning is the term used to refer to the possible increase in global temperature due to increased atmospheric concentrations of Greenhouse gases. Over the last 100 years, average global temperature has increased between 0.3° C and 0.6° C while atmospheric Greenhouse gas concentrations have increased significantly due to human activities (Carlson Key. 1995).

The major Greenhouse gases include carbon dioxide (CO_2), methane (CH_4). chlorofluorocarbons (CFCs) and nitrous oxide (N_2O). CFCs are non toxic, non flammable and chemically unreactive. This was one of reasons they were considered ideal candidates as coolants in appliances like refrigerators and as product propellants in spray cans. But these properties also will remain in the atmosphere for extended period of time, estimated to be 6- to 130 years, before being destroyed. Each CFCs molecule has a Greenhouse effect 5000 to 10.000 times greater than that of a molecule of *COi*. This means that although the total atmospheric CFCs are small relative to CO2, it accounts for approximately 10% of CCb equivalent emissions. Before CFCs were associated with global wanning, they were associated with stratospheric ozone depletion. In the upper atmosphere molecules of ozone are destroyed in natural process when they absorb solar ultraviolet radiation. This radiation would otherwise be harmful to life on earth. The addition of CFCs to the atmosphere due to human activity affected the natural formation/destruction process of ozone.

Most Greenhouse gases have two sources, natural processes and human activities. The major Greenhouse gas sources are outlined in Table (1.1). The atmospheric concentration of these gases has increased in recent history. Scientists have been able to determine the concentration of these gases in ancient atmosphere. For some cases, scientists are able to analyse the tiny bubbles found in the ice core from areas like Antarctica then determine the concentration of these gases in ancient atmosphere. In more recent times, scientists have measured atmospheric CCb concentrations from on top of Mauna Loa in Hawaii. Scientists consider CO: the most important gas being produced by human activities. However, the other major Greenhouse gases, especially CH_4 and the CFCs play significant roles in Greenhouse gas affects.

Table 1.1 Greenhouse Gas and its sources

Greenhouse Gas	Natural Sources	Human Activity Source
CO:	Respiration. Fires Rolling Wood. Decomposition of organic material in soil	Burning fossil, fuels for transportation of commercial energy. Tropical deforestation. Cement manufacture, and other land use changes.
CH_4	Wet Lands, Termites Oceans, Grazing animals	Losses to the atmosphere of natural gas during oil and gas production. Transportation and use Coal mining. Cattle raising. Animal waste. Rice cultivation. Tropical deforestation. Domestic sewage treatment landfills. Animal waste. Domestic sewage treatment
CFCs(CFC-11&CFC-12)	None	Chemical products and processes, including solvents and blown foam insulation
	Biological processes in soil	Coal combustion. Industrial production of nylon. Fertiliser use. Tropical deforestation. Burning wood and industrial biomass Agricultural wastes. Cultivated land. Nitric acid production. Automobiles with 3-way catalvsts

Source: Tonulee Carlson Key, (1955): The effect of population on global climate change, pp 4-5.

1.3.2 Impact of industrial development and environmental degradation on climate

Exploitation of natural resources in order to meet the industrial demand of raw materials has resulted in: (1) reduction of forest covers due to reckless felling of trees, (2) reduction in available land due to industrial expansion (3) excavation of land for mining purposes (4) lowering of ground water table due to excessive withdrawal of ground water (5) collapsing of ground surface due to withdrawal of mineral oil and ground water etc.

Development in agricultural sector in order to supply raw materials to factories such as sugarcane (for sugar industry, cotton for cotton textile industry), etc, has been responsible for over utilisation of soils, which has resulted in soil pollution due to excessive use of chemical fertilisers and pesticides and insecticides.

Release of gases, smoke, ashes and other aerosols from the chimneys of the factories adversely affects the environment in a number of ways. The burning of hydrocarbon fuels (coal and petroleum) has increased the concentration of CO_2 in the atmosphere and this has changed the natural gaseous composition of atmosphere. The increase in the concentration of COi content of the atmosphere may change global radiation and heat balance by increasing the level of sensible heat in the atmosphere because COT intensifies the Greenhouse effect of the atmosphere as CO2 allows more absorption of outgoing long wave terrestrial radiation and thus more counter radiation towards the earth's surface.

Release of chlorofluorocarbons in the atmosphere through spray can dispensers. Refrigerators, air conditioners and fire extinguishers is capable of depletion of ozone layer. Depletion of ozone layer means less absorption of ultraviolet solar rays and thus substantial increase in the temperature at the earth's surface. Thus changes in the global radiation and heat balance caused due to increase in the concentration of CO_2 in the atmosphere and depletion of ozone layer may cause changes in weather and climatic conditions at alobal and regional levels. The rate of increasing sulphur dioxide and hydrogen sulphide gases released from the rayon manufacturing plants cause sulphuric acid falling as acid rain over large industrial cities.

1.3.3 Impact of urbanization and environmental degradation on climate

Previously towns and cities were considered to be the centres of higher standard of life because of better living conditions but now most of the urban centres of developed countries in general and of the developing countries in particular have become unsuitable for human beings because of marked lowering of environmental quality due to phenomenal increase in the level of air, water and noise pollution, crowded streets and roads, slums, increasing trend of murder, theft, dacoity and other crimes, etc. In fact, increasing urbanisation means phenomenal increase in the concentration of human population in a limited space which resulted in the increase of buildings, roads and streets, sewage and storm drains, pucca surface area, vehicles (motor cars, trucks, buses, scooters etc.). number of factories, urban wastes, aerosols, smoke and dust, sewage water etc, which causes several environmental problems. For example, increasing population of the urban centres use enormous amount of water. Also, sewage water, if untreated, pollutes the streams and lakes, which are further polluted by industrial effluents allowed to be drained into them.

Urban centres affects rather modify patterns of air circulation in and above the cities and their immediate surroundings and the modified air circulation in turn affects temperature, humidity, pressure and precipitation patterns. Tall buildings in the cities obstruct free How of air and thus retards wind speed. According to the findings of Landsberg, (1970) annual mean wind speed is usually 20 to 30 per cent less over the cities than the surrounding countryside. And the speed of extreme gusts is 10 to 20 per cent more frequent in the cities than their immediate surrounding countryside. The pattern of airflow in the cities located in the coastal areas is complicated by sea breezes during daytime and land breezes during night. This mechanism of land and sea breezes is responsible for circulation and recirculation of atmospheric pollutants over the cities.

Urban air pollution largely modifies the climatic conditions of large urban centres in a variety of ways. Most of the urban pollutants are released to the atmosphere as waste products from different combustion processes, mainly human volcanoes (chimneys of factories) and automobiles. The main pollutants emitted through the chimneys of factories are mono oxidised nitrogen, carbon dioxide, coarse ash, fine smoke, sulphur dioxide etc; where as the pollutants emitted from automobile exhausts include lead, unburned hydro carbons, carbon monoxide, nitrogen monoxide, water vapour, carbon oxide and unoxidised nitrogen. These pollutants form a thick layer over the cities generally at the height of 1000m. Such a thick layer of the concentrated pollutants over the city is called a "pollution dome". This urban particulate concentration is responsible for absorbing or reflecting up to 20 per cent of the solar radiation, which arrives above the pollution dome and can also reduce solar radiation (Rouse. 1981).

Higher concentrations of particulate pollutants decrease visibility in the city and form dense fog when there is abundant moisture in the urban air. In fact, particulate pollutants provide numerous hydroscopic moisture which increases the incidence of fog by 100 per cent and water vapour readily condenses around numerous hydroscopic nuclear and thus forms innumerable tiny water droplets which form fog. When fog is formed due to the combinations of smoke, dust, aerosols, water droplets and nitrogen oxide, it is called smog or urban smog. This smog when associated with sulphur dioxide becomes poisonous because the resultant form of sulphuric acid becomes very injurious to organisms in general and human beings in particular.

Photochemical smog caused due to the reactions of nitrogen dioxide, hydrocarbons and sunlight becomes very dangerous when they mix up with ozone. The nitrogen dioxide emitted from anthropo-genetic sources after absorbing ultraviolet rays of solar radiation is decomposed into nitric oxide and atomic oxygen, which combines with molecular oxygen and forms ozone. This process is called photochemical process. The photochemical produced urban smog reduces atmospheric visibility, solar radiation and influence precipitation. The cities located in the valleys are very often affected by persistent inversion of temperature. This inversion of temperature intensifies fog and enhances their duration. Thus persistent smog in the cities causes irreparable loss to human health and biological communities, (e.g. the poisonous smog of Donna town located in Pengy valley USA, (October 20, 1948); Meuse valley of Belgium (december 1930) and of London (1952) are a few examples of the deadly after effects of urbanisation and smog).

1.3.4 Impact of deforestation and environmental degradation on climate

Forests are a very important part of the ecosystem and carbon cycle. They are home to a vast amount of the plant and animal life and their loss has far reaching effects on biodiversity. As part of the carbon cycle, forests serve as huge carbon reservoirs. Loss of forests affects the amount of carbon in the cycle in two ways; one. is that they are no longer available to remove carbon from the cycle and the other is that the burning or decay of the trees adds carbon back into the cycle.

Worldwide forest coverage is approximately 80% of what it was 3.000 years ago when agriculture began to expand. Activities resulting in the deforestation include logging, farming, and ranching, use as fuel wood and lumber, mining, building of hydroelectric dams and urban expansion. In temperate zones, logging roughly balances growth of new trees. Abandonment of farmlands due to economic factors has increased in recent decades resulting in new woodlands. Tropical forest clearing for fuel wood, farming and ranching was estimated at 1% per year for the last decade. In many cases, development of tropical forests is seen as the only possibility that some population have for survival. However, often the soils and other conditions on the cleared land do not allow sustainable production, they are abandoned and serious land and soil degradation begins. In addition, since the 1970s the increased demand for tropical land woods has seen wood production in Asia and South America has risen dramatically which suggests further deforestation. It is estimated that every square kilometre of tropical forest contains from 20.000-50.000 tons of carbon. This means that since the 1970s approximately 1.3-giga tone of carbon, in the form of CCb has entered the atmosphere due to deforestation (Carlson Key, 1995).

The major causes of deforestation at global and regional levels are conversion of forest land into agricultural land. Shifting cultivation, transformation of forests into pastures, overgrazing of forest, forest fires, lumbering for domestic and commercial purposes, multi purpose of river project (dam construction) and biological factors.

Deforestation also results in the increase of concentration of carbon dioxide in the atmosphere because forests consume carbon dioxide during the process of photosynthesis for the manufacturing of their food but absence of forests allows more concentration carbon dioxide in the atmosphere because of its non-consumption. It is thus; obvious that deforestation increases Greenhouse effect of the atmosphere, which raises the temperature of the earth's surface, and the atmosphere. Increased rate of soil erosion consequent upon deforestation and destruction of grassland has been responsible for soil pollution in addition to land degradation and leads to subsequent desertification.

In some cases, deforestation can be beneficial given the right mix of social needs, economic opportunities and environmental conditions: it can be rational conversion from one type of land use to a more productive one. But. most lands that have been deforested in recent decades are not suited for long-term farming or ranching and they quickly degrade once the forest has been cut and burnt. Unlike the fertile soils of temperate latitudes, most of tropical soils cannot sustain cropping. The earning capacity of soil will not support intensive annual cropping without rapid, irreversible degradation. Similarly, intensive cattle grazing cannot be supported because of grasses grown on forest soils do not have the same productivity levels as those available soils.

Deforestation is an important contribution to global warming of climate. The negative consequences of global warming are catastrophic increasing drought and desertification, crop failures, melting of the polar ice caps, coastal flooding, and displacement of major vegetation regimes. The principal cause of global wanning is the excessive discharges in industrialised countries of Greenhouse gases, mostly from the burning of fossil fuels. Annual discharges from burning of fossil fuels are estimated to be about 6000 million tons of carbon, mostly in the form of carbon dioxide. It is thought that an additional 2000 million tons or about 25 per cent of the total carbon dioxide emissions are a consequence of deforestation and forest fires (WCFSD, 1997). At the regional level, deforestation disrupts normal weather patterns, creating hotter and drier weather.

1.4 Select Literature Review

1.4.1 The Asian Monsoon Circulation

Originally the term" Monsoon" was applied to the surface winds of Southern Asia, which reverses winter and summer. The characteristics of the monsoon climate are to be found mainly in the Indian sub continent including Mvanmar. where over much of the region the annual changes may conveniently be divided into the Northeast (dry) and Southwest (wet) monsoon seasons.

When upper winds are taken into account, it is found that the Asian monsoon is a fairly complex system. During the Northern winter season, the sub tropical westerly jet stream lies over Southern Asia, with its core located at about 12 km altitude. It divides in the region of the Tibetan Plateau, with one branch flowing to the north of the plateau, and the other to the South. The two branches merge into each of the plateau and form an immense upper convergence zone over China. In May and June the subtropical jet stream over Northern India slowly weakens and disintegrates, causing the main westerly flow to move North into central Asia. While this is occurring, an Easterly jet stream, mainly at about 14 km. builds up over the equatorial Indian Ocean and expands westward into Africa. The formation of the Equatorial Easterly Jet stream is connected with the formation of an upper-level high-pressure system over Tibet. In October the reverse process occurs, the Equatorial Easterly Jet stream and the Tibetan high disintegrate, while the Sub-Tropical Jet Stream reforms over the Northern India. The driving force for the India summer monsoon is high-level heating over the Tibetan Plateau together with latent heat release in tropical storms over India. It is a good example of tropical circulation patterns being modified by a powerful heat source. The Southwest Monsoon is of particular importance to India and Mvanmar because it provides much of the rainfall required for agriculture.

The Himalayan-Tibetan Plateau is of importance because it appears to be accelerating the onset of the Asian Monsoon and to increase its ultimate intensity. Satellite data indicates that the central and southwestern parts of Tibet remain free of snow throughout most of the year. Hence, the Plateau must heat rapidly during the northern spring. This direct warming of the middle troposphere creates an upper-level anticyclone which is readily observed as synoptic charts, upper-level divergence, and low-level convergence. Thus, suitable conditions are produced for the Asian monsoon in the north spring. Latent heat released in intense tropical storms over India keeps the system functioning during the northern summer. Since a complex feedback system produces the southwest monsoon, failures in the system are common and produce extensive breaks in the monsoon rains. When the whole system starts sign of collapsing, variations in winter snow cover over Tibet will influence the start and intensity of the Southwest monsoon. General cooling over southern Asia at the end of the Northern summer causes its collapse.

According to Miller and Keshawa Murthy (1968), the Southwest Monsoon current in the lower 5 km. near India consists of two main branches: The Bay of Bengal branch, influencing the weather over the Northeast part of India and Myanmar. and the Arabian Sea branch, dominating the weather over the central and northwest part of India. The low level flow across the equator during the southwest monsoon is not evenly distributed the latitudes 40°E and 80°E. but has been found by Findlater, (1969. 1972) to take the form of low level high-speed southerly currents, which are concentrated between about 99° E and 55^{U}E. A particularly important feature of this flow is the strong Southerly current with a mean wind speed of about 14 ms''^{1} observed at the equator over Eastern Africa from April to October.

The strongest flow occurs near the 1 -5 km level but it increases to more than 25 ms''^{1} and occasionally to more than 45 ms''^{1} at heights between 1-2 and 2-5 km. According to Find & et al (1969). this high speed current flows intermittently during the Southwest monsoon from the vicinity of Mauritius through Madagascar. Kenya, eastern Ethiopia. Somalia and then across the Indian ocean towards India (the low-level southerly current off the coast of East Africa is generated by the dynamics of flow patterns of this nature and has fundamental consequences for the climate of

Kenya).(Barry & Chorley, 1978).

1.4.2 Global Circulation Patterns and the Monsoon Rains in Myanmar

The atmosphere circulation in winter December, January, February, exhibits substantial low frequency variability. This fluctuation often strongly influenced the temperature and precipitations due to major shift of locations and intensity of jets and storms. The primary circulation patterns are the Pacific North American Pattern (PNA), the West Pacific Oscillation (WPO). the North Atlantic oscillation (NAO). the European Teleconnection Pattern (EU) and the ENSO (El -Nino and Southern Oscillation Patterns).

Preliminary review of these air circulation patterns in relation to the general monsoon rainfall in the whole country of Myanmar by San Hla Thaw (1996) indicated that

1. When P.N.A. is normal or above normal, the seasonal rain tends to be normal in the whole country.
2. When NAO is highly positive or around normal, monsoon rain is around normal.
3. When EU is around normal, rainfall of Myanmar is around normal.

Among the circulation patterns, the ENSO is a major phenomenon of the tropical world with widespread repercussions within the global system and it has a marked relationship with rainfall variability of Myanmar.

In the assessment of droughts based on the monsoon rainfall and climatology for the union of Myanmar. during the period of 1950-1997. the driest years were 1957-58, 1972-73, 1979. 1982-83. 1986-87. 1992-93 and 1997-98. During this period El Nino was weak in 1951-52. 1953 and 1963. moderate in 1968-69. 1976-77. 1982-83 and strong in 1957-58. 1965-66. 1973-74. 1980-83. and 1997-98. The dry year in 1979 is due to the failure of the Southwest monsoon. All the remaining driest years coincide with the strong El Nino episodes. Therefore a major drought ma}' be predicted in the Asian region by monitoring El-Nino/ENSO events and abnormal shift/ extension of semi permanent regional synoptic features. There is a need for research and studies for prediction of El Nino events that markedly related to the insufficient rainfall in Myanmar (Thaw. 1997).

Variability of rainfall in different parts of the world is estimated by researchers by using different techniques. Naumann (1990) analyzed inter-annual rainfall variability to 17 meteorological stations in Srilanka for a period 1980-81 found that the inter-annual variability of rainfall was high in Dry Zone when compared to wet zone. Dyer (1982) investigated the behaviour of inter-annual rainfall variability over both time and space by using principal component analysis for the period 1921-1974 in South Africa. Krepper et al (1989) examined rainfall variability over time and space for control and coastal regions of Argentina. They used both orthogonal function and spectral analysis for a 30 years record. This analysis identified area of maximum rainfall variability in the region. Wang and Lis (1990) investigations regarding the rainfall fluctuation in the semi arid region of northern China revealed a trend towards drain and warmer climates. Blandford (1986) made an extensive study of rainfall variability over India.

Patnaik et al (1977) analyzed the temporal variation of summer and winter rainfall over the country. India. Raghavendra (1974) analyzed seasonal and annual rainfall variability in meteorological sub divisions of Mahahrastra State. Parthasarathy (1984) tried to examine the inter-annual and long term variability of summer monsoon rainfall for 29 subdivisions of India taking 108 year of time period and found high and low inter-annual rainfall variability over Saurashtra and Kutch sub-divisions and South Assam sub-division, respectively. Varma et al (1985) did a statistical analysis of summer monsoon rainfall of India for hundred years period (1881-1980). They found that the last two decadal periods (1960-1980) were the periods of the highest coefficient of variation and the lowest average monsoon rainfall for India. Muoley and Shukla. (1987) studied summer monsoon of India over three destined spaces scales, i.e. large, medium and small scale variability. The result of all three analyses is different. The study of Ananthakrishnan and Soman (1987) highlighted the nature of troposphere thermal conditions for years of excess, deficit and normal monsoon rainfall over India and concluded that the decrease in monsoon rainfall is associated with weakening of the troposphere thermal gradient across the country-. In another analyses, they (1989) also studied the daily rainfall date from 15 rain guage stations of India over 1901-1990 and found that normal was uniquely determined by the coefficient of variation of the rainfall series. Ram Mohan and Nair (1991) worked out monthly and annual rainfall variability for Kerala State during the period (1901-1989) and concluded that more than five consecutive wet or dry years do not occur in the state. Singh and Mulye (1991) demonstrated that the value of standard deviation, absolute mean decoration and mean absolute inter-annual variability increased linearly with the amount of means rainfall.

In 1970, the first long range - prediction of seasonal rainfall in Myanmar was statistically developed by Dr. Po.E (1970). He imposed the pressure departure at selected global position as predictors.

Yin (1948) has put forward a very outstanding ecological synoptic feature related to the southeast monsoon onset in Asia. Particular attention was given more to the long-range weather forecasting in the later years.

Teleconnection approaches, statistical approach, typhoon remnants that originated from the N.W. Pacific and South China Sea in Myanmar was first presented by Po.E (1956).

Tropical storm related floods were studied by different authors such as San kyaw (1968). Htay Aung (1968). Sein Shwe. U &et al. 1968) etc.

Droughts in Myanmar in April-May 1957 were analyzed by Thuta (1958). Some synoptic situations responsible for the rain in central Myanmar area were studied by Hla (1908).

The study in the low and middle Ayeyawady floods in relation to heavy rain fall in the headwater region of Chindwin and Ayeyawady River was undertaken by Pe Kyi (1968).

The assessment of the monsoon rainfall and synoptic situation responsible for dry and wet monsoon season of the countn' was studied by Htay Aung (1981). In the early season rainfall in Ayeyawady Division that serves as rice bowl of Myanmar was attempted by U Hla and San Hla Thaw (1969) by using change of geopotential at selective locations.

So as to prepare the agricultural activity, early monsoon rainfall for the month of June was developed by San Hla Thaw (1974) by using change of semi permanent features in the troposphere from April to May. The rainfall of later part of monsoon were carried out for September by Htay Aung (1975) and for October by San Hla Thaw (1975).

The study "'Summer Monsoon of Myanmar" was done by Khin Swe Win. Daw, in 1976. The study was emphasized on the upper circulation patterns and seasonal rainfalls of Summer Monsoon.

In 1995. ""Rainfall regimes of Myanmar "have been analyzed by Swe Swe Aung. Daw. In the study, distribution patterns of rainfall were assessed spatially and seasonally.

Myanmar is one of the countries having rainy season in the region of Asiatic Summer Monsoon. The most important feature in the meteorology of Myanmar is the alternation of seasons known as monsoon. Strictly speaking, monsoon and seasonal winds whose direction more or less reverse twice during the year lying in their the tropics and with the great Asiatic continent to the north and the wide expense of the Indian ocean to the south. Myanmar furnishes are of the best examples of a monsoon country.

During the winter part of the year, the general flow of surface air is known North to South in the Northern parts and Northeasterly in the rest of the country. In this season the air over the country is mainly of continental origin and hence of low humidity and the season is known as the Northeast or winter monsoon. In the summer months May to September the general flow of wind is from the opposite direction from sea to land and the season is one of much humidity, cloudiness, and rain. The direction of winds in the Bay of Bengal and Andaman Sea being Southwesterly, the season's name is Southwest monsoon or rainy season, or summer monsoon or simply monsoon. Between these two principle seasons are the transition seasons of the hot weather months of March. April, and May, and the retreating month of October and November. Out of the two-monsoon season, the Southwest or summer monsoon is more pronounced and important in Myanmar.

Das (1995) stated that monsoon circulations are important to many countries of Asia and Africa because of their capacity to generate seasonal rains. Agriculture and the replenishment of water resources rely heavily on monsoon rains. The economy of many countries is thus dependent on the timely arrival and subsequent distribution of rains.

Myanmar is an agricultural country and most of the major crops are grown during the Southwest monsoon or rainy season, which is usually known as summer monsoon. Most of the rains that are crucial to the farmers are more or less continuous during the monsoon period. As the monsoon in Myanmar is one of the most important natural meteorological phenomena for the agricultural sector of the country, agricultural **activities** each year are regulated according to its behaviour.

1.4.3 Role of mid **latitude frontal systems intrusion in** Myanmar

Mid latitudes frontal system intrusion into the monsoon marginal area was observed when cloud images from the operational meteorological satellite were receiving the system moved into the southwest monsoon region during the cold season, hot season and also in the rainy season. Though there is no clear identity of the cold frontal system in the conventional temperature, dew point temperature and wind field. The cloud pattern would be extending across northern part of South East Asian region when compared with the cyclone in the Bay of Bengal. San Hla Thaw (1983) in his extensive study on mid -latitude and the cyclones in the Bay of Bengal, concludes that the interaction of the mid-latitude frontal system and the cyclone in the Bay of Bengal would lead to prolonged heavy rainy season and post monsoon season.

With the mid latitude system, out break of cold air takes place in the whole country except the southern coastal strip and in hot season this is believed to reduce the thermal potential of the land and the adjacent sea by reduction of sea surface temperature. The lowering of thermal potential in turn affects the cyclone genesis potential in the bay until a few weeks before the recovery of the seasonal temperature (Thaw, 1995).

Monsoon depression in the Bay of Bengal has long been recognized as one of the semi-permanent features. Downstream amplifications is one of the causes for the formation of the depression in certain times, at an another times, it is required to confirm that the depression is due to interaction of Southwest monsoon current and the mid-latitude frontal cloud system.

1.4.4 Influence of Tropical Storms

The influence of pre-monsoon cyclones in the Bay of Bengal upon the seasonal rainfall of Myanmar by using 30 years date, was studied by San Hla Thaw and Htay Oo Kyi (1983). the Bay storms were classified into 13 categories and it was found out that (1) below normal monsoon rainfall condition when there was absence of pre monsoon cyclones in April. May and June. (2) About/around normal monsoon rainfall condition when one cyclone occurred each month in April. May and June. (3) Above normal monsoon rainfall conditions when the disturbances have long span of life over the Bay of Bengal.

The effect of the typhoon in the North west pacific and the South China Sea has long been recognized by many meteorologists such as Thu Ta (1957), San Kyaw (1961) etc. among others.

1.4.5 Geography and Environment: A Review

Environment refers to the sum total of conditions, which surround man at a given point in space and time (Park. 1980. p.28). In the beginning the environment of early man consisted of only physical aspects of the planet earth (land, air and water) and biotic communities but with the march of advancement of society, man extended his environment through his social, economic and political functions. Goudie (1984) in his book "The nature of the environment"' has taken environment as the representative of physical components of the earth wherein man is an important factor affecting the environment.

Right from the beginning 'Man and Land". 'Man and Nature". 'Man's relationships to his earthly environment", etc. have been the recurring themes of Geography irrespective of the dichotomy of "Earth made Man' versus "Man made the Earth". Whether visible or not the concept of ecosystem and emphasis on environment has been always lurking in the background but the approach has been too fragmentary and hardly any composite picture of environment emerged. Obviously, the objective was never to understand the environment but to make use of it for demonstrating its role in emerging cultural landscape or the regional diversities (Dikshit. 1984). Elements of physical environment like topographic characteristics: climate, soils etc. were taken as physical or geographical factors to explain variable distribution of matter in the general and human population in particular over space, location of industries etc. It may be emphasized that the study of environment has always been associated with geography but with varying significance during successive phases of methodological development of the subject .It may also be stressed that the environmental studies were based on much more generalizations and assumed relationships involving secondary data and information rather than on in depth study of different components of environment based on empirical studies.

Geography is a spatial Science, which studies spatial attributes of various phenomena on the earth's surface through time. In other words, phenomena, which exist in space-time framework, becomes the subject matter of geography. Besides this traditional definition in a highly generalized sense, geography has been variously defined as the study of areal distribution of phenomena, spatial patterns, locational analysis, human ecology, man-land relationship, environment-man and man-environment relationships, spatial organization, ecological studies etc.

Peter Haggett (1972) has attempted to integrate the structure of geography and various approaches of study into three broad modes of analysis viz. (i) Spatial analysis involves the study of locational variation of significant property or series of properties of objects on the earth's surface (ii) Ecological analysis interrelates human and environmental variables and interprets their links and (iii) Regional complex analysis combines the results of spatial and ecological analyses.

Variable phenomena on the earth's surface can be treated separately or in association. They are classified or categorized into physical phenomena or human phenomena or are treated as interrelated phenomena. So the subject of Geography, which studies those phenomena, also has two branches. Physical Geography, and Human Geography. Physical geography is concerned with the study of the descriptions of physical phenomena, encompassing the systematic sciences of Geology. Meteorology, Botany, Zoology, and Chemistry. Physical geography has its origin in antiquity when the ancient Greeks and Roman scholars developed their interest in the study of nature and its different attributes and became a very prominent subject during the later phase of nineteenth century. Physical geography has a number of sub- branches which studies different kinds of phenomena, e.g.. Astronomical geography, mathematical geography, Geomorphology, Climatology, Oceanography and Biogeography. etc.

K.J.Gregory and D.E. Walling (1981) summarized the development of ideas concerning the impact of man on environmental processes and have pointed out four major trends in this field . The first theme was related to the deduction of the rate of erosion in various areas and the presentation of a comparative picture .The second theme of interest was the initiation of investigation of natural hazards/environmental hazards. The third trend was the initiation of International Programme to study the influences of man on natural processes e.g. I.H.D (International Hydrological Decade (1965-74). M.B.P (Man and Biosphere Programme. 1970) .The fourth trend was the realization of environmental concern which was reflected in a number of writings. The influence of man on gully erosion in S.W U.S.A. (W.M Denevan. 1967). on fire and floods (J.G Nelson and A.B Byrne. 1966). on changes of geographic environment through industrialization and urbanization (S.Gilewska. 1964) etc. are few examples that demonstrate the initiative taken to study man-environment processes and relationships. These developments internal to geography were achieved within the intellectual environment that embraced growing concern for the future, and this provided one of the motivating reasons for the initiation of international research programme. (Gregory and Walling. 1981,p5). This trend resulted in a number of studies, organization of national and international symposia and conferences and publication of a number of research papers, research monographs and books on impact of man on environmental processes and on man environment relationships, {e.g., Environmental problems (I.R.Manners and M.W Mikesell, 1974). Man's impact on environment (T.R Detwyler, 1971). Environmental geomorphology and landscape Conservation (in two volumes, D.R Coates, 1972 and 1973). Urbanization and Environment (T.R Detwyler and M.G Marcus ,1972). Urban Geomorphology (D.R Coates. 1976), Geography and ma's Environment (A.N Strahler and A.H Strahler ,1976) Applied Climatology (J.E Hobbs,1980). Environmental Change and tropical Geomorphology (Ian Douglas and T.Spencer. 1985), Environmental management (L.R Singh.Savindra Singh. R.C Tiwari and R.P Srivastava . 1983). First International Conference on Geomorphology and Environmental management (Allahabad.India.1987) Geomorphology and Environment (Savindra Singh and R.C.Ti\vari,1989). Second international Conference on Geomorphology and Geology (1989.Frankfurt. West Germany etc.).

Human geography as a branch of geography is a more recent development. According to Vidal De La Blache. ""Human geography is a recent sprout from the venerable trunk of geographical science and it offers a new conception of the interrelationships between the earth and man". Knowledge of the natural environment in which man has played a function and of the part physical factors play in the interpretation of human activities, is in fact, human geography.

In the words of Ellen Semple, "Human geography is the study of the changing relationships between the unresting man and the unstable earth". Efforts on the part of man to make adjustments to his natural setting are universal and involve some of the major and important problems in which the drama of human life and activity is constantly being enacted. Professor Roxby summarized the modern concept of human geography in his presidential address before the British Association in 1930. In his view it consists of "First, the adjustment of human groups to their physical environment, including the analysis of their regional experiences, and of second, inter-regional relations as conditioned by the several adjustments and geographic orientation of the group living in respective region" (Negi, 1992).

Human geography and physical geography are inseparable; the reason being the variable phenomena on earth's surface have human elements on them. Human geography is the study of three closely linked components; the spatial analysis of the human population (i.e., its numbers, its characteristics and activities, its distribution over the earth's surface); the ecological analysis of the relation between human population and its environment; and the regional synthesis which combines the first two themes in an area of differentiation of the earth's surface.

In Environmental Geography, the physical environment is more significant than the social or cultural element. The economic function of man becomes more significant than his other functions as it is more concerned with the functioning of ecosystem. Thus, the interaction of man through his economic functions and hence as an environmental process and human response to the environment is the fundamental concern of Environmental geography. Environmental Geography is the study of various aspects of the environment on the ground, and it can be differentiated from other disciplines studying environment because geography studies the spatial attributes of matter and phenomena on the earth's surface. Moreover, the nomenclature of the theme of environmental studies as "environmental geography" instead of ""geography of environment" lays more emphasis on the application of geographical information (both physical and human) to the solution of environmental problems. Environmental geography may serve as the bridge between physical and human branches of geography on the one hand and it may associate geographers in general and environmental geographers in particular with other allied life and earth scientists on the other hand.

Thus. Environmental Geography may be defined as the branch of geography which studies the characteristics, composition, and functions of different components.

various processes that link the components, the interactions of different components of the natural environmental system (including man as a biological organism—a physical man), mutual dependence of different components, various processes that link the components, the interactions of different components with each other and among themselves and consequent responses in spatial and temporal contexts in terms of "geoecosystem," as well as interactions of technologically advanced 'economic man' with different components of natural 'geoecosystem' and resultant modifications and changes leading to environmental degradation and pollution , the techniques and strategies of pollution control measures and management of ecological resources" (Singh,1989).

Geography is a discipline that can pursue the study of environment in a holistic manner because:

(1) It studies the spatial attributes of all the phenomena including man in a given space and highlights complex man- environment relationships at different stages and phases in a time - space continuum while other sciences study individual phenomenon and do not focus on spatial organization.

(2) Being an integrating science, geography synthesizes all the elements and components of planet earth into one body and links the Social Sciences with the Natural Sciences.

(3) It lays stress on the synthesis of all the near surface spheres into interacting systems (Annuchin, 1974). That is to say geography studies the biosphere (the interface oi" air. land, and water) in totality, all components of biosphere-abiotic and biotic. their characteristics, and interrelationships.

(4) With regard to the physical system, it is geography that has an advantage over other sciences because geographers have the knowledge of physical structure, geomorphic processes, climate, vegetation and soils while other scientists specialize in only one of these aspects.

(5) Geographers besides identifying complex relationships between man and physical environment have the capability of locating the distribution of such relationships in space . mapping them and exploring the causes of variations in distribution . and;

(6) Geographers recognize that the quality of life layer varies from place to place in terms of richness or poverty of life forms capable of being supported. Geographers are

the only scientists who can recognize and identify the environmental regions, locate them in space and present them on maps (Singh, 1999).

There is a dualism in geography between physical and human geography. Some scholars study problems in each separate field either physical or human geography. This particular study draws on the interface between the physical and human as it argues that Geography as environmental studies integrates both these very vital branches of geography.

1.4.6 Environmental study of Myanmar - A review

The analysis of "Environmental Law in Myanmar" has been done by Peter Gutter in 2001. He found that the main problem is that there is no upto date laws that regulate pollution and no regulations for environmental impact assessments of projects. He further pointed out that reasonably effective environmental laws were enacted under the British rule. The Democratic period in Burma, from 1948 to 1962 did not improve the laws. After 1962. the Military Junta repealed and replaced the British laws. The current legislation is too general and has never significantly provided for the protection of the environment.

The study of "The Changing faces of the Ayeyawady Delta from 1850 to 2000" has been done by Mya Than in 2001. He stated that unless measures are taken to prevent the further degradation of environment by over logging (legal or illegal), over fishing, improper mining, and misuse of water resources, the impact on the Delta and its inhabitants would be enormous and most probably irreparable.

"Environmental Issues in Land and Water Development in Myanmar" was studied by Tha Tun Oo. U. Land use Division. Agriculture Service. Yangon. in 1991. His study was focused on the Land capacity and its environmental issues in Myanmar under two main categories.i.e. Low Potential Production Area (LPPA) and High Potential production Area (HPPA).

"Wood fuel Production and marketing in Ayeyawady delta"" was studied by Tun

Paw Oo in 1999. He summarized the current situation of Ayeyavvady Mangrove Forest and its degradation. He further suggested giving more attention for the development of mangrove reforestation and establislinient of forest nurseries to reduce the local wood fuel requirement.

The study of "Wood Fuel Flows in the Dry Zone of Myanmar" has been done by FAO, Bangkok in 1993 in collaboration with the pilot integrated watershed Development Project for Kinda (MYA/81/003) Ministry of Forestry, Myanmar.

Myint Thein. U. has made an assessment of the current state of agriculture, forestry and marine resources of Myanmar. He stated that at present, Myanmar resources are sufficiently endowed to support its population but the development and extraction of these resources were adversely affected to some extent by the policies. He suggested having better sectoral policies, objectives and strategies in agriculture, forestry and fisheries for the sustainable development of the resources.

A study "Country Profile on Environment of Myanmar" was done by Japan International Cooperation Agency in 1999. In the study, we can see that Myanmar still needs to concentrate on environmental conservation especialh' on pollution.

From the studies that were done on environment pertaining to Myanmar. it was found that not enough academic research was taken to bridge this gap between environment and other variables. It is therefore hoped that this study on climate-rainfall variation and its impact on environment of Myanmar from an interdisciplinary perspective would provide some understanding on this issue.

1.5 The Focus of the Study and the Choice of the Study Areas

1-5.1 The Focus of the Study

The development of agricultural economy of Myanmar with its growing Population is closely related to **the** availability of water or annual rainfall for crop production. This is considered to be the life and soul of Myanmar because the livelihood of the population depends upon timely and adequate amount of rainfall. A large proportion of rainwater is used for agricultural purposes. Due to this reason, it is important to know whether the available rainfall is adequate and how well distributed it is for crop production in various parts of the country. Abnormalities in the amount of the rainfall are manifested as flood in one part and drought in another part of the country. Further more, it is also important to know about the nature of rainfall trends in Myanmar. The statistical analysis of a time series data of rainfall may enable us to understand the long-term behaviour of rainfall. The seasonal pattern of rainfall is a general feature of the rainfall distribution over the year. Apart from the monsoon season, agricultural production depends on other sources of irrigation, which are also indirectly influenced by rainfall. This analysis is intended to find out the extra amount of rainwater available, which can be utilized in the period of scarcity.

The cropping pattern of a region depends mainly on the availability of irrigation water; it may be from rainfall or from ground water. The analysis of rainfall behaviour of a region helps in considering a particular cropping pattern. It also guides other agricultural schedule related to farm operations .The rainfall information is also considered to be an important factor in estimating the agricultural production of a region. The planning for soil and water conservation programme cannot be done without an analysis of rainfall because it determines the efficiency of soil and water conservation activity in the region.

Rainfall is very important for both physical and human environment as well as for every socio economic activity. The present study concentrates only on rainfall as the dominant climatic factor that shapes the physical and human environment of Myanmar. Myanmar does not have many studies that are attempted from an interdisciplinary-perspective. The debates on deforeststation in the country make the research excited about examining the links between climate and environment.

1.5.2 Choice of the Study Areas

The study area consists of two different geographical entities, with differing rainfall regimes viz. the Central Drv Zone reaion and the humid Ayeyawady Delta region of Myanmar. The researcher belongs to one region (Ayeyawady Delta) and this is an advantage in research, the availability of comparable data on the two related regions was a crucial consideration in the selection of these two regions for study. In terms of rainfall variability, the Dry Zone shows the highest variation over the last few decades, while the Delta region too has high rainfall variation. This prompted the choice of these regions as the study areas. Other reasons for choosing these two areas are: these two regions are located on the passage of Ayeyawady river channel, they have fertile alluvial soils that are producing the largest amounts of rice and other crops: they consist of numerous large and small irrigation projects; they both support the highest density of population in the country, both regions have smooth communication routes on both western and eastern sides of the Ayeyawady river; have good conditions of accessibility and transferability of commodity flow's at national and international level : and the two areas have a high density of industries and manufacturing areas .These two areas are the most important zones for the economic development of the country and hence a comparative study becomes meaningful.

A comparison of these two regions reveals the following:

Ayeyawady delta region is humid with low variability of rainfall, soil fertility is high, it is rich in agriculture, has the highest density of population, is more developed in every sector of economy, the environmental degradation is high due to high loss of mangrove forest due to high demand for wood fuel in the region.

The Dry zone has a semi arid climate with high variability of rainfall. Dry zone is dry because of lying in the leeward side of Western Mountainous ranges as rain shadow area and does not receive well the southwest monsoon rain like other locations in the windward side of the mountains. Moreover, being in the location of central basin and far from the sea, with the lack of mechanism of lifting force in the passage of the southern winds. Central dry zone has less chance to get rain from conventional rain. Being a semi arid climate area. Central Dry Zone experiences top soil erosion, with scarce vegetations with dry forest (thorn and shrubs forests). But, it has fertile soils through deposition of Ayeyawady River and its tributaries. In Myanmar history. Central Dry zone was the strategic location of Myanmar kingdoms. Mandalay. Inwa. Amarapura. Sagaing, Pinya. Bagan are the famous historical places of Myanmar. Till today, Central Myanmar has a number of irrigation reservoirs, dams, water pumps, and canals in the area and agriculturally is the second most important area of the country. It has the second highest density of population. Thus, the government in the construction of development of the country has concentrated Ayeyawady Delta Region and Dr}' Zone Area. Both are lying in the Ayeyawady River basin as the lowland areas, but because of the differences in weather and climate, the Dry Zone Region is obviously lagging behind in development compared to the Ayeyawady Delta Region.

Although the physical environments are different, both regions are environmentally fragile or high-risk areas by having problems of high wood fuel needs. The natural forests in the vicinity of the villages are affected by repeated cutting of wood fuel and by being encroached for cash crops cultivation. As a result, the degraded forests are gradually expanding in Dry Zone Region, making it into the area of desertification. A similar condition exists in Ayeyawady Delta Region where mangrove forests have been excessively exploited and reduced due to increasing demand of wood fuel and charcoal, and eventually turned into agricultural lands.

1.6 Objectives of the Study

Rainfall data is most readily accessible among various climatic elements. In the present analysis, intensive observational analysis was carried out to understand the rainfall behavior in Myanmar. The variability of rainfall and its impact on the environment was examined. The focus of this research is to understand the links between deforestation-environmental degradation and rainfall changes. The broad objectives of the present study are:

1. To attempt an interdisciplinary study of rainfall and environment in Myanmar.
2. To study distribution, variability, seasonally and the trends of rainfall over the last 50 years,
3. To con-elate the environmental situation of Myanmar with rainfall variability by focusing attention on the wood fuel crisis in two regions; the humid Ayeyawady Delta and the Drv Zone area.

1.7 Hypotheses

(a) Rainfall variability in Myamnar has increased over the last decades.

(b) Variation in rainfall is highest in the lowest rainfall regimes, e.g. Dry Zone,

(c) Environmental degradation is high in the Dry Zone,

(d) In high rainfall regions with high population density (Ayeyawady Delta), deforestation rates are high resulting in a wood fuel crisis.

1.8 Data Sources

The information on rainfall in Myanmar for 45 rain gauge stations for the period (1950 to 2000) is collected from the Department of Meteorology and Hydrology. Yangon. Myanmar. The present analysis is based on 45 rain gauge stations distributed throughout the country.

Besides the rainfall data, the reports and monthly bulletin of World Meteorological Organization (WMO) are also used as secondary sources, besides other secondary sources that include books, articles, reports on rainfall and environment. The data regarding the environmental issues are obtained from the Myanmar Agriculture Service (MAS) . Ministry of Planning and Finance . Ministry of Forestry. Department of Irrigation . Dry Zone Greening Department . Myanmar Agenda 21, National Commission for Environmental Affairs .Yangon , Myanmar . Myanmar CD ROM 1998 .and Internet source websites, www.myaiimar.com and www.google.com. Primary data on the wood fuel crisis in the Dry Zone and Delta region was collected through field survey.

1.9 Methodology

The nature of rainfall varies over time and space. To understand this variability different methodologies are proposed. A detailed analysis of different aspects of rainfall is carried out throuah different statistical methods.

In this study the methodology subscribed to both qualitative and quantitative methods for the rainfall analysis and for the wood fuel analysis respectively. No one particular method can be used to study the rainfall variability, as rainfall is a complex variable. The simple rain gauge method, seasonality method, statistical method and analogue method are adopted to analyse the trends of rainfall.

1.9.1 Distribution of rainfall

The spatial distribution of rainfall is analysed with the help of sample rain gauge stations by plotting the mean annual or monthly rainfall of each rain gauge station on the map of Myanmar. In the present analysis, average method is used for mean annual rainfall in the region due to the fixed area of the region. The distribution of annual, seasonal and monthly rainfall across the country or various climatic zones will be analysed to have a clear picture of rainfall situation over space and time in the country.

1.9.2 Seasonality of rainfall

Seasonality Index can easily understand the seasonal variation of rainfall. The seasonality of rainfall considers the monthly distribution of rainfall in a year. This mean refers to degree of variability in the monthly rainfall throughout the year. Two types of hypothetical extreme conditions emerge in the calculation of seasonality. (1) Total rainfall of the year occurs in a single month and the other months of the year remain rain less or dry. This reflects that maximum concentration on rainfall occurs in that short span of time and is represented by the maximum seasonal index value. (2) Total annual rainfall is fairly distributed across all the twelve months of the year. It shows that there is no seasonality and this is represented by a minimum index value. The seasonality of a particular place always lies between these extreme values.

Dividing all the twelve months of the year into four standard seasons carries out the seasonal distribution of rainfall. Winter or cold season is between January and February, summer or pre-monsoon season is for three months from March to May, monsoon or rainy season extends from June to September and the period from October to December is considered to be the post-monsoon season.

1.9.3 Variability of rainfall

Rainfall variability can be analysed by the different statistical method like mean, standard deviation, coefficient variation of rainfall.

The onset and withdrawal dates of monsoon rainfall are important factors for production and growth of a crop in a season. The onset and withdrawal dates of monsoon rainfall in the country can be estimated by simple graphical method plotting the daily rainfall distribution between June 1st and October 15 of each year. On the basis of this information, the mean and standard deviation (SD) are calculated. The mean of SD gives the extreme values with respect to the onset of monsoon. The onset date of monsoon is also fixed on the basis of the daily rainfall. According to this method, daily rainfall of all the sample rain gauge stations is analyzed and a date is obtained based on high widespread rain and it generally occurs on probabilities. That date is considered as the onset date for the country. In the same way. date of rainfall withdrawal is also obtained.

1.9.4 Analogue Method

The sequence of meteorological pattern in the monthly mean charts of the mandatory levels in the troposphere from the month of March, and where possible February and January were examined for the onset. If the pattern closely resembles any of the previous year, the date of the onset for the year, is chosen for the forecast. And for the retreat, August and earlier months were examined. If the pattern closely resembles any of the previous years the date of retreat for the year is chosen for the forecast (Sein Shwe U. 1974). In Myanmar. analogue method is still used for forecasting the date of onset and withdrawal of monsoon.

1.9.5 Trends of rainfall

Using various statistical tests such as Mann-kendall rank statistics can cany out the trend analysis of rainfall in the country: regression analysis, student "t" test and low pass filter methods. The study of trends examined by more than one statistical method confirms the existence or otherwise of an)[1] general trend in rainfall time series data of annual, cold. hot. monsoon, and post monsoon seasons. In the present studies simple graphical methods also used for rainfall trends. Coefficient variation is also calculated by statistical method. For this purpose rainfall series from 1950-2000, of the 45 meteorological stations in Mvanmar is studied.

1.9.6 Regional Analysis

Further to study the interdependent and interface of rainfall variability and environment, two regions of Myanmar were selected as areas of field study. These are,

(l)Ayeyawady Delta Region (Kyunyarshay village (Pathein district), Yaedwingon village (Hinthada district) and Theinlargutsu village (Myaungmva district) which is a heavy rainfall area, and (2) the central Myanmar **Dry Zone Area** (Sagaing, Monywa, and Shwebo districts) which experience the least rainfall in the country. It is intended to compare how the variation of rainfall has a bearing on environment especially on agricultural patterns and its impact on the socio economic conditions of the people. The study will focus on the wood fuel collection and marketing economy of the people in Sagaing division. Monywa. Sagaing and Shwebo districts at a macro level (at the district level) and wood fuel collection from non forest area of the Ayeyawady division (Pathein. Hinthada. and Myaungmva districts) at micro level (at the village level) that cause the forest degradation in both areas. Using the random sampling technique. 1 have selected 200 houses from each region as respondents and some government officers of the areas were also interviewed. Information was elucidated using open and close-ended questions and from target group discussions with local people from the two regions.

1.10 Organization of the Stedy

The study is organized into six chapters.

Chapter one comprises the introduction to the stud}' and includes definition of climate and environment and their inter relationship, the focus of research and choice of study area. Objectives of the study. Methodology and Data sources, and organization of the study.

The **second chapter** highlights the profile of Myanmar providing a background to the study. It consists of the physiographic setting, climatic setting and socio economic setting of Myanmar.

The **third Chapter** examines the rainfall variability of Myanmar. In this chapter, rainfall characteristics are analysed in terms of annual rainfall variation, rainfall with abnormal condition, spatial rainfall distribution, seasonal or temporal distribution, and trends of rainfall study by accumulative coefficient method.

The **fourth chapter** deals with environmental problems of Myanmar and focuses on the major environmental issues such as deforestation and desertification, soil erosion and land degradation problems, marine resource degradation, and pollution.

The **fifth chapter** provides an account of Environmental Degradation in Myanmar on the basis of wood fuel use in the two selected rainfall regime regions. This chapter is divided into two sections; one is the case study of Dry zone in Sagaing Division, which discusses the wood fuel collection, the wood fuel productivity, and marketing which is accelerating forest degradation in central Myanmar. The second section focuses on the Ayeyawady delta region where wood fuel collection from non-forest area has been taking place that has caused the mangrove forest degradation.

Chapter sis summarises the major observations and concludes with the major findings of the study.

1.11 Limitations of the study

At the outset it needs to be confessed that there are some major limitations in this research work that has had an impact in shaping the thesis. They are:

(1) Myanmar's political history has kept it away from mainstream global research agendas for decades. It was in this context, and the fact that studies from an inter- disciplinary perspective are few, that this study was conceived to explore the climate-rainfall variation-deforestation links .The initial excitement of undertaking research on a fairly new area became difficult to sustain as detailed secondary data on environmental variables was not easy to collect.

(2) The second major constraint was the fact that fieldwork was done by the scholar before leaving Myanmar to register for her doctorate degree in India. Hence, this primary data was collected in 1998 and could not be improved upon and updated, as it was not possible for the researcher to go back to Myanmar for more intensive fieldwork.

(3) This meant that the study had to be structured around whatever data was available here in India. While data on rainfall was recent and detailed, the study could not weave in detailed environmental data as required during the formulation of the research out line. This has meant some gaps in data on environmental variables.

(4) Also, there is not much research work on Myanmar available in India and this is reflected in the lack of material for review. This poor documentation limited the background information available for the study.

(5) Keeping these factors in mind, the thesis has attempted to work around these data constraints. In some ways, this study assumes significance in the light of these limitations as it seeks to provide some interdisciplinary insights into a country not much is known about to the outside world.

CHAPTER-II

MYANMAR: A Profile

The profile of Myanmar is presented in four sections. Section A highlights the physical setting of Myanmar; section B emphasizes the climate setting of Myanmar with a focus on controlling factors of climate; section C discusses the Socio-Economic Setting of Myanmar; and Section D identifies the Environmental regions of Myanmar based on the physical, climatic and socio economic setting of the country.

Section A

PHYSICAL SETTING OF MYANMAR

2.1 Location, Size and Shape

The union of Myanmar lies between North latitudes 9'30 and 28 31 and between East longitudes 9 10 and 101 11 The Tropic of Cancer passes near Tiddim (Chin state). Tagaung (Sagaing Division) Kufkhai (Northern Shan state). Such being the case, two thirds of the Southern portion of the country lies within the tropics. Myanmar is bounded by Laos on the East, on the Southeast by Thailand, on the Northeast by People's Republic of China, on the West by Bangladesh, on the North West by India and on the South by the Bay of Bengal and the Katpali Sea (Andaman Sea) (see Fig.2.1). Under the political administration. Myanmar is made up of 7 states and 7 divisions as political units: namely Kachin. Kayin. Kayah. Chin, Mon. Rakhine, Shan states and Yangon. Ayeyawady. Mandalay, Magway. Sagaing. Bago and Taninthayi divisions (see Fig 2.1a).

The total length of the coastline of Myanmar. from Naaf River to Kawthoung is 2228 kilometers (1385 miles). The total length of Myanmar-Bangladesh boundary is 271 kilometers (168.7 miles). It consists of two parts, namely the Naaf River boundary 64 kilometers (39.5 miles) and the land boundary 208 kilometers (129.2 miles). The total length of Myanmar-India boundary is 1338 kilometers (831.8 miles); Myanmar-China 2204 kilometers (1370 miles): Myanmar-Thailand 2107 kilometers (1309.8 miles) and Myanmar- Laos 238 kilometers (147.9 miles), respectively.

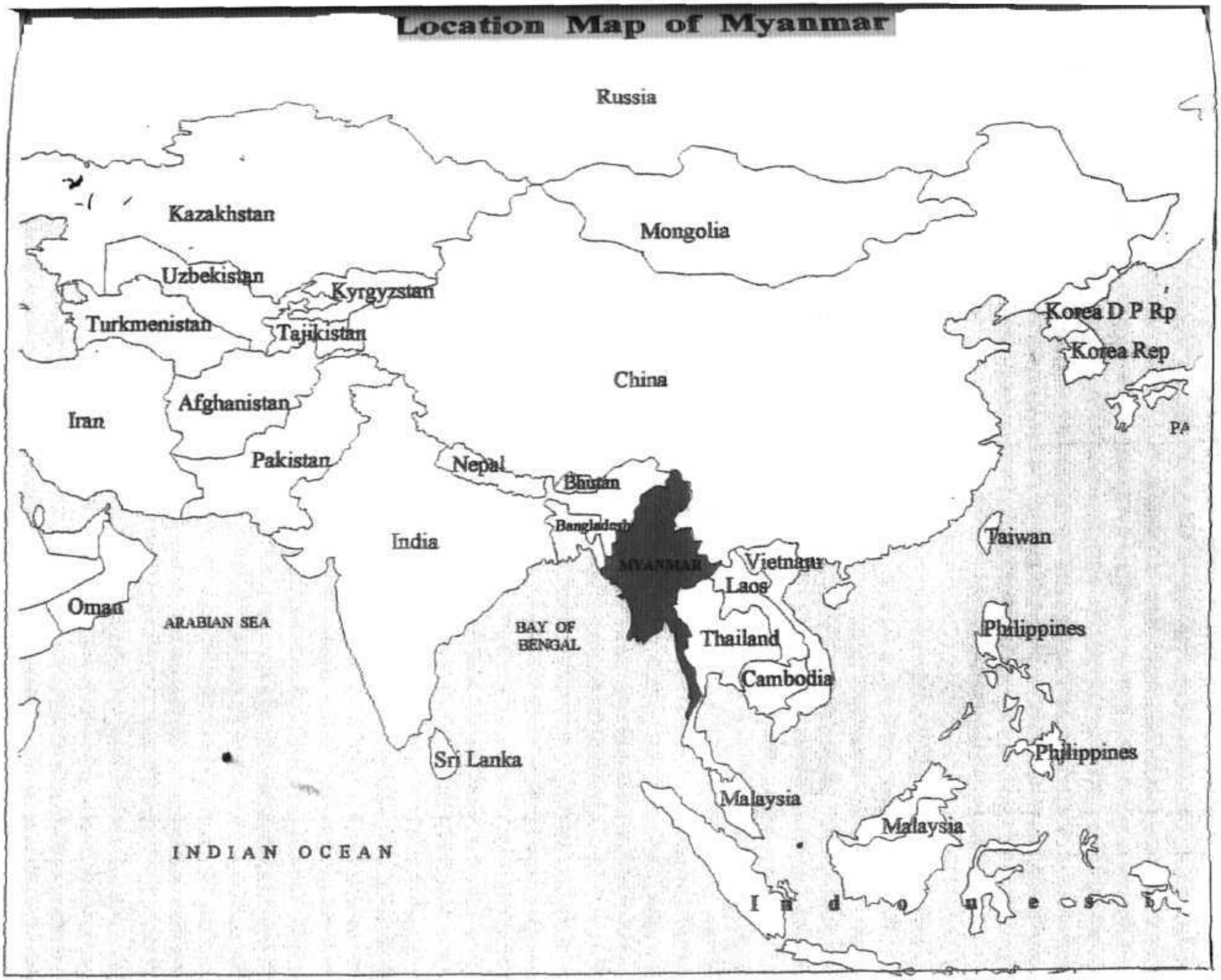

Figure 2.1 Myanmar and neighbouring countries

Figure 2.1a States and Divisions of Myanmar

The longest distance from North to South is 1,300 miles whereas the widest distance from East to West is about 575 miles. The area of the country is about 676,587 sq km or 261, 789 square miles. The shape of the union of Myanmar is not compact but is elongated, resembling a kite with a tail at coastal Taninthayi.

2.2 Topography (Relief)

Physiographycally Myanmar can be divided into four major Divisions (Bender, 1983) as shown in Fig. (2.2), and they are as follows:

(1) The Sino-Myanmar Ranges;

(2) The Indo-Myanmar Ranges;

(3) The Rakhine coast Area; and

(4) The Inner Myanmar Tertiary Basin.

(1) The Sino-Myanmar Ranges:

This includes the Shan or Eastern highlands and their continuation into Taninthayi. The Northern most portions are ruggedly mountainous with the loftiest peak higher than the regional snow-line altitude of about 15,000 feel. The highest peaks are Hkakaborazi (19,296 feet) which is (5,881m) and Gamlangrazi (19,142) feet which is (5837 m). Other notable high peaks with heights above 17,000 feet are Tuataras and Dindawrezi. These mountains constitute the source areas of Maikha River, which flows in between the Shan-gaw Range, and the Northern extension of the Kaolikung range in China, where Sino-Myanmar border is demarcated. This range is more than 10,000 feet high and forms the water-divide line for the Ayeyawady and the Than- Lwin rivers. Between Myanmar and China, there are many passes, but the Tapeng and the Shweli are the most important.

The central portion is the continuation of Yunan Highland and has an average height of about 3,000 feet to 4,000 feet. This portion contains both Shan and Kayah plateau with many lofty peaks higher than 7,000 feet. Most of the ranges are generally aligned North-South, though some ranges such as Loilun range runs East-West, parallel to the Shweli River. In this region, there are many rift valleys and fault lines where many rivers and lakes are found. Inle Lake is located in a rift valley, at the height of 2,915 feet which is (888 m) above sea level. In this portion, there are many

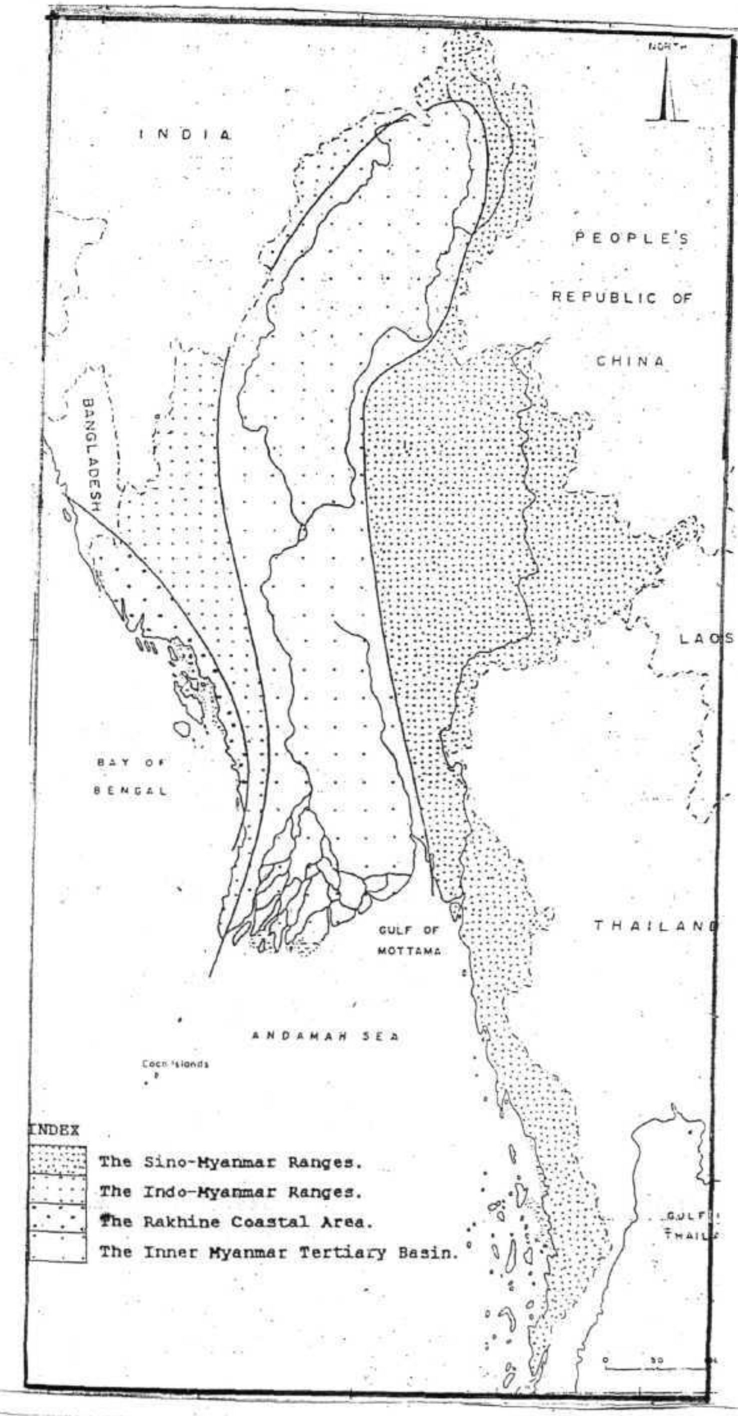

Figure (2.2) Four Major Physiographic Units of Myanmar.
Source: Bender, 1983."Situation Map"

wide plains, such as Thein-ni plain, Thi-baw, Nyaung-Shwe and Kyaington plain. The most important route via Lashio to Kumming in China is known as the Myanmar-China Road.

Kayin State, Mon State, and Taninthayi Division are included in the Southernmost portion. The Dawna Range lies between the Hlaingbwe-Haungthayaw and the Thaung-yin rivers. The coastal range between the Sittoung and the Thanlwin estuaries continues southward as Taungnyo and Taninthayi ranges. The average height of these ranges is over 3,000 feet. Myintmoletkhat Taung, the peak of the Taninthayi range is over 6,800 feet. There are some isolated limestone hills such as Zwegabin and Kyauktalone hills between Dawna and coastal ranges. In this region, some natural limestone caves are also found, such as Karon and Sadan caves near Hpa-an. The Taninthaiyi coastal strip is narrow and elongated. South of Kyaik-khami, the coastal plain becomes narrower and it is even discontinuous at some places. The shoreline of the Taninthayi is rocky and neatly fringed with islands. Off the coast from Myeik to Kawthoung coast, there is a group of islands known as Myeik-kyunsu (Myeik-archipelago).

(2) The Indo-Myanmar Ranges:

The Indo-Myanmar Ranges comprises a series of hills and form the Southeastern extension of the Himalayas. Patkoi is the Northern most range, which continues southward as Naga Hills with the Sarametik peak (12,553 feet). Towards the South are Lushai hills and Chin Hills with mount Victoria (10,018 feet) near Kanpetlet.

The Rakhine Yoma lies to the South of Mount Victoria with the highest peak of Hsung-Taung (6,000feet) .The average height of Rakhine yoma is over 4,000 feet in the North and about 3,000 feet in the South. Its elevation is only 500 feet in the Southern most part and drops to sea level at Mawtinsoon and submerges into the sea, the yoma continues southward to run below the sea, with the highest peaks appearing as an island chain of Coco, Andaman, and Nicobar islands.

(3) The Rakhine Coastal area:

In between the Bay of Bengal and the Rakhine yoma, "The Rakhine coastal area" is considerably wide in the North and tapers towards the South. In the Northern part, folded mountains align North-West to South-East. The coastline from the South of Naaf to the Thandwe River is broken into numerous low islands. The whole coast is very irregular with wide Inlets and Lagoons. In the Southern part, from the Thandwe River to the Mawtinsoon, the coastline also is much dissected by the steep spurs of the Rakhine yoma. All along the coast, moreover, there are numerous small river valleys and scattered Sandy bays, forming the scenic resort beaches in the region.

The Northern and middle portion of the Rakhine coastal strip is fringed with near shore and offshore islands. To the South of Sittway plain, there are three elongated islands known as Baronga Islands. Further South, there are two large Islands, Ramree (Yanbye) and Man-aung islands.

(4) The Inner Myanmar Tertiary Basin:

Indo Myanmar ranges and Rakhine yoma on the West and by Eastern Highlands in the East surround the central Basin or the Inner Myanmar Tertiary Basin. It consists of flat alluvial plains and low uplands with few exceptions for some mountain ranges and isolated hills. Besides, the whole river systems of Chindwin, Ayeyawady, and Sittoung flow in this basin from North to South in general. In the Northern-most basin area, the Kumon range, which has average height of about 8,000 feet, forms the river-divide line for the Chindwin and the Malikha rivers with the gradually declining in height, the range continues Southward into low mountains as Hmankin, Minwun and Sagaing ranges. All the parallel ranges extend North South in direction. Taung-thonlone, Zeepin Taung, and Zeephyu Taung constitute the watersheds of the Chindwin and Mu rivers. The Ponnya and Pontaung hills lie in North-South direction on the Western side of the Chindwin River. The Bago Yoma, the water-divide between the lower Ayeyawady and Sittoung River, begins near Myingyan and runs Southwards the Southern most end forms into an isolated hillock as Thein-Gottara Hill in Yangon. The Yoma's height is generally less than 2,050 feet except Mount Popa, which reaches 4981 feet in Kyaukpadaung Township. In the whole basin area, the plains are narrow in the North and gradually become broader

Source: www.atlapedia.com

Figure 2.3 Physical Map of Myanmar

towards the South. The Central Basin that forms the study area is divided into three physiographic subdivisions: the Northern most hilly region; the Dry Zone or middle section; and the Southern broadest portion.

(4a) The Northern most hilly region consists of the river systems of the upper Chindwin and the upper Ayeyawady along which the narrow elongated plains are formed. Some sizable plains in this region are Hukaung valley, Putao and Mogaung plains, and the plains along the Ayeyawady River; Indaw-gyi Lake also lies in the West of Myaung areas.

(4b) In the Dry Zone or the middle section, the mountain ranges are lower and the alluvial plains become wider. Some prominent plains are Mu-valley, pale- plain on West of Chindwin, and Mandalay - Kyaukse plain with Southward extension as the Sittoung valley. Minbu plain formed by the Salin, the Mone and the Mann streams, and Taungdwingyi plains between Bago-yoma and the Ayeyawady River are considerably wide as well. The Southernmost broad portion consists of large alluvial plains along the Sittoung valley and the wide, extensive plains between the Bago Yoma and Ayeyawady River. Even on the Western side of the Ayeyawady River, there are sufficient wide plains along the river, with the exception of rugged portion between Thayetmyo and Padaung townships.

(4 c) The delta of the Ayeyawady River begins at Myan-aung. The distance from the Apex of the data to the sea roughly is around 180 miles and the distance between the mouths of the Pathein and the Yangon River is roughly 150 miles. This delta region is narrow in the North and broadens Southwards toward the sea. Thus, the Ayeyawady deltaic region constitutes the largest plain in Myanmar with an area of more than 12,000 square miles (31,068 sq Km). Through nine mouths linked by countless channels, the Ayeyawady River finally drains into the Katpali (Andaman) sea. The delta of Ayeyawady is gradually extending seaward, and the shelf of Mottama is slowly silting up. At many places the sediments brought down by rivers are picked up by sea waves and are reworked and redeposit at other places. This process enriches sea beaches in other places while deterioration of habours in other places due to siltation. The Ayeyawady River has a sedimentation rate which is the

fifth highest in the world behind the Yellow, Ganges, Amazon, and Mississippi Rivers (WRM Bulletin, Issue No. 65, and December 2002).

2.3 Drainage

The predominant North-South alignment of the mountain ranges of Myanmar is reflected in the direction of all rivers, large and small. The four main rivers of Myanmar, the Ayeyawady, the Chindwin, the Sittoung and the Thanlwin, all flow in a general North-South direction (see Fig.2.4).

The Ayeyawady, the largest river of the country, rises as the Maikha River in the snow capped ranges in the extreme North of Myanmar. This Maikha is joined by the Malikha River at about 25' 45' North, approximately 30 miles North of Myintkyina (Nye, 1964). The Ayeyawady occupies a total drainage basin area of more than 16,500 square miles (Chibber, 1934). The Ayeyawady is navigable up to Bhamo.

The Chindwin River originates in the Western Kumon range; the Chindwin preserves a general Southerly course from Hkamti to its junction with the Ayeyawady, about ten miles Northeast of Pakokku. The river is navigable up to Homalin throughout the year by steamers. The drainage basin of the Ayeyawady-Chindwin system covers about 55 percent of the whole area of the country; some tributaries of the Chindwin are the Uru, the Yu and the Myinttha rivers.

The Thanlwin, the easternmost main river of Myanmar, originates in the Tibetan Highlands with 796 miles of its river-course lying in Myanmar. The Thanlwin flows across the greater part of Shan Highlands and enters into Mottama Sea. The drainage area of it is extraordinarily small and the riverbanks are steep and rocky. It is a rift river, flowing in a narrow valley, with a succession of great gorges, rapids, and cataracts. The river, therefore, is mostly used for floating logs. Navigation is possible only between MawlaMyaine and Shwegun. Some tributaries on the East are the Gyaing and Attaran, and on the West are the Nam ting, the Nam pan. the Nam kha, the Nam Teng, the Nam pawn, the Thaung yin, and the Yun-Salin.

The Sittoung River originates from the confluence of the Paunglaung, the Sinthe, and the Ngalike. The upper reaches of the Sittoung are known as the Paunglaung. The Paunglaung has its source in Southern Shan state, while the Sinthe and the Ngalike rise in the Eastern hills of Bago Yoma. Navigation is impossible except for floating timber, as the estuary is frequented by the tidal bores. The Eastern tributaries of the Sittoung are the Thaukyekhat, the Kyauk gyi, and the Shwegyin, and on the West are the Swa, the Ka-boung, the Phyu and the Ye-new, near its Southern and, the Sittoung is linked with the Bago River by the Bago-Sittoung canal. Between Bago yoma and Shan highlands, the Sittoung river valley provides a wide plain joining lower and upper Myanmar.

Between the Ayeyawady and the Sittoung, the Bago River flows from its source of Hsinamaung Taung of the Bago yoma and empties into the Yangon River. The Yangon River constitutes access to Myanmar port for sea-going vessels, and is linked by the Tuntay canal with the Ayeyawady River system.

Rivers in the Rakhine area include the Naaf, the Maiyu, the Kaladan, and Laymyo. The Naaf River is the Western most river of the country, used as a borderline between Bangladesh and Myanmar. The Maiyu, the Kaladan and the Laymyo flow from north to south and are noteworthy for their broad and fertile deltas.

2.4 Climate

In the climate of Myanmar. the significant feature is the alternation of seasons known as "monsoon". The name monsoon is derived from the Arabic word "Mausin" which means seasonal winds whose direction more or less reverses twice during the year. Lying within the tropics and with the great Asiatic continent to the North and the wide expanse of the Indian Ocean to the South, Myanmar furnishes one of the best examples of the monsoon country. Myanmar experiences three seasons:

(1) The Rainy Season (mid May to mid October);

(2) The Cold Dry Season (mid October to end of February); and

(3) The Hot Dry Season (March to mid May).

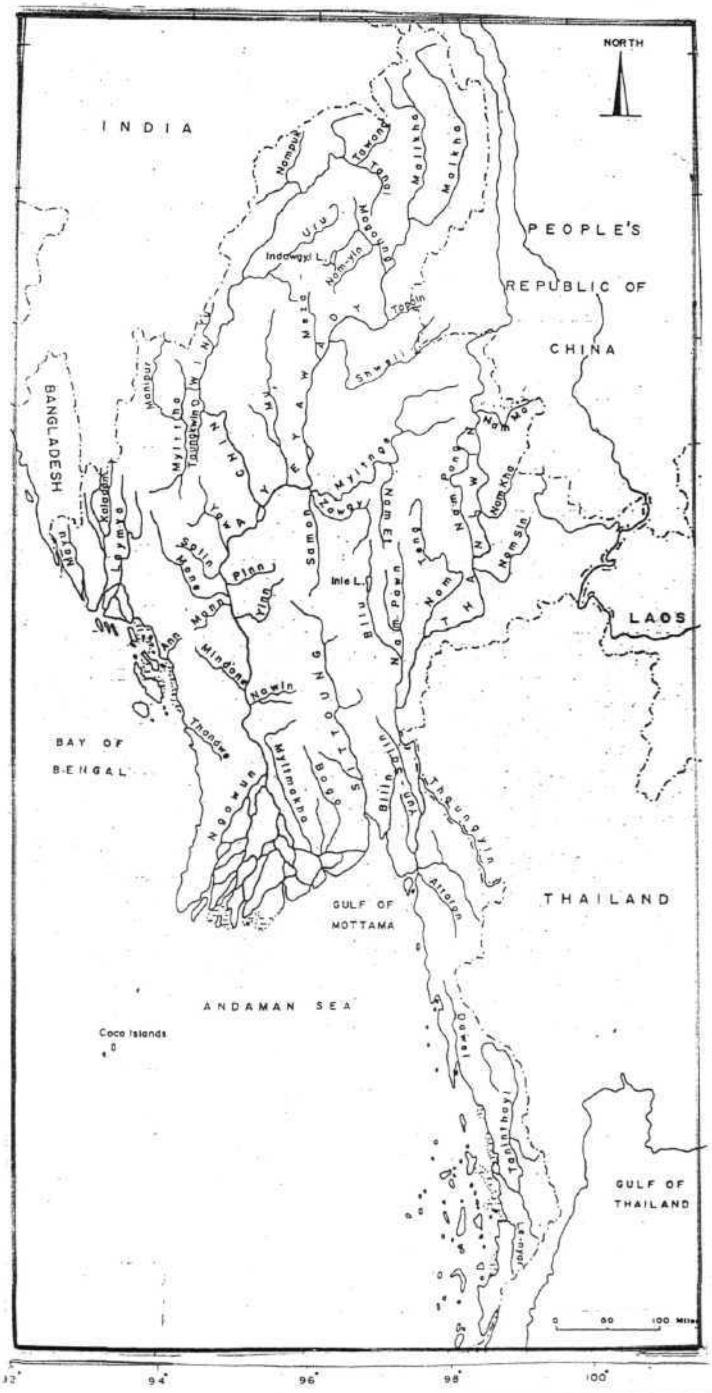

Figure (2. 4) Drainage of Myanmar.

Source : Survey Department.

The rainy season is generally from mid May to mid October (Moe, 1989). During this season, the Southwest monsoon winds dominate the whole country, so the season is named as Southwest monsoon season, since the wind direction is from sea to land; the season is of much humidity, cloudiness and rain. The season is designated as wet season or rainy season over Myanmar. It is found that over 80 percent of the annual rainfalls are received during this season.

The Southwest monsoon wind usually makes its appearance in Southern and lower Myanmar about the third or last week of May (Lwin, 1984). It gradually extends Northwards and is usually established over the whole country by about the first week of June (see Fig. 2.5). The dates of onset and withdrawal of monsoon over Myanmar during the period of 1951 to 2000 can be seen from table (2.1). To predict the date of the onset of the monsoon over Myanmar, it is necessary to watch the upper tropospheric phenomena over India and Pakistan where the subtropical jet stream causes very high wind velocity at upper troposphere (Hla and than, 1970) If the wind velocity rate over that region is observed properly, starting from beginning of April, then the gradual decrease in wind velocity-rate will be found. After noting the date on which the velocity begins to decline below the rate of 50 nautical miles per hour, it is necessary to continue the observation for 7 more days. If the velocity decreases continuously during the 7 days, then the above noted date is added with 37 days. The onset date of monsoon over Yangon is between +/- 5 days limit range. For the remaining places, the corresponding onset dates could be estimated accordingly.

With the advent of the Southwest monsoon rains, there is the rapid fall in the maximum temperature in the whole country temperature less than 26° C (80° F) are almost confined to the hilly region and some parts of Taninthayi division. The temperatures in the coastal strip of Rakhine and deltaic region are less than 28° C (82° F) and the Dry Zone has the temperature from 28° C (82° F) too more than 30°C (86° F) (see Fig. 2.6).

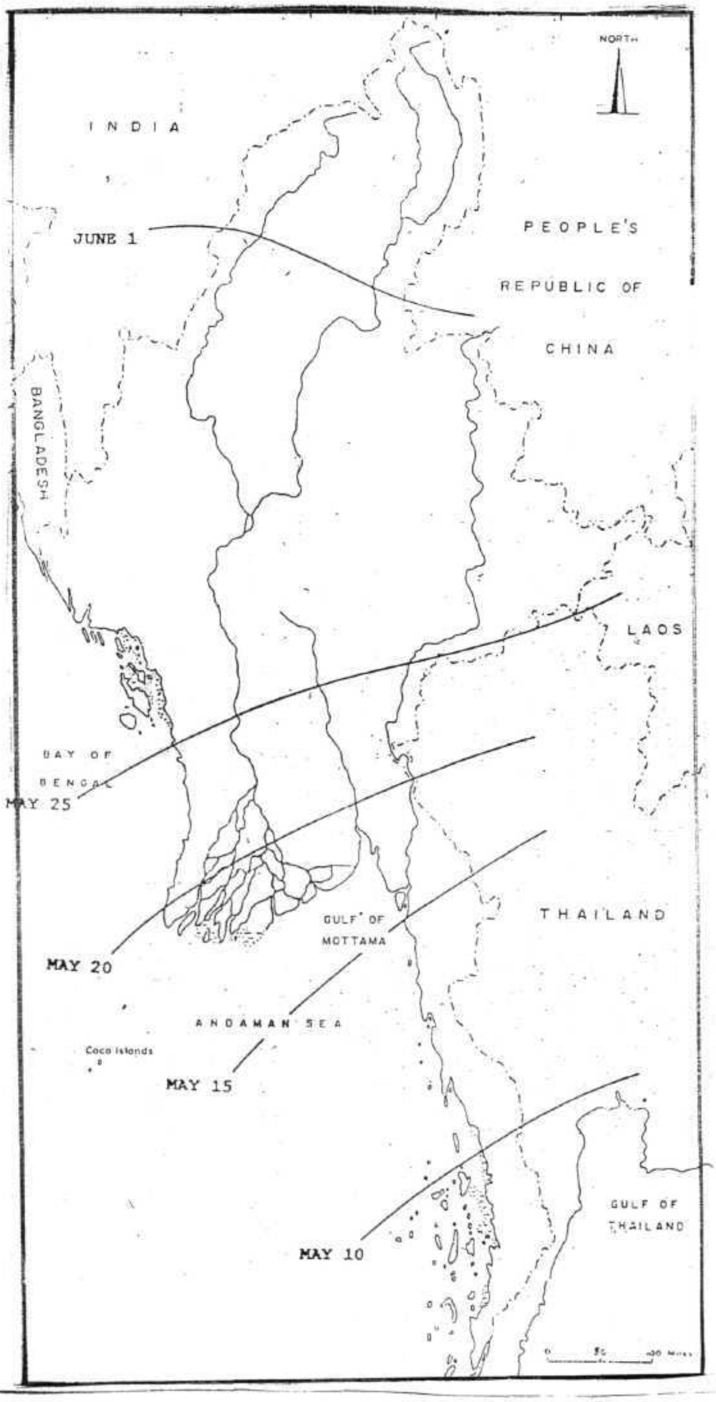

Figure (2.5) Normal Onset Dates of the Southwest Monsoon.
Source: Lwin, 1984.

Table 2.1 The Dates of onset and withdrawal of monsoon over Myanmar (1951-2000)

Year	Date of Onset	Date of Withdrawal	Period of Days
1951	June 04	October 17	136
1952	May 19	October 29	164
1953	May 27	October 12	139
1954	May 24	October 14	144
1955	May 23	October 15	146
1956	May 05	October 11	160
1957	May 29	October 13	138
1958	May 14	October 14	158
1959	May 29	October 19	144
1960	May 28	October 14	140
1961	May 30	October 27	151
1962	May 24	October 15	145
1963	May 27	October 20	147
1964	May 05	October 20	169
1965	May 21	October 14	147
1966	May 20	October 14	148
1967	May 19	October 18	153
1968	June 08	October 14	129
1969	May 25	October 07	136
1970	May 25	October 30	159
1971	Mav25	October 10	139
1972	Mav 25	October 19	148
1973	Mav 17	October 15	152
1974	May 11	October 23	166
1975	May 19	October 20	155
1976	Mav 29	October 05	128
1977	June 14	October 04	113
1978	June 05	October 17	135
1979	June 11	October 18	130
1980	June 06	October 08	125
1981	June 04	October 19	138
1982	June 09	October 06	120
1983	June 01	October 16	138
1984	Mav 29	October 07	132
1985	Mav 29	October 20	145
1986	June 07	October 08	124
1987	June 06	October 14	129
1988	Mav 30	October 20	143
1989	June 12	October 08	119
1890	June 04	October 07	126
1991	June 06	September26	116
1992	June 16	October 01	108
1993	June 13	October 11	120
1994	June 07	October 02	124
1995	June 06	October 02	119
1996	June 02	October 02	123
1997	June 09	September 09	118
1998	June 14	September 24	103
1999	May 26	September 30	128
LH2000	May 24	September 21	121

Sour"•e: Meteorology and Hydrology department, Yangon, Myanmar, 2000.

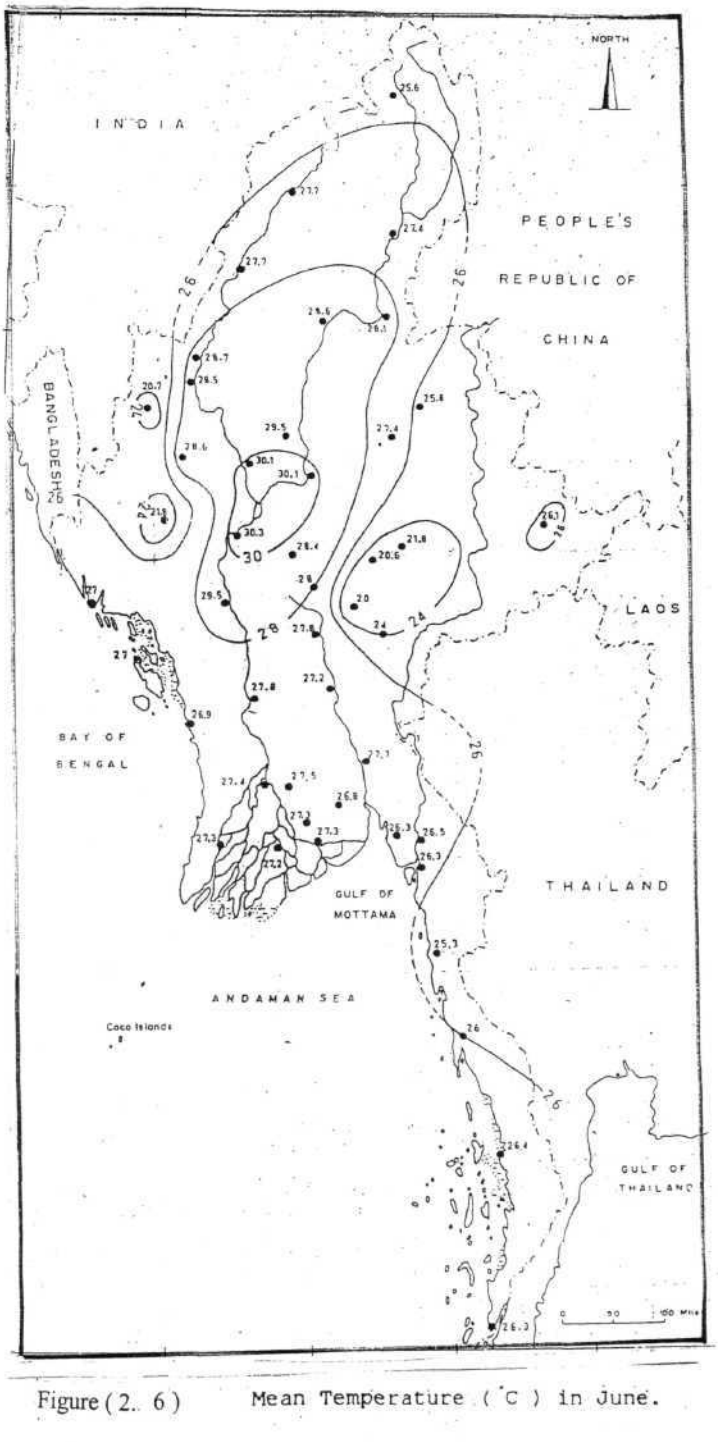

Figure (2. 6) Mean Temperature (°C) in June.

With the advent of the Southwest monsoon rains, there is the rapid fall in the maximum temperature in the whole country temperature less than 26° C (80° F) are almost confined to the hilly region and some parts of Taninthayi division. The temperatures in the coastal strip of Rakhine and deltaic region are less than 28° C (82° F) and the Dry Zone has the temperature from 28° C (82° F) too more than 30°C (86° F) (see Fig. 2.6). During the period of Southwest monsoon season, the air is very damp and the relative humidity ranges between 80 percent and 90 percent. In the rain during the spell of wet weather, the air is saturated and has relative humidity of 95 percent to 100 percent. During this period, depressions form in succession in the North Bay of Bengal, though they usually strike India's Northeast coastal area. During the peak monsoon months of July and August, there may be break in precipitation over the whole country. This condition may last for 3 to 5 days or, of prolonged, or may last for 7 to 10 days.

The cold dry season begins with the retreat of the Southwest monsoon and the arrival of the Northeast monsoon .The months of retreating monsoon or the post-monsoon months extend from the last week of September or early October, to November (see Fig 2.7) and December, January, and February are regarded as winter months. With commencing of rain the last week of May, temperatures begin to fall considerably. September with a slight increase (see Fig.2.8) shows that Myanmar enjoys another maximum of temperature in September though not as high as the pre-monsoon months. In the winter months of the Northern Hemisphere, a high-pressure belt occupies the whole central and Northern Asia. Over Myanmar, the weather associated with North to Northeasterly wind prevails over the whole country. Clear sky, fine weather, low humidity and temperatures and a large diurnal variation of temperatures are normal features of this season.

In December and January because of the continental dry winds, December and January are the coldest months, the mean maximum temperature rarely exceeds 32° C (92° F) except the Southeastern part of the delta, Mon state and upper Taninthayi Division (see Fig.2.9). According to the mean minimum temperatures (bared on the period of 30 years (1961-1990) of selected stations, the range of mean minimum temperatures is from about 22.7 ° C (72.9° F) to 4.5° C (40.1° F) (see Table 2.2).

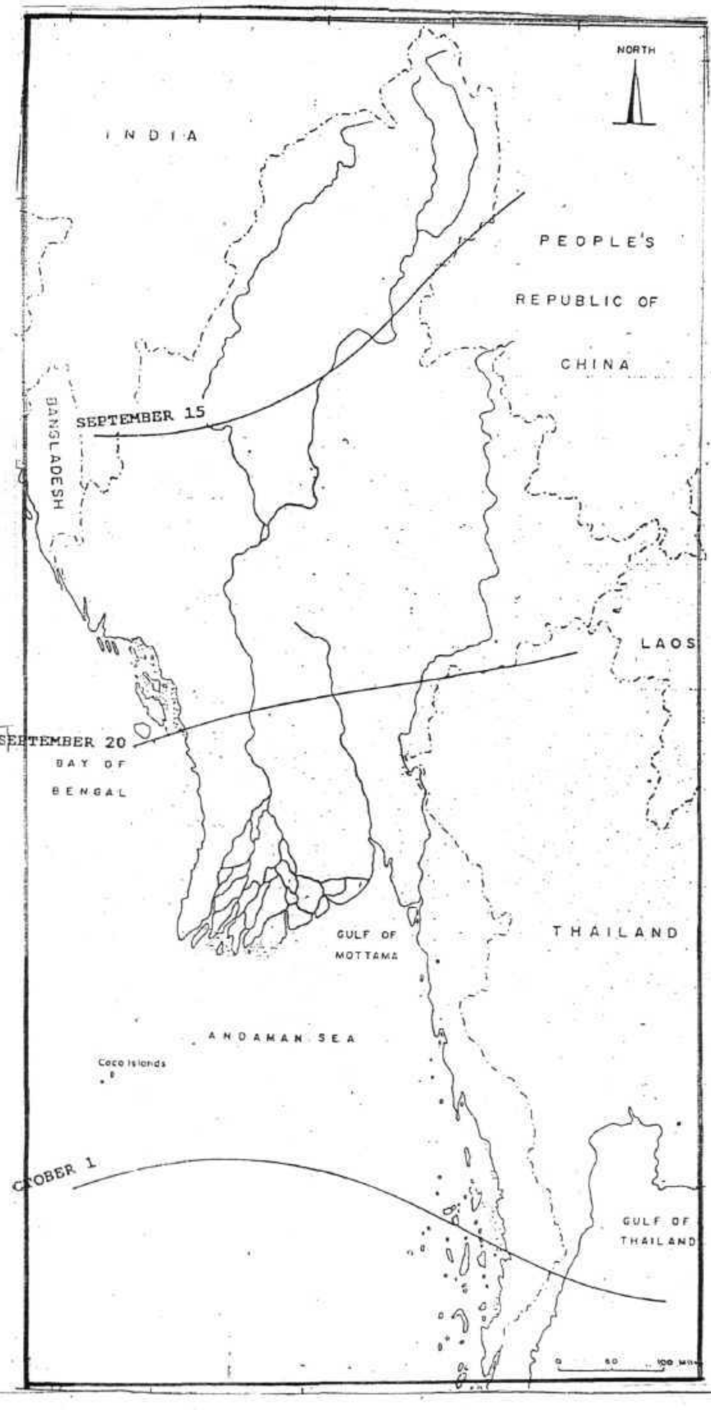

Figure ((2.7)) Normal Retreating Dates of the Southwest Monsoon
Source: Lwin, 1984.

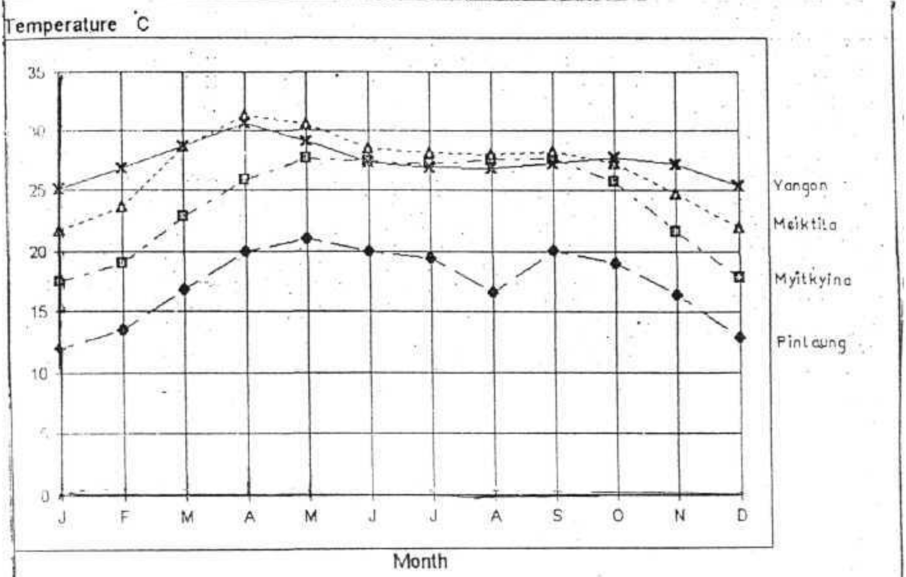

Figure 2.8. Mean Monthly Distribution Of Temperature in Degree Centigrate for Selected Stations.

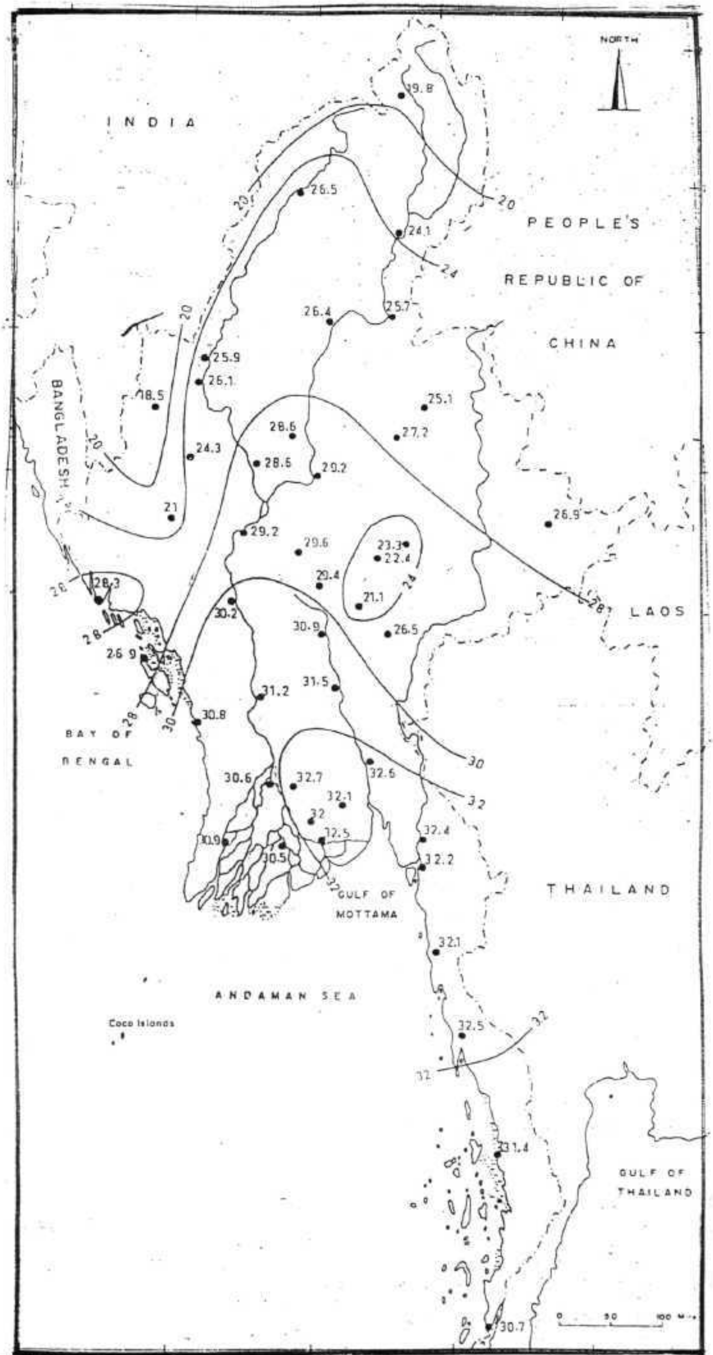

Figure (2.9) Mean Maximum Temperature (°C) in December and January.

During the cold dry season, humidity is generally driest in central part of the country with relative humidity of 55 percent to 60 percent and it increases out wards from this region, (see Fig. 2.10).

Table 2.2 Mean Minimum Temperature (c) in December, January, and February for select stations

Stations	December	January	February	Dec, Jan, Feb Mean
Kawthoung	22.60	22.3	23.1	22.7
Myeik	21,03	20.7	21.7	21.1
Mawlamyaine	19.70	17.5	19.8	19
Yangon	19.10	18.3	19.4	18.9
Pathein	18.60	17.1	18.8	18.1
Pyay	17.40	17.1	17.1	17.2
Toungoo	17.10	16	16.1	16.4
Sittway	17.10	14.5	15.2	15.6
Pyinmana	16.20	14.6	15.9	15.5
Monywa	14.60	14.1	14.6	14.4
Mandalay	14.80	13.3	14.9	14.1
Kalaywa	14.70	12.9	13.7	13.8
Thandwe	15.07	12.4	12.4	13.4
Mawlaik	14.00	11.6	11.7	12.4
Gangaw	13.10	10.8	10.9	11.6
Mvintkvina	11.60	10.2	12.5	11.4
Kyaington	11.00	9.7	10.6	10.4
Loikaw	10.50	8.5	10.1	9.7
Putao	08.00	6.9	9.3	8.6
Lashio	08.00	5.3	5.9	6.7
Loilem	05.10	4.4	5.9	5.1
Pinlaung	05.50	3.7	4.5	4.5

Source: Meteorology and Hydrology Department. Yangon, Myanma. 1998.*

During the post-monsoon months, depressions, and cyclones originated in the Southwest of West central Bay of Bengal way forms. They may move Northwestward at first, and then receiving towards the Rakhine or Bangladesh coast in their final stages. From about the middle of December the weather in Northern Myanmar is characterized by a series of disturbances from the middle latitudes (designated as Western disturbances) moving Eastward. The precipitation associated with them may be small in a mount but in very important for winter crops.

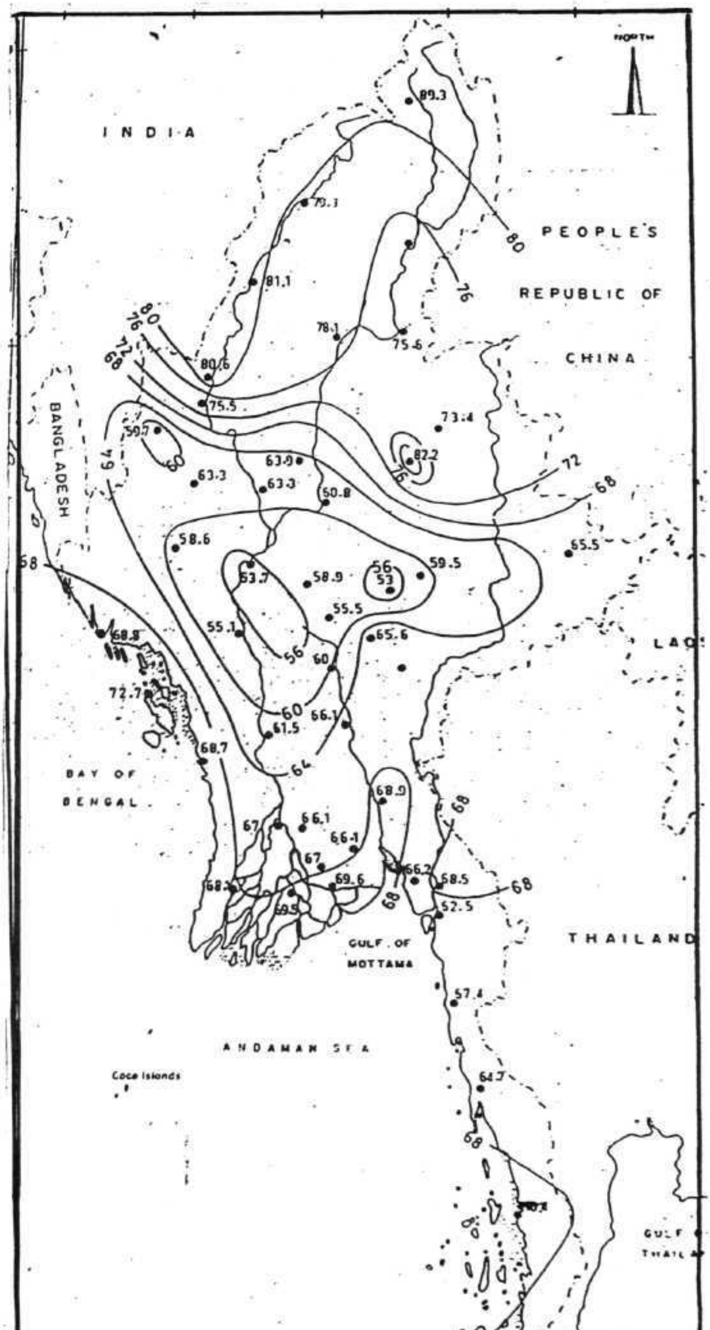

Figure (2.10) Mean Relative Humidity (%) (mean of 9 am. and 6 pm.), December-February.

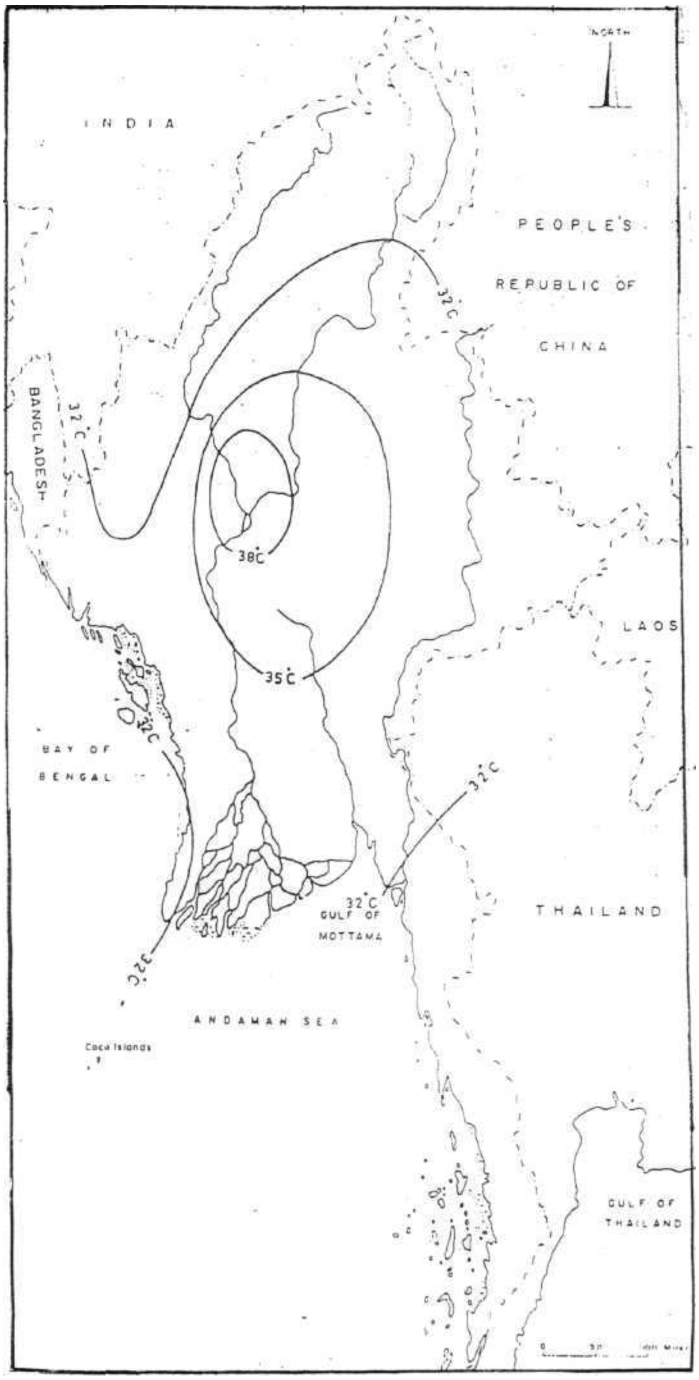

Figure (2.21) Mean Maximum Temperature in May.
Source: Lwin, 1984.

The hot dry season (March to mid May) is a period of continuous and rapid rise of temperature. With the Northward movement of the sun, temperature rise rapidly and in March the hot weather begins. The prolonged heat and scanty rain which the central part of Myanmar has been getting for some months cause thermal low pressure are over this zone until June. The temperatures of 37 °C (70 °F) and above occur in plains mostly in the central Myanmar and the coastal areas have the temperature of less than 35 °C (95 °F) (see Fig 2.11). Hence, temperatures are highest in the central districts and there is a contrast of temperatures between the central and other districts.

During this period of high temperature, important changes take place in the surface air movement over Myanmar. Local sea breezes prevail in the coastal districts and dry land breezes prevail over the interior. The rapid decrease of relative humidity of 40 percent or less occurred from coastal to the central districts. During the hot afternoon of summer, humidity has occasionally been recorded as low as 20 percent in the central Myanmar area. Violent local storms form in the region during May. These storms are often accompanied by violent winds, hail, and torrential rain. Cyclones storms and depressions which originate in the South Andaman Sea or the Southeastern part of the Bay of Bengal are formed during the month of May.

Drummond presented the six climatic zones for Myanmar (see Fig-2.12) according to the Koppen climatic types of classification as follows:

(a) Tropical monsoon climate,

(b) Tropical Savannah climate,

(c) Tropical steppe climate,

(d) Subtropical monsoon and subtropical montaine climate,

(e) Tundra climate, and

(f) Ice cap climate.

([a]) Tropical monsoon climate is found at Rakhine coast, Ayeyawady delta and Taninthayi region which experience annual mean precipitation of more than 2,500 nwi (98.5 in) and mean annual temperatures of more than 25° C (77° F).

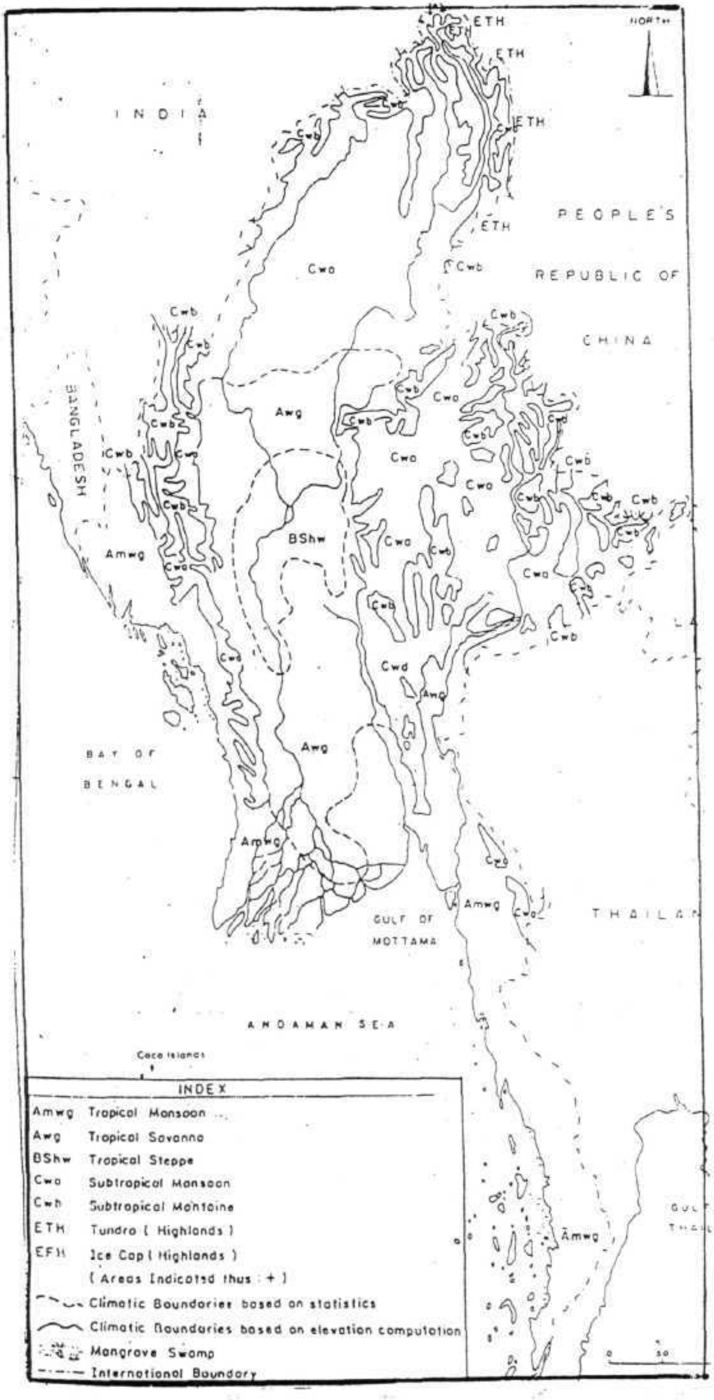

Figure 2.12 Climate Map of Myanmar, Köppen Classification.

Source : Drummond , 1958 .

(b) A considerable extent of tropical Savannah climate lies immediately to the North of tropical monsoon area. The dry season is pronounced and thus the significant difference lies in the rainfall regime (i.e. lower precipitation) but the temperature element is not unlike that of the area to the South.

(c) Tropical steppe climate (Semi - arid climate) is the area of the Dry zone. Mean annual precipitation is less than 1,250-mm (49.2 in) and mean annual temperature is above 27° C (80.6° F).

(d) Subtropical monsoon and subtropical mountain-climates prevail on the higher section of the Indo-Myanmar ranges and of the Shan massif; North of latitude 23 to 24° mean January temperature is well below 18 C (84.4 F). Areas having a mean temperature of the warmest month above 27 C (71.6 F) are termed subtropical monsoon climate. Those locations with the warmest month's temperatures below 22 C (71.6 F) are classified as subtropical montane climate. The boundary between them in Myanmar is directly related to elevation.

(e) Tundra climate occurs in the northern frontier areas of high elevation at 1,000 m (3,281) ft and above. The mean temperatures of the warmest month are less than 10°C(50°F).

(e) Ice cap climate prevails over the northern most part of Myanmar at an altitude above 4,000 meters (13,780) ft. Mean temperature of the warmest month of October is 32 F or less.

2.5 Soils

In Myanmar, there are many different soil groups, of which Ferralsols, Cambisols and Acrisols are predominant. Others include Fluvisols, Gleysols, Arenosols, Solonchaks, Nitosols, Vertisols, and Lithosols etc (see Fig. 2.13).

Ferralsols (Plinthic), or lateritic soils, occur mostly on the lower slope of Rakhine yoma, Bago Yoma, and Dawna range. They usually occur on the slope at the

SOIL MAP OF MYANMAR

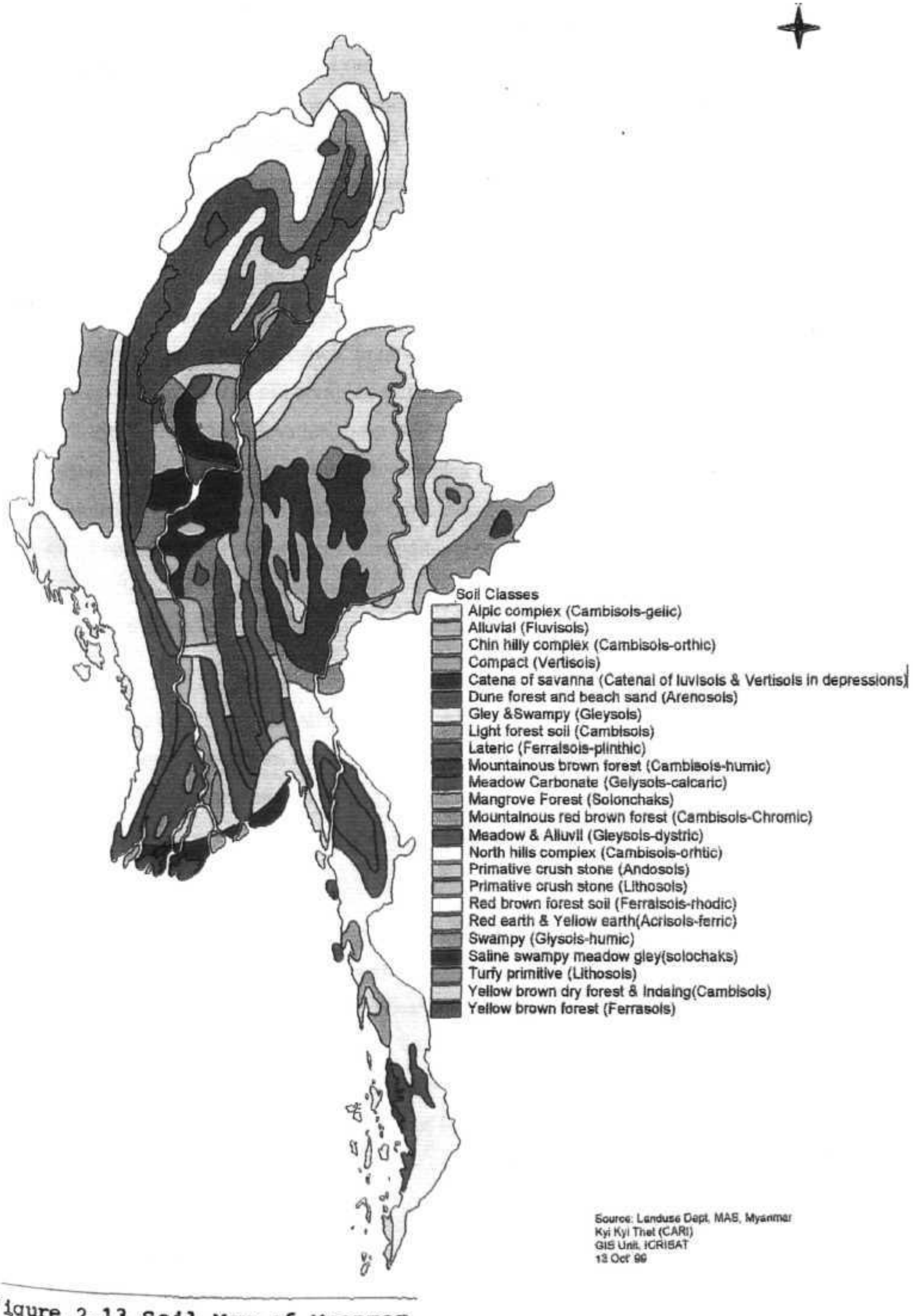

Figure 2.13 Soil Map of Myanmar

elevation not higher than 300 feet above sea level. Ferralsols (Rhodic) is a so-called red brown forests soil of Myanmar. They occur on the well-drained hill slopes at the elevation from about 1,000 feet to 4,000 feet above sea level. They can be found in the Northern mountainous region, Rakhine Yoma, Taninthayi yoma and Dawna range. The occurrence of tropical evergreen forests and the annual rainfall of about 80 inches to 200 inches are the characteristic factors of such soil formation.

Cambisols (humic) and cambisols (Chromic) are the mountainous brown forest soils and mountainous red brown forest soil respectively. They are typical soils of the Shan plateau at the elevation from 4,000 feet to 6,000 feet above sea level. Cambisols (orthic), or chin hill complex soils, are the typical soils of the steep slopes of the Chin Hills at the elevation from 4,000 feet to 6,000 feet above sea level. Cambisols (orthic), or Northern hill complex soils, occur on the Northern mountainous region and in Myintkyina. Cambisols (gelic), or alpine complex soils, are found on the highest snowcapped mountain peaks in Putao District in the group of Cambisols, the soils which are equivalent to yellow brown dry forest soils and Indaing soils occupy the level plains of the lower highlands in the Dry zone.

Acrisols (Ferric), or the alluvial soils can be found on plains and slopes where sediments brought down from the surrounding high lands are deposited. Gleysols (or meadow gley soils and meadow swampy soils are mostly found in lowland where drainage is very poor. Gleysols (calcaric) or meadow carbonate soils are found in the Dry Zone of Myanmar.

Arenosols, or dune forest and beach sand soils occur on the beach, Solonchaks, or mangrove forest soils occur along the coastal regions of Rakhine, Ayeyawady Delta and Myeik archipelago where the soils are affected by daily tides. Solonchaks (Glayic) or saline swampy meadow gley soils can be found on the islands and coastal plains of the Ayeyawady Delta and Mottama.

Nitosols or Cinnamon soils mostly occur on the lower slope of the hill in the Dry Zone and the Shan plateau. Catena of Luvisols on slopes and Vertisols in depressions mostly occurs on the undulating slopes of the hills and gently sloping plains in the Dry Zone.Vertisols, or compact soils occur on the level plains in the Dry Zone especially in Sagaing, Mandalay, and Magwe Division.

Andosols or Popa complex can be found only in the region of mount Popa in Myingyan district. Lithosols, or turf primitive soils and primitive crushed stone soils occur on the spurs of the Eastern slope of Rakhine yoma in Magway district. These soils are covered with low shrubs and sparse dry grasses and the soil surface is often covered with loose sand. By means of weathering activities, changes in climatic conditions cause the different types of soils. Precipitation provides the soils water for the chemical and mechanical processes of weathering. This soil water forms the essential agent in the processes of biological developments. It needs to be emphasized again that successful cultivation depends not only on the suitable soil type, but also on the appropriate amount of precipitation received within the area. Therefore, the rainfall regime and the soil formation are interrelated with each other and determine agricultural production.

2.6 Natural Vegetation

The extensive network of natural waterways along coast line, mountain ranges of varying altitudes, the wide geographical spread of land mass, and climatic zones, the environmental conditions are variable giving rise to rich variety of forest types, flora and fauna. In Myanmar, there are about 7,000 species in 285 families of tree, shrubs, herbs, bamboos, climbers, etc, of which 28.7 percent (about 2,000) species are trees. Over half of Myanmar is forested and forest cover in Myanmar can be seen in table (2.3).

Table 2 .3 Forest cover in Mvanmar of 1989

Forest Land	Area Sq. Km.	Percent
Closed Forest	293.269	43.34
_Degraded Forest	50,968	7.53
Forests Affected by Shifting Cultivation	154,389	22.82
Water Bodies	13,327	2.01
Non Forest	164,600	27.3
	676,553	100

Source: Forest Sheets, Forest Department, Myanmar, 1989.

According to the (Table 2.3), the actual forest area is about 344,237sq km or 50.87%of the total land area, of which 43.34% comprises closed forests and 7.53% degraded forests. The remaining 49.13% comprises 22.82% forests affected by shifting cultivation, 2.01% water bodies and 24.30% non-forested areas. (IFFN, 1999).

In Myanmar there are eight primary forest types (see Fig. 2.14), which are subdivided into 48 ecological classifications on the basis of their fioristic, and other ecological attributes. The forest types are as follows:

(1) Tidal forest,

(2) Beach and dune forest,

(3) Swampy forest,

(4) Evergreen forest,

(5) Mixed deciduous forest,

(6) Dry forest,

(7) Deciduous dipterocarp or Indaing forest, and

(8) Hill and temperate evergreen forests.

Of the actual forested area, 16% is Tropical Evergreen, 26% Hill and Temperate Evergreen, 34% Lower Mixed and Upper Mixed Deciduous and 4% Tidal, beach and Dune Types forests. The actual forested areas are predominantly natural. (IFFN. 1999)

(1) **Tidal forests:** These forests are found within the tidal limits and are found in the Ayayawady delta and on sheltered muddy coastal areas such as Rakhine, Taninthayi, and Myeik Archipelago. They are subdivided into a number of types depending mainly on how much the area is affected by the daily rise and fall of tides; these are the typical mangrove forests. Buchidauk and Kabaing are the main species in the outer belt of these forests and in the inner belt of forests, Kanazo, Tayaw, Thinbaung, and Thinban are the characteristic species.

(2) **Beach and dune forests:** They occur along the coasts wherever a fair width of sandy beach occurs especially in Rakhine and Taninthayi, the most characteristic

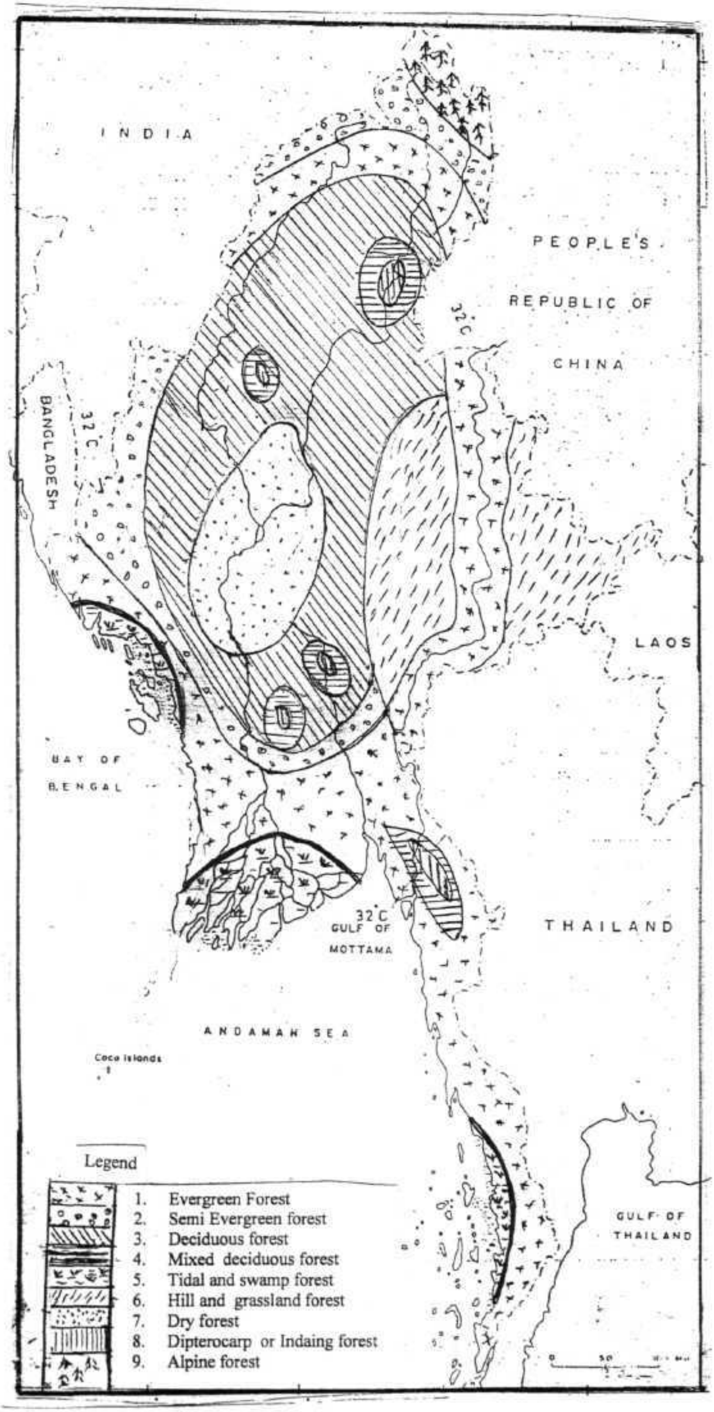

Figure 2.14 Natural Vegetation of Myanmar

species is Casuarinas. Other smaller evergreen species and a few deciduous types are found, species commonly found are Thinwin, Thabye and Thin ban.

(3) **Swampy forests:** They are found in inland fresh water swamps or low lying alluvial land usually near rivers and lakes. They are in dense, thickest of coarse savannah grass characteristic feature. The forest is a rather open one of medium height generally containing evergreen species. Species found in the type are Pauk, Kye, and Yon.

(4) **Tropical evergreen forests:** They cover the Western Rakhine yoma, Southern half of the Sittoung valley, and the whole Taninthayi division. They also occur in sheltered valleys with lower rainfall. Evenly distributed rainfall of over 120 inches (3,078 m) is essential for retentive soil on slopes. It is characterized by the presence of many species of evergreen trees with 150 feet or more in height. Tree species found in this type are Kanyin, Taungthayet, and Thingan. There is an under growth of smaller trees and a tangle of canes, bamboos and palms.

(5) **Mixed deciduous forests:** These forests are the most important forests in Myanmar. They are found where rainfall varies from 40 inches to 80 inches, but also occur on certain sites, which have a higher rainfall. The forest is a closed high forest of excellent quality having the height of 100 feet to 120 feet or more. These forests can be divided into three types, moist upper mixed deciduous forests, (2) dry upper mixed deciduous forests, and (3) lower mixed deciduous forests.

(6) **Dry forests:** They are found in places where the rainfall is less than 50 inches (1270 mm) and it is often difficult to decide where dry forest ends and the driest types of mixed deciduous begin as the two merge gradually into each other. There are three sub-types, namely (a) Than-dahat forest (b) Thorn forest (c) Aukchinsa - thinwin forest.

(7) **Deciduous dipterocarp or indaing forests:** They occur on sandy, gravely and laterite soils up to an altitude of about 2,500 feet. This forest is characterized by the prevalence of *In,* which may form almost as a pure stand. In some places Ingyin and

Thitya may replace In. Indaing high forest occurs over extensive areas in the parts of lower and upper Myanmar and locally in region of high rainfall. Pure high forest of this species may reach a height of 150 feet Semi-Indaing forest occurs throughout Myanmar in the drier tracts. It is found very commonly on ridge tops, where the rainfall is above 50 inches. Indaing shrubs forest occurs throughout Myanmar on suitable sites and soils with rainfall as low as 25 inches (635mm) and as high as 80 inches (032m). The principal species are Ingyin, Thitya, In, Thitsi, Te, Inchin, Linyaw, and Yindaik.

(8) **Hill and temperate evergreen forests:** They occur in high lands with more than 3,000 feet in elevation. If may be divided into three sub-types; (a) hill evergreen forest, (b) dry hill forest, (c) pine forest.

(a) Hill evergreen forest in characteristic of high rainfall and resembles typical evergreen forest the species are Quercus and Castanopsis, Laukya. They can be found in Rakhine yoma, Shan highlands and in the area of Myintkyina and Hkamti.

(b) Dry hill forest occurs on drier localities usually where rainfall is not so heavy. Characteristic species are quercus serrata with other deciduous or semi-evergreen species.

(c) Pine forest with pure or almost pure forest of Pine pinus khasya and Pine Merkusic may be found at elevation about 4.000 feet.

Although the general climate of Myanmar is monsoonal with distinct seasons, the numerous transitions between the climates of different regions resulted on an abundance of different transitional plants. Depending on the amount of rainfall, the forest types vary accordingly, Deciduous forest and deciduous dipterouscarp forest are common in areas of heavy rainfall and dry thorn forest are found in places with scanty rainfall.

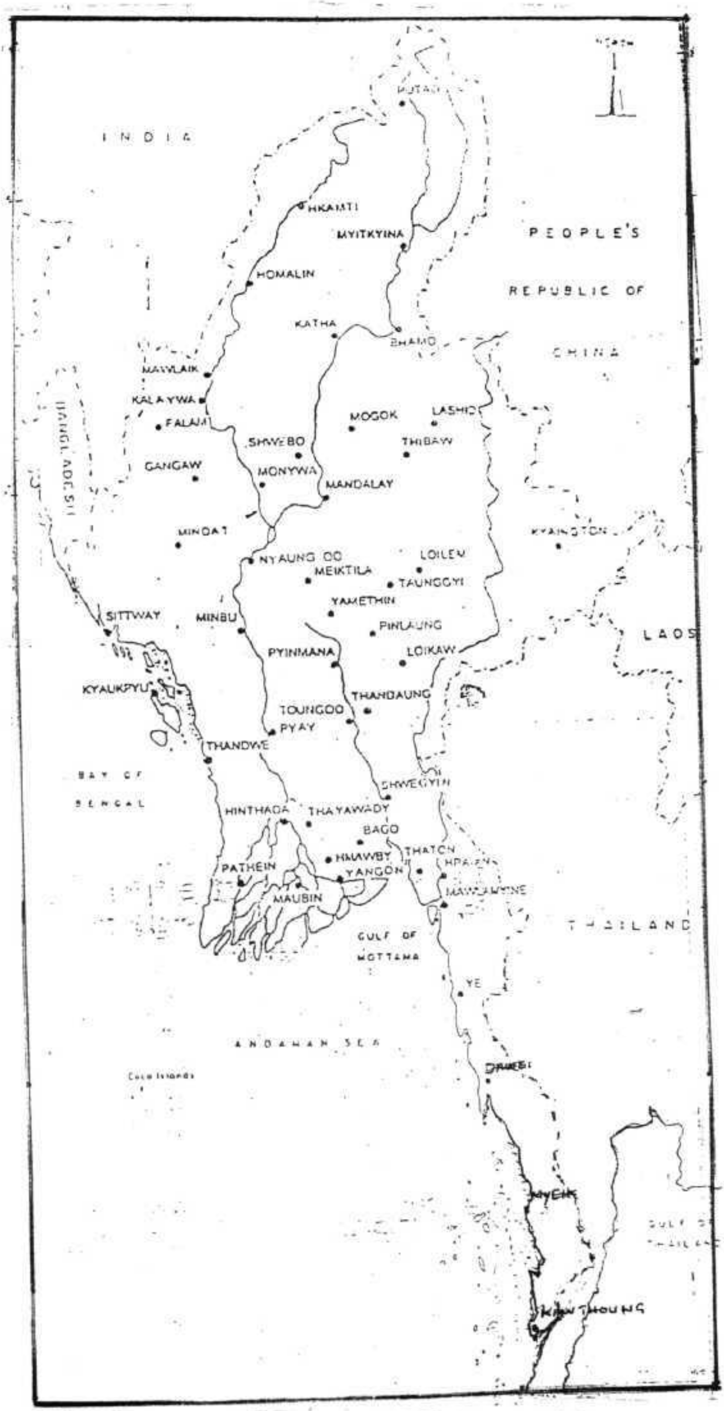

Fig. 14.a
Map showing the Selected Rainfall Stations of Myanmar

Section B

CLIMATIC SETTING OF MYANMAR

In this section the major factors which influence Myanmar's climate are discussed in detail.

2.7 Latitude

Latitude is a very important factor because it determines both intensity and duration of daylight, which increases in summer and decreases in winter. In Myanmar, the latitudinal location between 9° 30 North and 28° 31* North and the Tropic of cancer passing near Tiddim, Tagaung and Kutkhai, indicates that nearly two third of the country lies within the tropics. According to the climatic Zones for Myanmar presented by Drummond, nearly all of the tropical monsoon climate can be seen in the South of the tropic of cancer, (23 ^{l}A North).

Thus, latitude is one of the prime factors in determining climatic zones. According to the table (2.4) the difference in temperature between the warmest and coldest months is always small for the stations in low latitudes and tends to increase towards stations in the higher latitude (see Fig. 2 .15). A special feature of latitudinal effect is illustrated by fig (2.16). At the time of summer solstice (June 21st), the sun is overhead on the tropic of cancer. Thus in those stations located near 23 North, the month of June is the warmest month according to the'mean monthly temperature.

2.8 Altitude

Altitude also influences climate in many aspects. Temperatures may be the same along the same latitude. But, temperatures within the troposphere decrease vertically usually at the normal lapse rate of 6.5 C per 1,000 meter. Thus the mean temperature of Mandalay and that of Pyin-oo-lwin. both of which located almost at the same latitude, vary greatly. The mean temperature of Pyin-oo-lwin, which located almost at the same latitude, varies greatly. The mean temperature of Pyin -Oo- Lwin, which is located 3,500 feet height, is much cooler than those of Mandalay. Changes in altitude also affect air pressure. Air pressure like temperature decreases with increasing altitude similarly; Thandaung (Myohaung) experiences a normal rainfall of

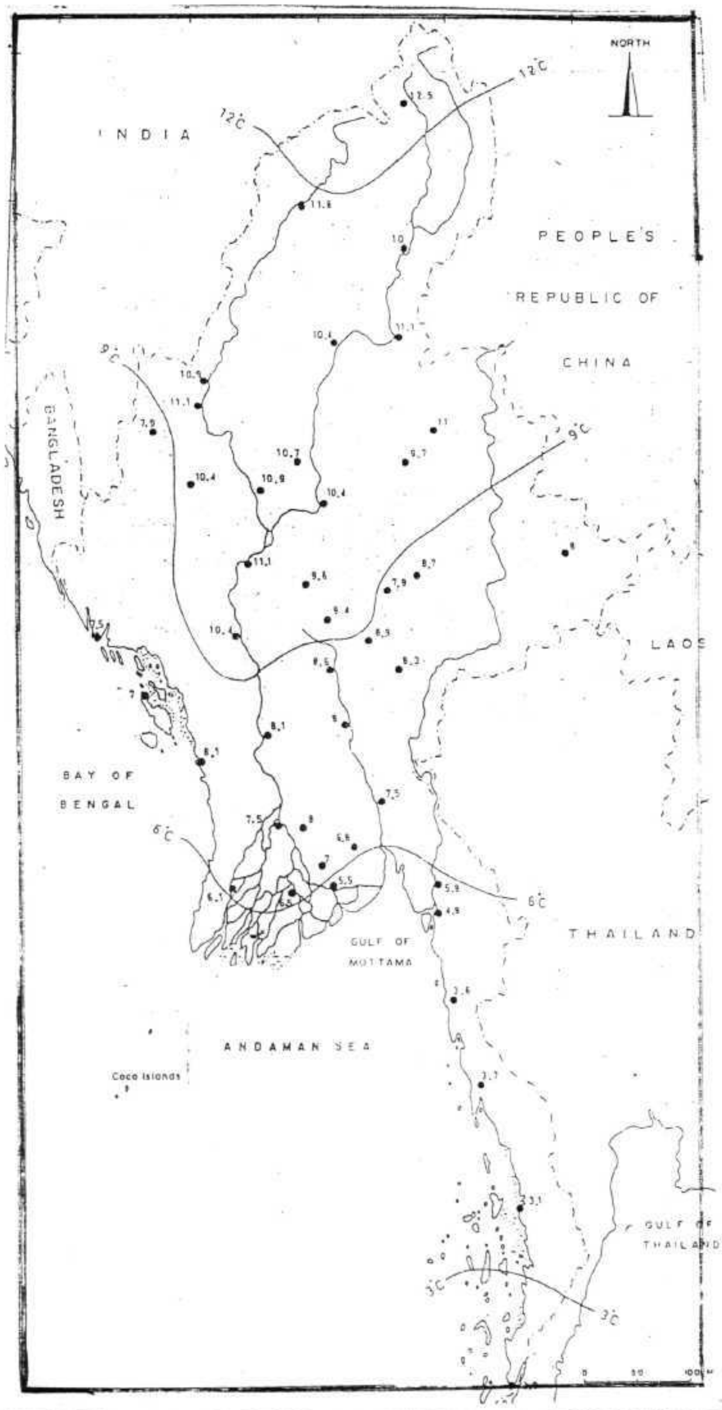

Figure (2. 15) Distribution of temperature differences between the warmest month and coldest month.

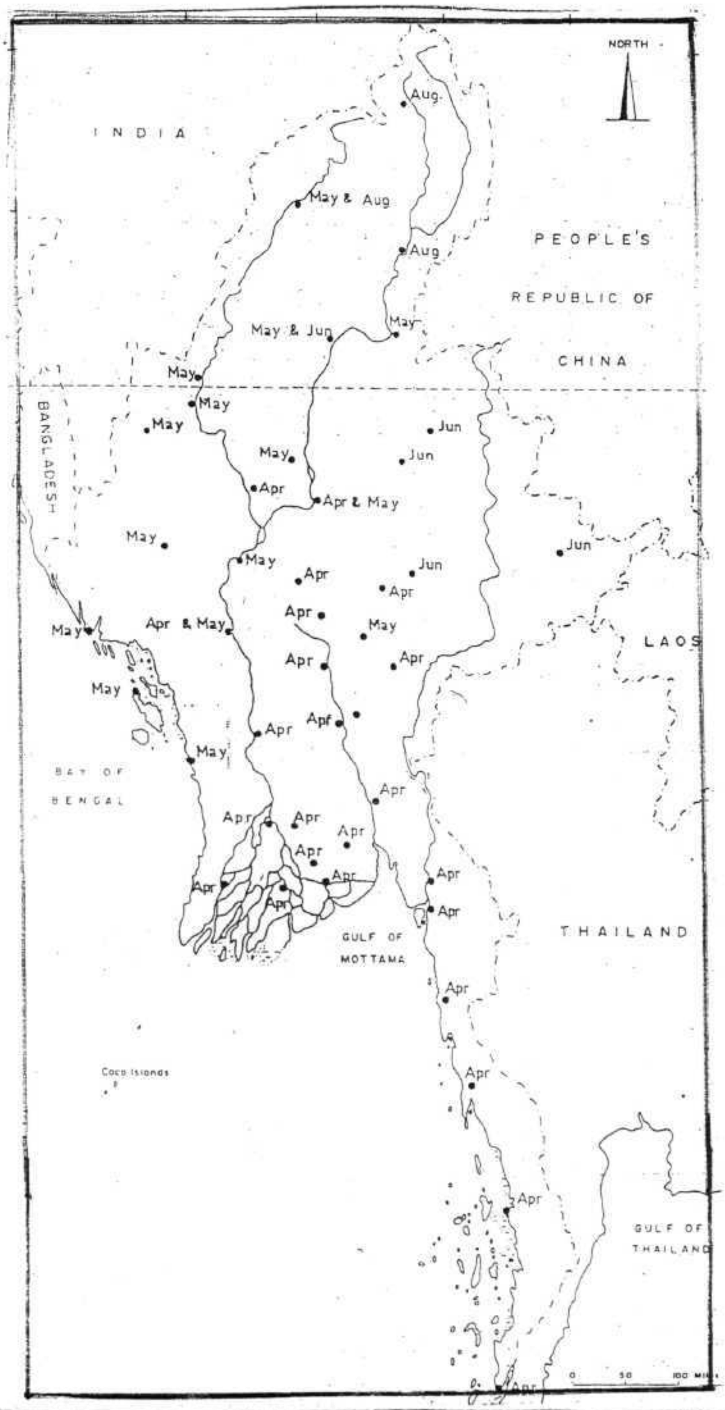

Figure (2.16) The distribution of warmest months according to mean temperature.

223 inches while Thandaung (Myothit) receives only 109 inches. These two stations are only 15 miles apart with latitudinal difference over 3500 feet (Saw, 1974).

Table 2.4 Mean Temperature Differences between the warmest month and Coldest month of Myanmar

Station	Temperature ° C	Station	Temperature ° C
Putao	12.5	Gangaw	10.4
Myitkyina	10.0	Sittway	7.5
Bhamo	11.1	Kyaukpyu	7.0
Thibaw	9.7	Thandwe	8.1
Lashio	11.0	Pyay	8.1
Taunggyi	7.9	Toungoo	8.0
Kyaington	8.0	Thayawady	8.0
Loilem	8.7	Shwegyin	7.5
Pinlaung	8.9	Bago	6.8
Falam	7.9	Hmawby	7.0
Hkamti	11.8	Yangon	5.5
Katha	10.4	Hinthada	7.5
Mawlaik	10.9	Maubin	6.5
Kalaywa	11.1	Pathein	6.1
Shwebo	10.7	Loikaw	8.3
Monvwa	10.9	Hpaan	5.8
Mandalay	10.4	Mawlamvine	4.8
Meiktila	9.6	Ye	3.6
Nyaug-oo	11.1	Dawei	3.7
Yamethin	9.4	Mveik	3.1
Pyinmana	8.6	Kawlhoung	2.9
Minbu	10.4	--	--

Source: Meteorology and Hydrology Department, Yangon, Myanmar, 1998.

2.9 Land and Sea

The distribution of land and water over the surface of the earth is an important control of climate. Due to geographical location, the effects of the Arabian Sea, the Bay of Bengal and the South China Sea influence Myanmar. The storms formed over them govern the amount and distribution of rainfall over Myanmar. Myanmar has a long coastline of about 1,200 miles and hence, the influence of the sea over Myanmar is obvious. Although central Myanmar lies not very far from the Bay of Bengal, the Rakhine Yoma blocks it. Because of this physical situation, the Dry Zone is beyond the reach of the moderating effect of the sea.

Continents and oceans directly affect temperature, as well as cloudiness and rainfall. Water is much more conservative of heat than land, in other words, water is slower to warm up, and slower to cool down. For these reasons, diurnal and annual variations of temperature over and near the sea are small compare to the variation over land. This is significant by the comparison of stations along coastal areas with the stations of central Myanmar the difference in the behaviour of land and water causes diurnal and annual ranger of temperature changes. This results in a difference of pressure, and hence in periodic diurnal and seasonal winds known as land and sea breezes. For rainfall, the proximity to the sea is most profoundly felt when favourable topographic conditions exist. Sittway on Rakhine coast receives rainfall of over 5000 mm (200.in) while Sale which lies to the East of the Rakhine yoma and just 120 miles away receives only 554 mm. (21.8. in) of rain.

2.10 Ocean currents

A considerable analogy exists between the currents in the atmosphere and in the oceans. Next to isolation, the ocean currents are the principal factors controlling the water temperature, which has a large effect on the climate. The North Equatorial Current and Equatorial Counter Current are the main controllers of the Asian climate. The surface currents of the Indian Ocean do show that in the upper layer of this ocean, which transported by the wind is an important factor because the direction of flow changes according to the wind direction. In the Northern part of the Indian Ocean the currents reflect closely the seasonal changes in the wind direction as the monsoon develops. The North Equatorial Current is well developed in February and March during the Northeast monsoon season and the general current drift is from the Northeast. When the Southwest monsoon develops in August and September, the drift of the North Equatorial Current is from the Southwest. During this season, the water flowing along the coast of Africa moves Northwards from latitude 10 South and some of this crosses the equator.

2.11 Mountain Barriers

Mountain barriers have an especially marked effect or rainfall amounts.

Rainfall is heavy where uplifting of air masses takes place. During the period of Southwest early winds, the Southwest monsoon winds encounter almost vertically with the Rakhine yoma and with the Taninthayi yoma and so the air ascends and produces heavy rainfall of 5,100 mm (200 in) per annum in the Western slopes and coastal areas. The deltaic region gets less rain because there are no mountain ranges across the path of the Southwest monsoon.

In Myanmar, mountain ranges run in a generally North-South trend with a gradual decrease of elevation Southwards. Owing to the N-S alignment of the mountains and valleys, the Ayeyawady and Sittoung river basins create the channeling effect. Although the monsoon winds generally blow from Northeast direction in winter months and from Southwest direction in summer months, the}' become Northerly (see Fig 2.17) and Southerly (see Fig. 2.18) in relative months along the river basins in Myanmar. The centra] Myanmar is a region of low-lying topography and most of its areas are under 500 feet contour line. Tae winds mentioned above can pass through the central Myanmar. Therefore, during Southwest monsoon season, the Southerly winds, which enter from the channels, can reach the Northern high land region and precipitate over Northern areas. During Northeast monsoon season, the cold Northeast winds easily cross the central Myanmar arid deltaic region, and the whole country experiences the effect of cold condition.

Central Myanmar lies at a great distance Northward from the seacoast that there is no effect of sea breezes. The existence of the Rakhine yoma prevents the maritime effects and causes the central Myanmar to be continental. During Southwest monsoon months although the wind is channeled towards central Myanmar, the absence of uplift of air or the lack of orographic efiect results in low rainfall in central Myanmar. The nonexistence of mountain ranges combined with the continental condition and with the location of the area, which is leeward side of the Rakhine yoma, central Myanmar, is known as the Dry Zone. Precipitation becomes higher in northern Myanmar due **to** the **high mountain** ranges.

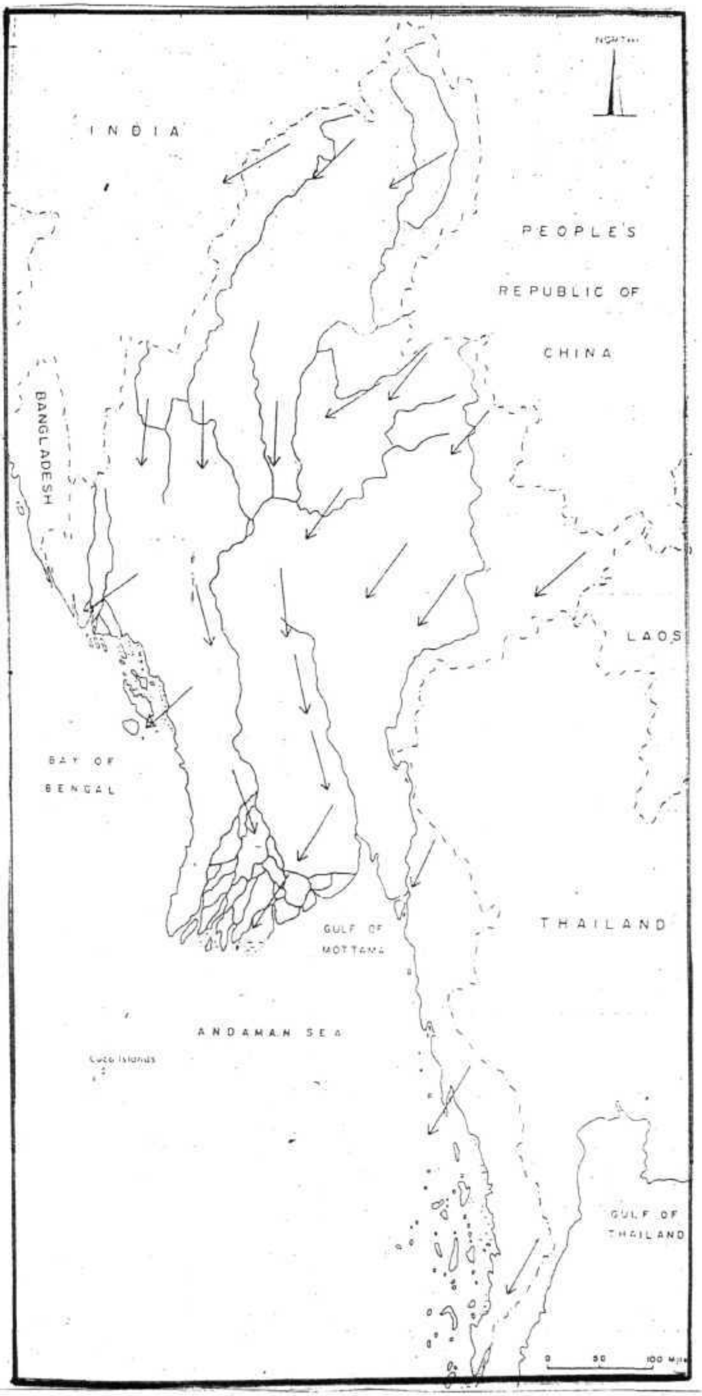

Figure (2. 17) Surface Wind Flows in January.
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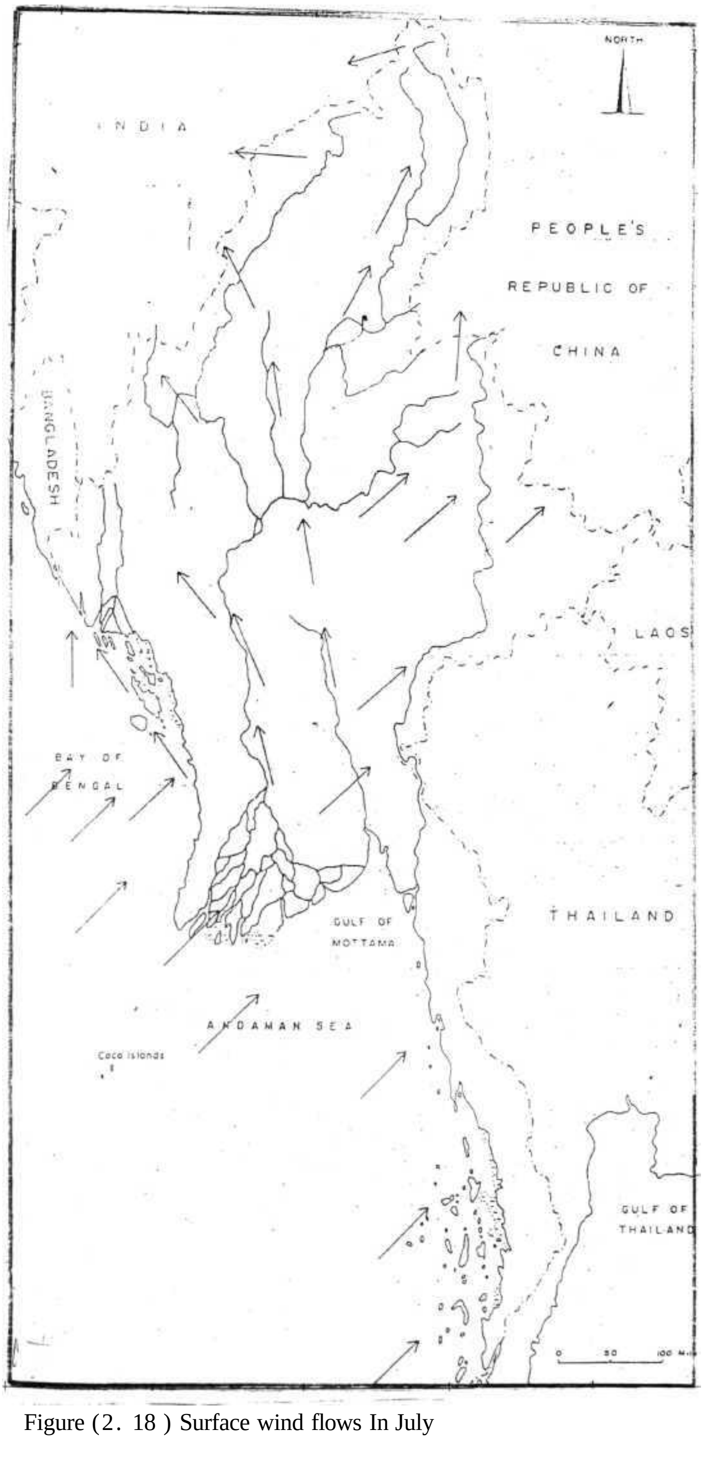


Figure (2. 18) Surface wind flows In July

2.12 Inter-tropical Convergence Zone

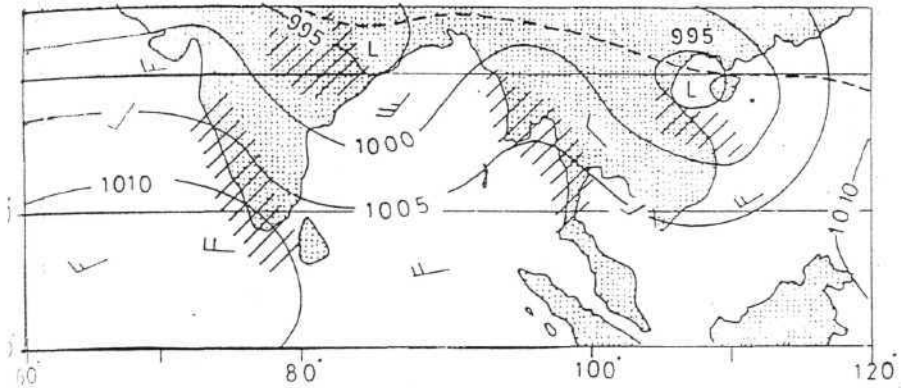
Inter-tropical Convergence Zone (ITCZ) is regarded the equatorial trough, formed in the equatorial convergence Zone where the trade winds from the two subtropical highs in the Northern and Southern hemispheres meet (Trewama, 1954), The structure and characteristics of the 1TCZ vary from region to region depending on such factors as topography and distribution of iand and water surface among others. ITCZ is known as the Northern limit of the South West monsoon or the Southern limit of the Northeast monsoon, and tends to move Northward during the Northern hemispheric summer and Southward during the Southern hemispheric summer.

The TTCZ reaches the Northern most position in Myanmar in July. It gradually moves back Southward and reaches the Southern most part of the Bay of Bengal in later October (Win, 1976). Fig (2.19) shows that the main rain areas lie South of the equatorial trough (ITCZ), and also tend to occur on windward coast and mountains of India, Myanmar and Malaysia peninsula The longest stay of the monsoon trough over the Dry Zone is during the first week of June and during the last week of September. Hie double maximum rainfall in the Dry Zone is associated with this monsoon trough (Hla, 1970).

The most important rate of equatorial trough is the production of the weather of pre monsoon period. There may be violent squalls and thunderstorms along a narrow zone. And ITCZ also provides a frame work for following the South-North motions of the rain-producing Southwest monsoon winds whose depth and motion influence rainfall amount, duration, and distribution (Ayoade, 1983).

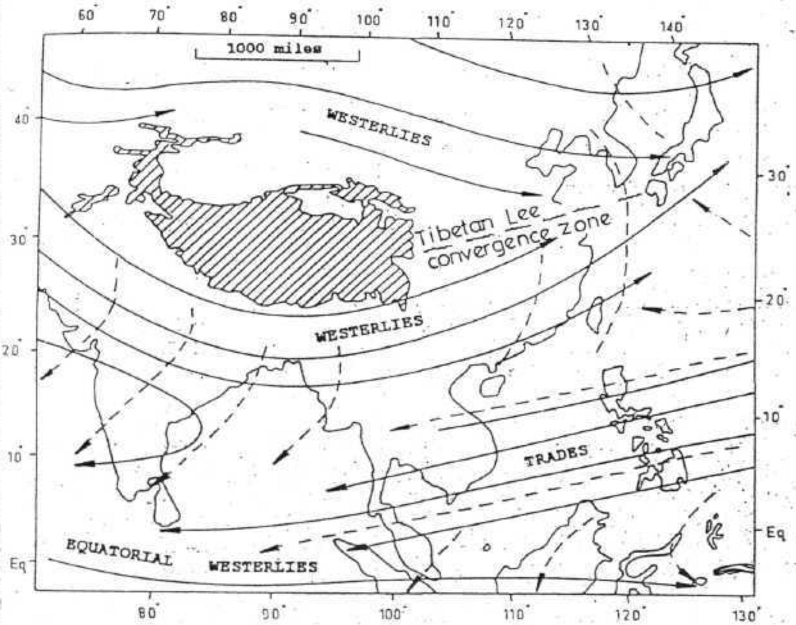
2.13 JetStream

The subtropical Jet stream and the tropical Easterly Jet stream affect the weather and climate of Myanmar. The axis of the subtropical Jet stream reaches latitude 35° North in summer and then shifts equator ward to latitude 20-25 North during winter. The axis **of the tropical Easterly** Jet stream lies between 5 and 20 North **latitudes. During the** winter season, the upper Westerly split into two currents to the North and South of **the high Tibetan plateau,** to meet again off the East Coast of China (see Fig. 2.20). The Northern Jet may be located over Northern India just South



Source: Barry and Chorley, 1982.

Figure (2. 19) Monsoon depressions of 1200 GMT, 4 July 1957. The broken line represents the Equatorial Trough, and precipitation areas are shown by the shading.



Source: Barry and Chorley, 1982.

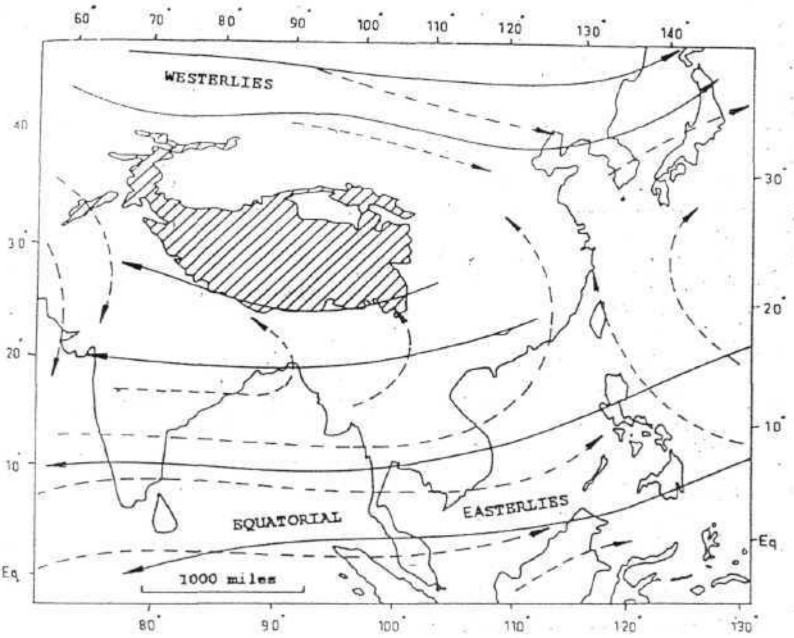
Figure (2. 20) The characteristics air circulation over southern and eastern Asia in winter. Solid lines indicate airflow at about 3,000 m (10,000 ft.), and dashed lines that at about 600 m (2,000 ft.).

of the Himalayas, North of about latitude 25 North. The subtropical Jet over Myanmar and India has its mean position in 27 North, which is the lowest latitude reached by the subtropical Jet over the Northern hemisphere (koteswaram, et al, 1953). Air subsiding beneath this upper Westerly current gives only out blowing Northerly winds. The surface wind direction is Northwesterly over most of Northern India, becoming NorthEasterly over Myanmar and Bangladesh (Barry and Chorley, 1982). Over Myanmar at the height of 40,000 feet (200 mb) the Westerlies have speed of 75-90 mph during to moths from November to January, which become(90-115) mph in February because of the shifting of the subtropical Jet stream South wards (Moe, 1989).

In March, the upper Westerlies begin their seasonal migration Northwards. The Northerly Jet strengthens whereas the Southerly remains positioned South of Tibet, although weakening in intensity. Gradually in late May or early June, the Jet disappears completely over Northern India and takes up a position at about 40 North to the North of Himalaya and Tibet (Trewatha, 1966). Over India, the equatorial trough pushes Northwards with each weakening of the upper Westerly South of Tibet, but the final burst of monsoon with the arrival of the humid, lower level South-Westerlies, is not accomplished until the upper-air circulation has switched to its summer pattern (see Fig. 2.21).

The early onset of summer rains in Bangladesh and Myanmar is favored by an orographically produced trough in the Westerlies at 300 mb (30,000 feet), which is located at about 85°-90° East in May (Barry and Chorley, 1982). The low-level changes are related to the establishment of a high level Easterlies jet stream over Southern Asia about latitude 15° North (see Fig.2.21). Over Shan highland at the height from 30,000 feet (300 mb) to 50,000 feet (150 mb), the upper flow becomes low speed from 50 to 80 mph because the Westerlies Jet stream shifts northward.

By mid July monsoon air covers of Southern and Southeastern Asia the South West monsoon in Southern Asia is overlain by strong upper Easterlies with a Pronounced Jet at 150 mb (50,000 feet). An important characteristic of the tropical



Source: Barry and Chorley, 1982.

Figure (2.21) The characteristics air circulation over southern and eastern Asia in summer. Solid lines indicate airflow at about 6,000 m (20,000 ft.), and dashed lines that at about 600 m (2,000 ft.).

Easterly Jet is the location of the main belt of summer rainfall (Barry and Chorley, 1982). Breaks (monsoon breaks) occur in the monsoon rains when mid latitude Westerlies accompanied by the Jet push Southwards.

During October the Westerly Jet re-establishes itself of the Tibetan plateau, often within a few days, and cool season conditions are restored over most of the Southern and Eastern Asia. Thus, the advance and the retreat of the SouthWest monsoon can be represented by the position of the subtropical Jet and of the tropical Easterly Jet.

2.14 Tropical Cyclones

Tropical depressions and storms form an important feature of weather over Myanmar and neighbouring countries. Their principal climatic significance is that they generate clouds and precipitation, and hence they are note worthy chiefly as affecting are climatic element, namely, rainfall. Many cyclones develop from some pre-existing weak tropical disturbances. Tropical storms form over tropical oceans except the South Atlantic Ocean and the area between 6 North latitude and 6 South latitude where the Coriolis force is small. They do not initially develop or become intense unless they are over tropical or subtropical oceans, whose surface-level water temperatures are in excess of 26^{0}-27^{O}C (Gray, 1995).

About 50 cyclones occur in a year in Northern hemisphere (Ayoade, 1983). These tropical cyclones are very notorious because they cause widespread damage and constitute a serious hazard to shipping and aviation. Many cyclones originate and develop in the Bay of Bengal during April, May and September to December, in the Arabian Sea during July to November, and in the South China Sea during the months of July to November (Moe, 1989).

2.14.1 Cyclones in Bay of Bengal

Storms of the Bay of Bengal are of primary importance for Myanmar as they bring heavy precipitation. All depressions and storms of the pre-monsoon season which cross Myanmar coast, originates in the Andaman sea and Southern pail of the Bay of Bengal (Win, 1976.In the Bay of Bengal , the surface temperature of 27.77 C

(82°F) and above during the period from April to October favours the formation of tropical cyclones (Kyi and Thaw, 1982).

Annually, the Average number of depressions and storms formed in the Bay of Bengal is 13. Of the annual total frequency of depressions and storms of 1036, 35 percent (368) has become intensified into storms. It is found that during the 80 years period (1890-1969), 58 storms of the Bay of Bengal occurred during the pre monsoon months of April and May, 135 storms during October and November of the depressions and storms occurred in the Bay of Bengal, 55 depressions and storms had crossed the Myanmar coast (see. Fig 2.22). Out of 55 depressions and storms, 31 crossed in the pre-monsoon months of April and May, 1 in the peak monsoon month of June, 22 in the post-monsoon months from October to December.

Fig 2.22. Frequency of Depressions and storms crossing different parts of Coast of Myanmar, 1890-1969

Coastal belt	J	F	M	A	**M**	J	J	A	S	**O**	N	D	Total
Sitway-Yangon	-	-	-	10	18	1	-	-	1	11	8	2	51
Yangon-Dawei	-	-	-		-	-	-	-			1		4
Total	-	-	-	31	18	1	-	-	1	11	9	2	55

Source: Thaung, et.al., 1994

The pre monsoon tropical storms can bring a lot of rain to almost all parts of Myanmar for at least two or three days. They developed mostly in the Southeast Bay of Bengal and moved into East central Bay of Bengal and crossed the adjacent coasts. During pre-monsoon period, storms which crossed the Myanmar coast were Sittway cyclone in 1884, Kyaukpyu cyclones in 1936 and 1967, Sittway cyclone in 1968, and Gwa cyclone in 1982.

During the peak-monsoon period, monsoon depressions and cyclones are more common in the Northern and in the adjoining central part of the Bay of Bengal. Some remnants of the South China typhoons crossed the Indochina peninsula and they usually intensified into depressions as the cyclonic disturbances of the peak-monsoon Period (August, 1985).

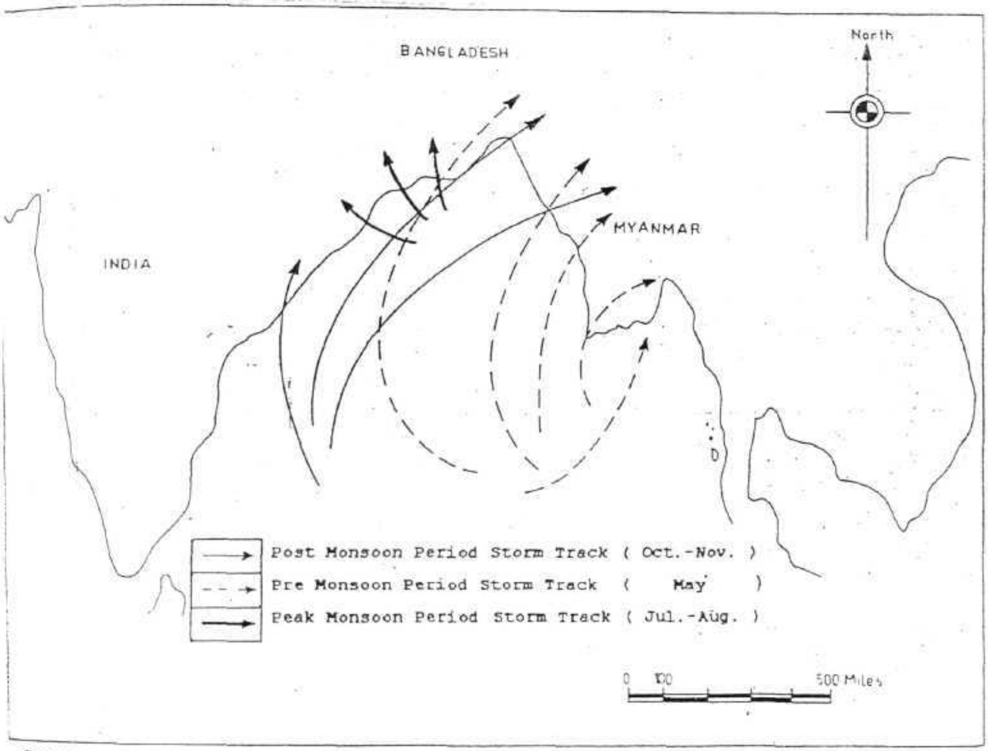
Depressions and cyclones may form during the post monsoon period, originating in the South West or West central Bay of Bengal. (Lwin, 1984). The frequency of depressions and storms that usually form during, the post monsoon period. And, the post monsoon cyclones carry less rain than the pre-monsoon cyclones (Kyaw, 1986). The tropical storms during the post-monsoon months of September, October, November and December; are found to have their origin in the Western pacific. They cross the Indochina peninsula at latitudes lower than that of the tracks of the early typhoon and are intensified in the Andaman and Southern Bay of Bengal .Of the cyclones which crossed the Myanmar coast in October, the cyclones occurred in 1948, 1952 and 1967 were the most pronounced.

The pre monsoon depressions and storms in the Bay of Bengal, while moving in some Northerly direction in the earlier stages, often recurve North or Northeast. During the peak-monsoon period, they usually strike India's Northeast coast (Lwin, 1984). These depressions give widespread rains along the coastal area of Myanmar. Depressions and cyclones occurred in the post monsoon months move Northwest ward at first, and then recurve towards the Rakhine or Bangladesh coast in their final stages, (see Fig. 2.23).

2.14.2 Pacific Cyclone

Storms that originate in the pacific and Gulf of Thailand occur particularly in late monsoon period. When these tropical cyclones move into the Indochina peninsula, they are weakening into waves and continue westward. Typhoons of the Pacific ocean pass the land mass of Vietnam and Laos as low pressure waves bringing some precipitation in the Shan state and Central Myanmar (Win, 1976).The low-pressure waves of the pre-monsoon period are confined to low latitude during later period of April and early May. It is believed that the rainfall of the Taninthayi coastal strip in the pre monsoon period can be attributed to these low-pressure waves. (Win, 1976).

It is believed that during the Southwest monsoon period, Easterly waves reach the North Bay of Bengal Passing across Myanmar and they become regenerate to form monsoon depressions and cyclones. It is found that when these waves become cyclones in the Bay of Bengal the rainfall along the Myanmar coast is much more



Source: Lwin, 1984.

Figure (2.23) Mean Storm Track of the Bay of Bengal intense. A bout 3 to 4 Easterly waves cross over the country towards the Bay of Bangle during this months (Moe, 1989). In Myanmar, many regions have maximum rainfall in July, and the central Myanmar has little rain in this month. Because the track of the waves locate North of the central zone and there are only 1 or 2 Easterly waves in this month. During the months of June and September, about 4 Easterly waves cross the Dry Zone and about 3 waves in August (Moe, 1989). These Easterly waves are usually weak disturbances and present in the form of waves. Most of these are the remnants of the tropical cyclones in the South China Sea and the Western North Pacific. Some are also found to be associated with land depressions (Hla, 1984). These remnants of typhoons give untimely rain and Flood in central and deltaic area.

2.15 Western Disturbances

Within the upper Westerlies, troughs move from West to East at varying speeds. Most of the troughs that are found in the Westerlies during the pre monsoon period produce thunderstorms only in very limited area ahead of the trough at 300 mb (30,000 feet). These Eastward moving low level cyclonic circulations are called "Western Disturbances"'. Western disturbances are very common from late March to May over Northern and central Myanmar. The post monsoon season of October and early November may still have periods of disturbed weather. Northern Myanmar has rains due to these Western disturbances. An average number of four to six disturbances can be expected in January and February every year (Lwin. 1984).

2.16 Thunderstorms

Most thunderstorms usually frequent in Myanmar are the heat or local thunderstorms that come under the air mass type. These thunderstorms mainly occur in pre monsoon (April and May) and post monsoon (October and November), hi Myanmar, most thunderstorms usually occur in Southern Taninthayi and Ayeyawady Divisions. As for the yearly average, Pathein has 78.7 days of thunderstorms, which still is the peak occurrence in the country. The lowest thunder storm frequency is in Mawlamyaine which has only 18 days.

Heavy rainfalls, caused by the thunderstorms, are usually short-time showers associated with sudden, gusty winds with blowing speed up to 80 miles per hour. Though very rare, the thunderstorms are sometimes associated with hail showers. Therefore, in central and Northern part of Myanmar, hail-stone showers occur from 20 to 50 times in a period of 100 years. When there is a break (monsoon break) in rainy season, the sun-heat could become intense which mostly causes local thunderstorm.

Section-C

SOCIO-ECONOMIC SETTING OF MYANMAR

The present section portrays the social economic and cultural setting of Myanmar. The purpose of this section is to show how environment determines the socio cultural and economic style of the inhabitants and vice versa.

2.17 Political History of Myanmar

Early history of Myanmar began with the founding of the first capital of the Myanmar Kingdom at Tagaung, 100 miles up-river from Mandalay, reputed to have been thriving during the 5th century B.C. the Pyu civilization which fallowed flourished in the Ayeyawady valley from Tagaung to Pyay (former prome) in the 1st century B.C., and reached a high level of economic, social and cultural development

Archaeological findings reveal that parts of Myanmar were inhabited some five thousand years ago .The ancestors of present-day Myanmar, the Pyus and the Mons established several kingdoms throughout the country from the 1st century A.D. to the 10^{tjl} century A.D. From that early beginning, till today a fascinating 135 nationalities call Myanmar home.

Myanmar's greatness in the history dates back to early 11th century. There were three golden periods in Myanmar history; King Anawrahta consolidated the whole country into the first Myanmar Empire in Bagan (1044 A.D-1077 A.D). The Bagan Empire encompassed the area of the present-day Myanmar and the entire

Menam valley in Thailand and lasted for two centuries. The Bagan dynasty collapsed with the invasions of Mongols under Kublai khan in the 13 ' Century.

The second Myanmar Empire of the Toungoo period (1551 A.D-1581 AD) was founded by King Bayint Naung. King Alaungphaya founded the Third Myanmar dynasty in 1752 and it was during the zenith of this Empire that the British moved into Myanmar. Like India, Myanmar became a colony of British but only after three Anglo-Myanmar wars in 1825, 1852 and 1885.

During the Second World War, the Japanese from 1942 till the return of the Allied Forces in 1945 occupied Myanmar. Myanmar regained the status of a Sovereign Independent State since 4th January 1948, after more than 100 years under the British Colonial Administration.

In 1947 the British and Aung San reached agreement on full independence for Myanmar. Most of the non-Burmese peoples supported the agreement, although the acquiescence of many proved short-lived. Despite the assassination of Aung San in July, 1947, the agreement went into effect on January 4n, 1948. Myanmar became an independent republic outside the Commonwealth of Nations. The new constitutions provided for bicameral legislature with responsible Prime Ministers and cabinet. Non-Burmese areas were organized as the Shan, Kachin, Kayah and Chin states and each possessed a degree of autonomy.

The government controlled by the socialist (Anti Fascist People's Freedom League) AFPFL, was soon faced with armed risings of Communist rebels and of Karen tribes people, who wanted a separate Karen nation. International tension grew over the presence in Myanmar of Chinese Nationalist troops who had been forced across the border by the Chinese Communists in 1950 and who were making forays into China. Myanmar took the matter to the United Nations, which in 1953 ordered the Nationalists to leave Myanmar. In foreign affairs Myanmar followed a generally neutralist course. It refused to join the Southeast Asia Treaty Organization and was one of the first countries to recognize the Communist government in China.

In the elections of 1951-52 the Anti Fascist People's Freedom League (AFPFL) triumphed. In 1958 the AFPFL split into two factions, with a breakdown of order threatening. Primer U Nu invited General Ne Win, head of the army, to take over the government (Oct., 1958). After the 1960 elections, which were won by U Nu's faction, civilians' government was restored. However as rebellions among the minorities flared and opposition in U Nu's plan to make Buddhism the state religion mounted, conditions deteriorated rapidly.

In March 1962, Nay Win staged a military coup, discarded the constitutions and established Revolutionary Council, made up of military leaders who ruled by decrees while the federal structure was retained; a hierarchy of workers and peasants' councils was created. A new party, the Myanmar Socialist Program party, was made the only legal political organization. The Revolutionary Council fully nationalized the Industrial Insurgency became a major problems of the Ne Win regime. Pro-Chinese Community rebels-the "While Flag" Communists-were active in the Northern part of the country. From 1967 onward, they received aid from Communist China, the Chinese established links with the Shan and Kachin insurgents as well. The deposed U Nu, who managed to leave Myanmar in 1969, also used minority rebels to organize an anti-Ne Win movement among the Shans, Karens and others in the East. However in 1972 U Nu split with minority leaders over their assertion of the right to secede from Myanmar. By the early 1970s the various insurgent groups controlled about one third of Myanmar. U Nay Win and other top leaders resigned from the military in 1972 but continued to retain power. A new constitution, providing for a unicameral legislature and one legal political party, took effect in March 1974. At that time the Revolutionary Council was disbanded and U Nay Win was installed as President. Economist strife and ethnic tensions throughout the 1970s and 80s led to antigovernment riots in 1988, which caused U Nay Win to resign from office. The series of government that followed failed to restore order, and the military seized control under the name of the State Law and Order Restoration Council (SLORC). In June 1989, the military government officially changed the name of the country from Burma to Myanmar. In 1992, General Than Shwe became head of the junta and assumed the position of Prime Minister, many political prisoners were released, most married law decrees were lifted, and plans to draft a new constitution were announced.

Under SLORC, Myanmar, adhering to an active and independent, non - aligned foreign policy, participated in the activities of the United Nations and its agencies, cultivated friendly relations with all countries, especially its neighbors, and took an active part in regional affairs, joining the Association of South-East Asian Nations on 23 July 1997. SLORC took initiatives to end the insurgency that had troubled the country since Independence and concluded cease-fire agreements with most of the armed ethnic groups. With peace restored in border areas, SLORC extended and intensified its development and drug eradication programmes in the border areas and established a separate Ministry for the development of the border areas. In the country as a whole SLORC embarked on construction programme which included the building of bridges, roads and railway lines to improve communication, the building of dams and reservoirs to expand cultivation, opening new colleges and Universities, Hospitals and Health centers to upgrade the education levels and to improve health conditions, the building of Satellite Towns for better housing living conditions.

On 15 November 1997 SLORC was reorganized as the State Peace and Development Council (SPDC) in order to better cany out its task of making Myanmar a modern, developed nation. The State Peace and Development Council (SPDC) Myanmar moved toward closer political and economic relations with neighboring India and Thailand in the 1990s and in 1999 it was accepted as a member of the Association of Southeast Asian Nations (ASEAN). (Facts about Myanmar, 2000)

2.18 Population growth

Myanmar has a long tradition of keeping population records, but during the reigns of kings no extensive census enumerations appear to have been made. In those days, population counts might have been made for the purpose of military recruitment and taxation, but those records have not survived to the present time.

The first population census was taken in 1872 for lower Myanmar, as a province of India, under British administration; it was followed by a second census in 1881. The first nation wide census was taken in 1891 and decade censuses were conducted regularly until 1941 (IMPD 1975 p.7).

Table ***2,$*** Census of Myanmar, 1872-2003

Year	Area covered Sq Km	Populations in (000'S)	Density Sq Km	Census Date
1872	226,770	2,747	12	15Augl872
1881	225,900	3,737	17	17Febl881
1891	703,004	8,098	12	26Febl891
1901	585,881	10,491	18	1 Mar 1901
1911	597,873	12,113	20	10 Mar 1911
1921	603,747	13,213	22	18 Mar 1921
1931	604,744	14,667	24	14 Mar 1931
1941	678,034	16,874	25	3 Mar 1941
1953	678,034	19,103	28	J Mar 1953
1973	676,578	28,921	43	31 Mar 1973
1983	676,578	35,308	52	31 Mar 1983
1985	676,578	37,544	55	31 Mar 1985
1990	676,578	41,354	61	31 Mar 1990
1993	676,778	43,116	64	31 Mar 1993
1995	676,578	4,5106	67	31 Mar 1995
1996	676,578	45,565	67	31 Mar 1996
1997	676,578	46,400	69	31 Mar 1997
2000	676,578	49,008	72	31 Mar 2000
2003	676,578	51,660	76	31 Mar 2003

Source: Asia-Pacific Population Journal Vol. 6, No.,pp.22

Several attempts have been made to estimate the population of Myanmar after independence in 1948. In 1953 and 1954 the census was taken in two stages, urban and rural, respectively. The first stage population count covered all of the urban areas, but the second stage could not cover all the rural areas because of security conditions prevailing at that time.

The nationwide census could only be taken in 1973 and 1983 as a mass movement with the enthusiastic and active participation of the entire working people of the country. According to the 1983 census, there were 2,190 wards or 288 towns, representing the total urban areas and 13,756 village tracts in the whole country. Of these, all urban areas and 12,814 village tracks were completely covered. Of the representing village tracts, 112 were only partially covered and 830 totally admitted for security reasons. As a result, the coverage of the 1983 census was 96.6 per cent of the estimated total population (Union of Burma 1986, Part-I, page-11). The 1990 round of census, due in 1993 was postponed as the country was preoccupied with the national convention held for reaching a census on drafting a new constitution.

Another source of data is vital statistics, which is collected by the department of health and the reports complied and published by Central Statistical Organization. The vital registration system covered about almost all of the total urban population and about 60 per cent of the total rural population.

The population was counted as 16 million in 1941 and in 1983 census it rose to 35.3 million. It showed that the population has more than doubled in 42 years. In the year of 1985, 1990, 1995 and year 2000, the population increased to 37,577 million, 41,357 million, 45,106 million, and 49,314 million respectively (Table2.8). The total population growth rate was 1.93, 1.74, and 1.80 respectively.

The urban population growth rate is higher than the growth rate of rural population, because much rural population migrated to urban areas due to the job opportunities and better urban facilities. When the rural population growth rate was 1.77% in 1990 from 1985, urban population growth rate was 2.77 per cent. If growth rates are analyzed for the year 1995 and 2000, rural population growth rates were 1.41 and 1.29 per cent, while urban population growth rates were 2.69 and 3.17 respectively.

2.19 Population Density

The population density of Myanmar has increased over time .In 1941, population density was 25 persons per sq .km, increasing to 43 in 1973 and 52 in 1983. In 2013, the projected population density of Myanmar would be about 93.95 to 120 persons per sq km. The population has increased not only in numbers but also in density per sq km over time. Geographically, the density' is highest in the Ayeyawady delta region, the Central Myanmar, the Sittaung Valley, Lower Thanlwin delta around Mawlamyaing plain, Rakhine Coastal area around Sittway Plain where fertile soils for agriculture are available and the communication and transportation mode is accessible. The Shan Plateau has moderate density of population while the mountainous regions such as Kachin, Chin, Kayin, Kayah States and Taninthayi division are having the lowest density of population.

2.20 Life Expectancy

In Myanmar, data on the expectation of life at birth are available from a few sources such as the Annual Vital Statistic Reports, the reports to the public or Pyithut Hluttaw (Parliament) and Medical research Reports. Results for the country as a whole, and estimates differ; therefore, some scholars have attempted to provide estimates of mortality for the whole country as shown in the table (2.6).

The table *(2&)* shows mortality conditions in Myanmar during the pre war and post war period. During the pre war period, male expectation of life at birth exceeded that of females. However, during the post war period, female expectation of life at birth exceeded that of males and the difference was gradually increased .The component of population growth of Myanmar, namely Mortality and Fertility have declined over time. Vital Statistics revealed that mortality decline was sharp at first and slow later. The estimates from the Census data also confirm the mortality decline over time in Myanmar.

The increase in life expectancy can be observed in three parts. Between 1911 and 1941, the average increase was 1-8 years for males and 1.7 years for females in every five-year period. During the years 1953 to 1973, the average increase was 2.5 years for males and 2.7 years for females in every five years period .In the decade of 1973 - 1983; the average increase in each five-year period was 2.2 and 2.4 years to males and females respectively. However, since these estimates were obtained by using different information and different methods, their consistency is limited and therefore, no reliable estimate for the trend of increase in life expectancy at birth can be made. According to United Nations, 2000 Escape Population Sheet, Life expectancy for male was 60 and 63 for females in Myanmar.

Table *2.S* Expectation of Life at birth Estimated by different Scholars

Year	Life Expectancy of Males	Life Expectancy of Females	Female's Expectancy more than Male's...
*1911	28.91	27.9	-0.21
•1921	27.69	30.58	+2.94
•1931	32.54	34.49	+1.95
*1941	38.60	37.86	-0.74
#1953-1954	35.60	38.2.0	+2.60
#1954-1958	7.37	38.30	+1.00
#1958-1963	39.70	40.80	+1.10
#1963-1968	42.10	43.30	+1.20
#1968-1973	47.50	45.80	-1.30
&1973	45.60	49.00	+3.40
&1973	48.48.60	51.50	+2.90

**ByLwin. 1974pp. 14-22, # byNyunt, P.88, &by Myint, 1980, P.7.*
Source: Asia-Pacific Population Journal, Vol. 6, No.2, p 29.

2.11 Mortality Rate

Myanmar is experiencing relatively high fertility and declining mortality rates. The government of Myanmar promotes a pronatal policy and the country is characterized by high mortality. Mortality, fertility and migration are three basic components that determine population growth .Of these mortality and fertility defines natural increase (or decrease) by the surplus (or deficit) of births over deaths in a given period. Because births substantially out number deaths, rapid population growth is of great concern in many developing countries. The level of mortality is both a basic population parameter and an indicator of the health and development of a country. A decline in mortality rate occurred during the post war period and the greatest reduction was in the decade of 1960-70. During these 10 years, declines of up to 50% occurred in mortality measures. One of the plausible reasons behind these declines might be the effort of the national health programmes, started by the Government of Myanmar in 1950 to improve the health conditions. In this Programme, the government emphasized control of malaria and leprosy, infrastructure and professional training. In the 1960s government expenditure on the health centers rose and were more than double that of earlier times (United nations, 1980, 1993). Estimated mid-year 2000 for maternal mortality is 140 per 100,000 and infant mortality (1-4 yrs), 70 per 1000.

2.22 Fertility

Crude birth rate fluctuated within the range of 42 to 27 per thousand populations over the 30 years period (i.e, 1950-1980). It is apparent that the crude birth rate started to decline during the decade 1970-80. This may be due to many reasons. Of these, knowledge and the use of fertility control may have spread among women, especially the younger generation. One study reveals that, some level of fertility control was present in all age groups of urban women and knowledge of family planning was wider among females in the age group of 25-34 years.

2.23 Migration

As in many developing countries, data on migration are very limited in Myanmar. The last two modern censuses of 1973 and 1983 did not include questions concerning migration. Therefore, the extent and magnitude of international and internal migration are unknown. At the international level, owing to the close population policy of Myanmar, it may be assumed that migration is severely limited and negligible (United Nation, 1987. p 92).

Before Myanmar's independence, many Indians came to Myanmar, especially to work in the docks and factories and bazaars of Yangon, along the railways and in the river ports. A few of them returned to India while others brought their families and settled. The Chinese also came to Myanmar and settled in Yangon and other towns as merchants and artisans. In the far North some Chinese came overland to places like Bhamo. Many of the Chinese have settled in the villages of Myanmar, intermarrying with the Burmese. (Stamp, 1973, p. 148).

2.24 Age structure

The age structure of population is very important because it influences current and future fertility, mortality, and migration. Although there are various ways of examining the age structure of a population, only two are discussed in this section, the distribution by broad age groups and the dependency ratio. The proportion of the young population (aged less than 1-5 years) was about 39 percent. This further increased to 41 percent at the end of 1980. The greater is the decrease in fertility, the greater is the increase in the proportions in the working age group (15-59 years).

The dependency ratio, one of the important economic development indicators for Myanmar can be obtained from the age structure. The ratio is calculated to measure the burden on the working age group of supporting the young and elderly population. Changes in the dependency ratio depend on changes in the proportion of young and elderly people. In pre-war days the dependency ratios were stable at about 0.75 on the average. However the ratios started to increase in the post war period and reached their peak in 1973 at about 0.87 although the dependency ratio had declined slightly to 0.82 in 1983, it was still high. This high level will continue during the next 15 years and decrease again to 0.58 by the year 2013.

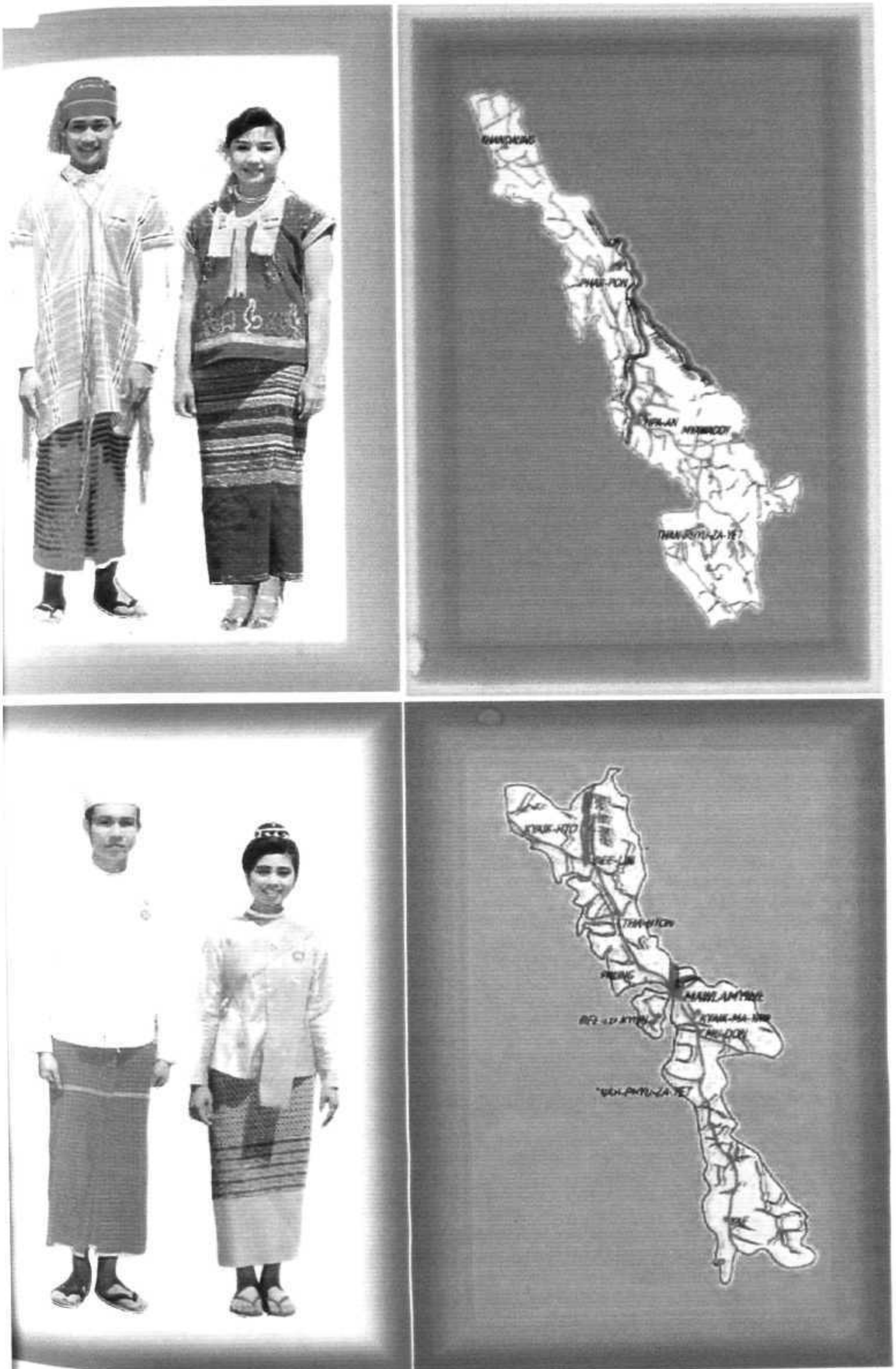
2.25 Ethnic Diversity

Myanmar's population, spread over 7 States and 7 Divisions, was about 46 million in 1996. It is a Union of nationalities of as many as 135 groups, each with their own languages and dialects. The term Myanmar embraces all nationalities: the Bamar, the Kachin, the Kayah, the Kayin, the Chin, the Mon, the Rakhine and the Shan. The population growth rate is 1.88 percent. Current estimates hold that approximately 68 per cent of the Myanmar is Bamars, while a wide array of ethnic groups makes up the remaining 32 per cent. The Bamars dwell largely in the central river valley. The surrounding mountains and coasts contain seven distinct minority states; Chin, Kachin, Karen, Kayah, Mon, Arakan (Rakhine) and Shan. The Shans (9%) and Karens (7%) are the most numerous of the ethnic groups. Each of these and their many subgroups are descended from one of the three major linguistic groups; the Mon-Khamers, The Tibeto-Burman and the Thai-Shans. The main ethnic groups of Myanmar and their regions are shown in (Fig.2.24 to 2.2g)

2-26 Religion

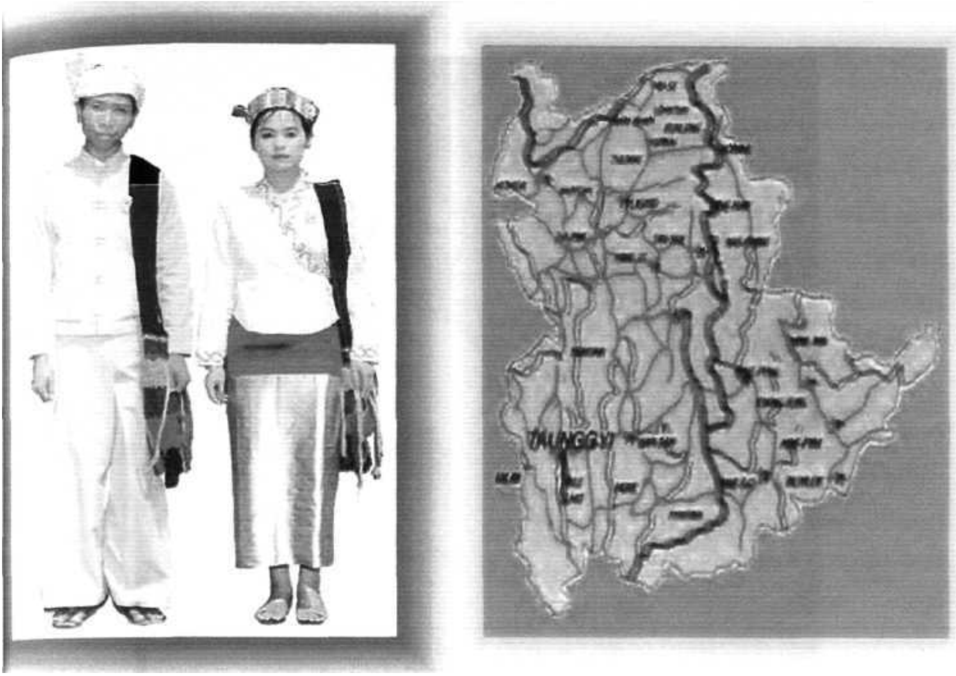
Throughout central Burma and among 85 percent of the Burmese people, the teachings of Buddha are thoroughly interwoven into the fabric of everyday Burmese "fe. Buddhism has dramatically shaped Burmese culture and civilization. An

igure 2.24 Kachin and Kayah Ethnic Groups and their States



igure 2.25 Kayin and Mon Ethnic Groups and their States

ure 2.26 Chin and Rakhine Ethnic Groups and their States



gure 2.27 Shan Ethnic Group and Shan State

Figure 2.28 at Ethnic Group of Bamar

appreciation of Buddhism and its history in Myanmar is crucial to outsiders wanting to understand the Burmese mind. Within Myanmar's several thousand monasteries reside approximately 800,000 monks, novices, and nuns, and most villages are centered on at least one monastery. No Burmese Buddhist household is complete without a small Buddhist shrine, which occupies a prominent place in the home.

The Burmese practice Theravada Buddhism, an ancient sect that adheres most closely to the original teachings of the Buddha spanning 2,500 years. The Mon were the first people in Myanmar to practice Theravada Buddhism, also called the Southern school since it took the Southern route from India, its place of origins during the third century BC when the great Buddhist missionary King Ashoka sent mission to Indochina. A second wave is thought to arrive in Southeast Asia via Sinhalese missionaries from present-day Sri Lanka, sometime between the 6n and 10th centuries.

Christianity is yet another religion practiced in Myanmar through the influence of missionaries when it was under the colonial rule. Since Myanmar became a meeting place for trade and commerce it also lent space for many religious literatures from Hinduism. Most of the people from Divisions, Shan State, Rakhine State and Mon State are practicing Buddhism. From the remaining States especially, Kachin, Kayah, Chin and Kayin, majority are Christians. The Buddhist percentage of the population mainly includes the Bamars, Shans, Mons, Rakhines and some Kayins. People of Indian origin mainly practice Islam and Hinduism.

2.27 Economy

Myanmar is incredibly rich in natural resources; the imperial jade, the best pigeon blood rubies and the finest sapphires, all come from the soil of Myanmar. The fame of Myanmar gems, jade and pearls has attracted many of the wealthiest jewel dealers in Asia and the world.

Myanmar teak is the wonder not only in Asia but the world over. Thousands of elephants and riders each year **extract more than a** million tons of teak and other hardwoods from Myanmar's deciduous monsoon forest. Myanmar is richly endowed with renewable and non-renewable energy resources, which are being exploited by the state sector with the participation of local and foreign investors. Agriculture remains the main sector of the economy and measures have been taken to increase productivity, diversification of crop patterns and revitalization of agriculture exports.

Myanmar suffered extensive damage in the II World War and some sectors of its economy have not been fully recovered. About 70% of its population works in agriculture and forestry and rice accounts for about half of the agricultural output. Other important crops are corn, peanuts, beans, oilseeds, and sugarcane. Myanmar's forests, which are government-owned, are the source of teak and other hardwoods. In 1985 teak replaced rice as the largest single export and together, the two products make up over half of Myanmar's exports.

The country is rich in minerals. Petroleum is found East of the Ayeyawady in the Dry Zone. Tin and Tungsten are mined in East of Myanmar, the Mawchi mines in Kayah State are also rich in tungsten. In the Shan Sate, Northwest of Lashio, are the Bawdwin mines, the source of lead, silver, and zinc. Coal, Copper, Natural gas and Iron deposits have also been found in Myanmar. Gems (notably rubies and sapphires) are found near Mogok. Since the 13th century, Myanmar has exported to China jade from the Hukawng valley in the North.

Besides food processing, other manufactured goods include textiles, footwear, wood and wood products, and construction materials. The country's chief trade partners are Singapore, China, Japan and Thailand. In addition to teak and rice, exports include oilseeds, beans, rubber, metals hardwood, and gemstones. The chief imports are machinery, transportation equipment, food products, and consumer goods. Myanmar's developing economy, depressed by political turmoil, began to recover in the 1980s with increased private activity and foreign investment.

Though Myanmar is one of the least developed countries (L.D.C.), recently it has shown political, social, and economic change. Historically, the key sector in Myanmar economy is agriculture, which provides employment for 70% of total labour force and accounts for the country's major export earnings. The people of whom about seventy five percent live in rural areas are engaged in subsistence agriculture.

Since late 1988, Myanmar has replaced the centrally planned economy with a more liberalized economic policy based on market-oriented system. In moving towards a market-oriented economy, Myanmar has liberalized domestic and external trade, promoting the role of private sector and opening up to foreign investment. The Union of Myanmar Foreign Investment Commission has been set up. Foreign Investment Law, New Central Bank of Myanmar Law, Financial Institutions of Myanmar Law and Myanmar Tourism Law has been enacted and "Chamber of Commerce and Industry" had been reactivated. Myanmar is richly endowed with renewable and non-renewable energy resources, which are being exploited by the State sector with the participation of local and foreign investors.

Agriculture including livestock: fishery and forestry is the most important sector of Myanmar's economy. It is the main source of livelihood for the nearly three quarters of the population who live in rural areas. On the average, the sector accounts for nearly 60 per cent of GDP, providing employment to about 66 per cent of the labour force, and contribute more than 60 per cent of export earnings. In addition to this, the sector provides not only input for processing industries but also a growing market for domestic manufacturers. During the. last four years, the structure of the economy has remained substantially unchanged. The service sector accounts for more than 30 percent of GDP. The share of industrial sector, which composes of energy, mining, processing and manufacturing, electric power and construction, has remained at about 10 per cent. A glance at the ownership of production reveals the private sector as the leading sector, accounting for 77% of real G.D.P. followed by the state sector with 22% and cooperative with 1%, in 2000-2001.

Section D

2.28 Environmental Regions of Myanmar

To identify the Environmental regions of an area, one should thoroughly understand its geography. Geography is not just a description of the countries of the world, but it is the study that seeks answers to the questions of what, where, when, how. There are three important factors in geographical control: Position or Geographical location on the earth surface, Physical features (topography) and Climate, hi many countries the physical features almost make the climate. The physical features of the country control its climate but the next important thing for us to learn is how the control acts. First, physical features and climate together control the distribution of vegetation and the vegetation controls the soils and animal life (flora and fauna). Each type of vegetation has its own characteristic animals.

Man is influenced by all these factors:- physical features, climate, vegetation, soils and animal life. Like in other countries, location and physical features of Myanmar obviously control its climate as discussed in detail in the previous Section. Two thirds of the country, its Southern part, lies in the Tropical Zone (due to its Latitudinal location), and it experiences tropical Monsoon climate. But due to its topography or North-South alignment of the mountain ranges, not all the two thirds of Southern part of the country uniformly receive the tropical monsoon rain. Instead, windward side of the mountainous regions such as Rakhine coastal area and Taninthayi coastal area get more rain than the other regions. The Central belt of Myanmar, being in the leeward side of the Western mountain ranges, receives the least rain of the country as a rain shadow area. After passing over the lowland area in central Myanmar, the Monsoon wind has to rise over the higher Shan plateau and give more rain once again .In this way, if one looks at the cross section of the middle portion of the country, the Western part is the heaviest rainfall area, the middle lowland (central belt or central dry zone) is the least rainfall area and the Shan plateau area is the moderate rainfall area.

According to the physical feature map, the Inner Tertiary Basin can be divided into three regions: the Northern region of Tertiary Basin, from the central dry zone to the North tip of the Khakaborazi peak; the central dry Zone or the middle portion of the Tertiary basin; and the Ayeyawady Delta region or the Southern most part of the Central Tertiary basin. Among these three regions, the Ayeyawady delta region receives more rain due to nearness to the sea and equator, being the flat lowland and free from obstruction as a wind channel area. The Central dry Zone is not only the Reward side of the Western mountain ranges but from the Southern channel wind it can not get rain because of the lack of lifting force which lift up the heat to create convention rain.(Hla,1970). The Northern mountain region is totally located in the temperate zone, and because of the mountains it gets more rain than Central Dry Zone and Shan upland plateau.

Thus, the Central tertiary Basin can be divided into three environmental regions. The remaining Western part of the country can be divided into two as the (Arakan) Rakhine Coastal Strip and Western Mountainous region due to the contrast of topography. The Taninthayi Coastal Strip is an environmental region, which is similar to Rakhine Coastal Strip, but remotely located from it. Due to the country's location, physical features, and climate characteristics of the natural vegetation, soils, and fauna are also different. These natural geographic phenomena again control the socio-economic activities, the agricultural patterns, the human activities, the communication routes, accessibility of the region, the custom and culture, the language, the complexion and the food habit of the people (all the human landscapes) and make them different from one region to another.

Thus, seven Environmental regions can be identified in Myanmar:

1. The Rakhine Coastal Strip, narrow, very wet, and warm.
2. The Taninthayi Coastal Strip, narrow, very wet, and hot.
3. The Western Hills Region, or the Rakhine Yomas, which forms the mountain wall between Myanmar and India.
4. The Shan Plateau, high, with a moderate rainfall, thickly populated.
5. The North Hills Region, or tract of country lying to the North of the Dry Belt, and in which the Ayeyawady and Chindwin have their upper courses,
6. The Dry Belt of Central Myanmar (Central dry zone)-dense population,
7. The Deltas Region of Lower Myanmar-highest population (see Fig. *2.1tf)*

The Rakhine Coastal Strip forms a narrow tract of land between the mountain wall and the Bay of Bengal. It is broadest in the North and gets narrower towards the South. It is mostly hilly, only in one place there is a stretch of flat land. This is in the North near the town of Sittway. The coast is rocky, and there are numerous inlets and islands. The rivers are for the most part short, rushing torrents from the mountains. Only one-tenth of the land is cultivated, one-half a wasteland and

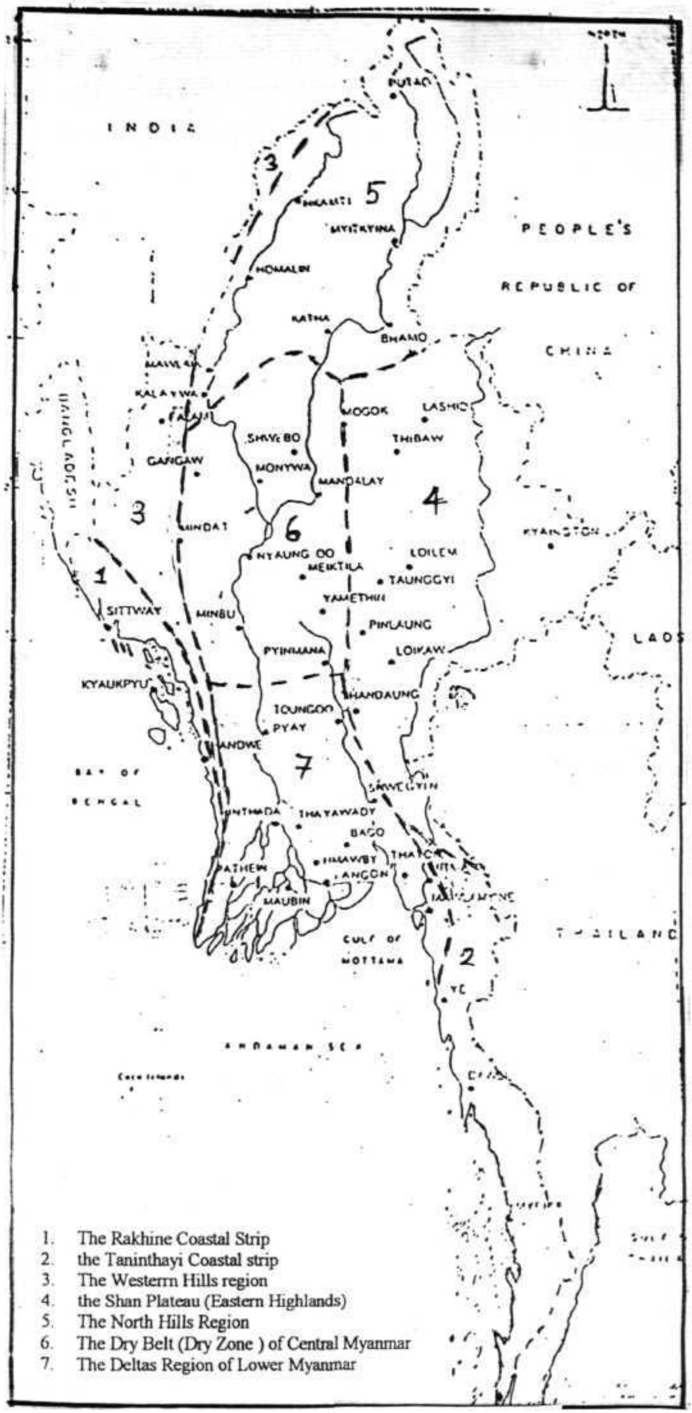


Figure (2.29) Environmental Regions of Myanmar the remainder are covered by evergreen forest or bamboo jungle. Some, but not all, of the wasteland might with difficulty be cultivated. The region catches the full force of the South-West Monsoon and all parts get a heavy rainfall not less than 100 inches (2,500 mm). The most important crop is rice. Most of the people live on the flat land, which lies near the town of Sittway. The ethnic race, Rakhine is the majority in this area. Sittway has a good harbour but it is only a small port because it has a small hinterland backed by high mountains. Some fishing is carried on along the coast. The only easy way between Rakhine and the remainder of Myanmar is by sea.

The Taninthayi Coastal Strip also forms a narrow tract of land, stretching from the Siamese (Thailand) border to the Gulf of Mottama (Mataban). In many respects it is like the Rakhine coast. It is nearly everywhere hilly or mountainous; only in the North, around Mawlamyaine, is there a stretch of flat land. The country is formed largely of ranges of hills running North to South and consisting of granite. Where the granite masses reach the sea they form rocky islands. Between the granite ranges is lower land consisting of old but softer rocks which have been worn away near the coast to form low islands or mangrove swamps. The Thanlwin River passes through the North of the region, past the town of Mawlamyaine, and empties itself into the Gulf of Mottama (Mataban). A large part of the region is covered with dense evergreen forests. This part of Myanmar is getting near the equatorial region, and the rainy season is prolonged and the forest is of equatorial type. Everywhere the rainfall is more than 100 inches (2,500 mm.) and often more than 200 (5,000 mm.). Rice is by far the most important crop. Rubber plantations cover a considerable area, but less than one-tenth of the area is cultivated. The majority of the people live around the old port of Mawlamyaine, but the harbour is becoming choked by mud brought down by the Thanlwin and is not suitable for large ships. Dawei exports the tin, which is mined in the district. Farther South is Myeik, a small port. From the West bank of the Thanlwin, opposite to Mawlamyaine, there is a railway line to Yangon and another Southward from Mawlamyaine. A branch across to Thailand was also built but is disused.

The Western Hills Region consists of a series of parallel ranges, sometimes nsing, as in Mount Victoria, to 10,000 feet. The hills are difficult to cross, and there ^e only a few difficult mountain roads from one side to the other. From South to

North there are the Taungok Pass, the An Pass, the Manipur Route, and the Tuzu Gap. The hills broaden out to the North and taped to sea in the South. During the Japanese War, a motor road was built through the State of Manipur from the Assam railway to Kalewa on the Chindwin and was used by the invading armies of British and /Americans who drove out the Japanese.

The Western slopes of the hills receive a heavy rainfall, but the rainfall rapidly aets less on the Eastern side. The region is clothed mainly with a poor evergreen oak forest of very little value. In some places there are pine forests, but the forests are too difficult to reach for the timber to be of value. In the highest parts are rhododendrons and alpine shrubs. Large parts of the region are practically uninhabited. The few Chin inhabitants lead a difficult existence by growing a few fruits, crops, and paddy on hillside after clearing and burning of the forest as shifting cultivation for life subsidence. The steep sided valleys are often hot in the hot weather, but damp, cold, and feverish in the rains. There are a few towns in the region, but there is a line of large villages to be found where the hill regions pass into the plains. These are frontier villages between the hills and the plains where the people fonn one region meet those from the other to exchange goods. Examples are Saw, Gangaw, and Kalemyo.

The Shan Plateau is a broad area of old hard rocks, mostly 3,000 feet above sea-level, but deeply entrenched by the deep, narrow Thanlwin valley, and by other river valleys. The Western border is well marked, and the land drops rapidly to the level of the Ayeyawady and Sittaung Valleys. The plateau receives a moderate rainfall and a large area of the wasteland might be cultivated, but the land is very sparsely populated, and the Shans, Palaungs, and Wah are not very progressive. Then there are considerable areas of grassland suitable for sheep, goats, and cattle. Especially in the valleys there are valuable pine forests, as yet little used. Mention has already been made of the mineral resources. Two railways penetrate into the Shan plateau; one from Mandalay through the hill station of Maymyo to Lashio. Near this railway, and connected with it by a narrow gauge line, are the Bawdwin Mines and Namtu melting Works. From Lashio a road runs on to the Chinese border, crossing the Thanlwin at Kunlong Ferry (Kunlong Ferry Route). North of Lashio is the border town and market of Namkham. The other railway runs from the main Yangon-Mandalay line through the hill station of Kalaw or Heho. A road goes on to Taunggyi, one of the most important centers in the Shan States and on across the Thanlwin to Kyaington, another important center. In the North of this area there used to be an old trade route from Myanmar into China from the town of Bhamo on the Ayeyawady, along the Taping Valley into the Chinese Province of Yunnan. It had long been projected to build a modern motor road connecting the two countries and when the Japanese invaded China in 1937 and cut off the Chinese from their ports, the famous Myanmar Road, as it is called, was completed, one branch running from the railway at Lashio, another from the port at Bhamo, both going to the Chinese town of Yunnan.

The Northern Hill Region. This region stretches from the mountain wall, which separates Myanmar from Assam and Tibet, as far Southwards as the borders of the Dry Belt. To the East of the region lies the valley of the Ayeyawady. The region on the whole, therefore, slopes from North to South. The rainfall in the North is heavy- more than 80 inches (2,000 mm.) getting less as one goes Southward. The hills are clothed with valuable forests and much tea is obtained from this region. In the North the country is wild, inhabited by a few Shans and Kachins, and is little known. In this Northern region lies the small town of Putao, formerly 290 miles by mule track from the Northernmost point of the railway. During the war against Japan this track was replaced by a motor road, continued across the mountain to the railhead in Assam. The terminus of the Myanmar railway is at Myitkyina on the River Ayeyawady. The famous jade mines of Myanmar are in this region, and the jade is brought to Mogaung and sent to China through Bhamo. On the River Chindwin are several river ports such as Kalewa.

The Dry Zone is next to the Deltas Region, the most important region of Myanmar. It is generally speaking a plain and in the center lies the isolated mountain of Mount Popa, nearly 5,000 feet high. Mount Popa is an old volcano, and lies at the Northern end of the Bago Yomas. The Dry Zone may be defined as the region, which receives less than 40 inches (1,000 mm.) of rainfall. In the center the rainfall is as low as 20 inches (500 mm). It is too dry for the proper growth of forests, and the natural vegetation is a poor scrub. One of the small trees is cutch, from which a yellow dye is made. Although it is so dry, there is a good population in the Dry Belt. Some parts, especially round Shwebo, South of Mandalay and near Minbu, are irrigated and paddy ls grown. In other parts the Dry Zone crops - sesames, millet, beans, groundnuts, and cotton are grown. The great oilfields of Myanmar are situated in the Dry Belt. The most important is Yenangyaung; others are Singu, Minbu, and Yenangyat-Lanywa. Most of the oil is sent by pipeline direct to the refineries at Rangoon (Yangon). The main highway through the Dry Belt is the River Ayeyawady. Along it are numerous river ports-Myingyan, Pakokku, Magway, Minbu, and Thayetmyo. The main railway from Mandalay to Rangoon serves the Eastern part of the region, and a branch runs to Myingyan. The Dry Belt is the natural center of Myanmar, and from it all parts of the country are easily reached. So we find the old capitals, such as Mandalay and Bagan, are in the Dry Belt.

The Deltas Region comprises the most important part of Myanmar. It consists of the broad valley of the lower course of the Ayeyawady its large delta, and the narrower valley of the Sittaung and the much smaller Sittaung delta. Separating these two alluvial plains is the low range of the Bago Yoma, covered with valuable deciduous forests. Yangon is situated at the Southern end of the Bago Yoma, and so commands both valleys. The rainfall is good, over most of the true delta it is more than 80 inches (2,000 mm.), but decreases Northwards. At the Southern end of the Bago Yoma evergreen forest is found, but farther North is Monsoon forest of teak, pyinkado, and other valuable trees. It is the nearness of these forests to Rangoon and the sea, which had made them especially important. The lower alluvial lands are almost entirely cultivated, and by far the most important crop is rice. All other crops are of little importance. This part of Myanmar is thickly populated except in the forests. The cultivators are mostly Bamars, but there are many Kayins also who have settled in the delta. The towns of the region are mostly collecting centers for rice-examples are Hinthada, Pathein, Maubin, and Bago (Stamp, L.D, 1973).

Summary:

Physically, Myanmar is a well-endowed country- its advantages being its large networks of rivers, its moderate rainfall, its fertile soils and these factors ensure a thick forest cover. Socio-economically, the country is one of the less developed regions of the world, a nation that has not been able to use its physical resources gainfully. In terms of an environment report, Myanmar has diverse ecosystems that make for rich biodiversity and is still relatively unpolluted. But many of its ecosystems are getting degraded due to excessive deforestation, and consequent land degradation. This study selects two such regions that show varying degrees and forms of environmental degradation for a more intensive analysis. Both these regions, the Dry Zone and the Ayeyawady Delta are part of the Inner Myanmar Tertiary basin and hence are part of the same physiographic region, but climate/ rainfall plays an important role in delineating them as two separate distinct regions. In terms of development, these two selected regions show a better profile than the rest of Myanmar. But, environmentally, these two regions, while similar in their other settings, differ in terms of the type and degree of degradation they suffer. Further, both the Dry Zone and the Delta region are two areas that have seen highest ecological degradation in Myanmar.

CHAPTER-HI

RAINFALL VARIABILITY IN MYANMAR

3.1 Introduction

Rainfall variability is of great practical significance in water resource analysis. It explains the availability of water at a particular time and space. The variability of rainfall can be analyzed through variability in the onset and withdrawal of monsoon and variations during seasonal, annual and inter annual periods. The temporal variation in rainfall is also an important component of rainfall analysis. The temporal analysis will help to explain the nature of rainfall variability across time. It may reflect the presence or absence of cyclic nature in it. This type of analysis can reveal the nature of rainfall variability for coming period. These aspects of rainfall variability express rainfall patterns through a time period over a year and also during particular time period of the year.

Variability of rainfall can also be categorized according to the size of region for which it is measured, such as small scale, medium scale and region of large-scale variability. The small-scale variability considers the district, township or any other small area for its measurement. The regional variation of rainfall can be put under the medium category, the state or part of country's rainfall variability analysis may be termed as the large scale value of variability. The unit of duration of rainfall also influences the value of variability. The results of these analyses of variability substantially differ from each other. This means that the result of one spatial unit may not be replicated by the other size/space-unit. The time duration also influences the value of rainfall variability. The daily rainfall variability will always be higher than the annual one. Gupta (1990) has explained that the variability increases with decreasing duration of time considered for analysis. This brings in duration of rainfall as an important factor in variability analysis. The detailed analysis of rainfall variability incorporates variability at various levels.

Variability in rainfall in different parts of the world is estimated by researchers by using different techniques. Naumann (1990) analyzed inter-annual rainfall variability to 17 meteorological stations in Srilanka for the period 1980-81 found that the inter-annual variability of rainfall was high in dry zone when compared to wet zone. Dyer (1982) investigated the behaviour of inter-annual rainfall variability over both time and space by using principal component analysis for the period 1921-1974 in South Africa. Krepper et al (1989) examined rainfall variability over time and space for control and coastal regions of Argentina. They used both orthogonal function and spectral analysis for a 30 years record. This analysis identified area of maximum rainfall variability in the region. Wang and Lis (1990) investigations regarding the rainfall fluctuation in the semi arid region of Northern China revealed a trend towards drier and warmer climates. Blandford (1986) made an extensive study of rainfall variability over India. Patnaik et al (1977) analyzed the temporal variation of summer and winter rainfall over the country, India. Raghavendra (1974) analyzed seasonal and annual rainfall variability in meteorological sub Divisions of Mahahrastra State. Parthasarathy (1984) tried to examine the inter-annual and long term variability of summer monsoon rainfall for 29 subdivisions of India taking 108 year of time period and found high and low inter-annual rainfall variability over Saurashtra and Kutch sub-Divisions and South Assam sub-Division, respectively. Varma et al (1985) did a statistical analysis of summer monsoon rainfall of India for a period of hundred years (1881-1980). They found that the last two decadal periods (1960-1980) were the periods of the highest coefficient of variation and the lowest average monsoon rainfall for India.

Muoley and Shukla, (1987) studied summer monsoon of India over three destined spaces scales, i.e. large, medium and small scale variability. The result of all three analyses is different. The study of Ananthakrishnan and Soman (1987) highlighted the nature of troposphere thermal conditions for years of excess, deficit and normal monsoon rainfall over India and concluded that the decrease in monsoon rainfall is associated with weakening of the troposphere thermal gradient across the country. In another analyses, they (1989) also studied the daily rainfall date from 15 rainguage stations of India over 1901-1990 and found that normal was uniquely determined by the coefficient of variation of the rainfall series. Ram Mohan and Nair (1991) worked out monthly and annual rainfall variability for Kerala State during the period (1901-1989) and concluded that more than five consecutive wet or dry years do not occur in the state. Singh and Mulye (1991) demonstrated that the value of standard deviation, absolute mean decoration and mean absolute inter-annual variability increased linearly with the amount of means rainfall.

(a) Rainfall studies on Myanmar

The first long range prediction of seasonal rainfall in Myanmar was statistically developed by Dr. PO.E (1940). He imposed the pressure departure at selected glacial position as predicators.

Yin (1948) has put forward a very outstanding ecological synoptic feature related to the Southeast monsoon onset in Asia, specific attention was given to the long range weather forecasting in the later areas.

A drought in Myanmar in April-May 1957 was analyzed by Thuta (1958). Some synoptic situations responsible for the rain in central Myanmar area were studied by Hla (1908).

The study in the low and middle Ayeyawady floods in relation to heavy rainfall in the head water was undertaken by Pekyi (1968). Tropical storm related floods were studied by different authors such as San kyaw (1968), Htay Aung (1968), Sein Shwe, U & et al 1968 etc.

In order to investigate the climatology of drought in Myanmar, Aung and Win (1984) and Aung (1990) studied the decade rainfall data from 58 stations. These studies found that the result obtained according to the El Nino years, the droughts of Myanmar were the highest.

hi the assessment of the monsoon rainfalls and climatology droughts for the union of Myanmar during the period of 1980-1998, the driest years were 1957-58, 1972-73, 1979, 1982-83, 1986-87, 1992-93 and 1997-98. During the period;, EL Nino was weak in 1951-52, 1953 and 1963, moderate in 1968-69, 1976-77, 1992-93 and strong in 1957-58, 1965-66, 1972-73, 1982-83 and 1997-98 the dry year in 1997 is due to the failure of the South-West monsoon. All the remaining driest years coincided with the strong El Nino episodes.

Therefore, major drought may be predicated in the Asian region by monitoring EL-Nino events and abnormal shift extension of semi-permanent regional synoptic features. There is a need for research studies for prediction of El Nino events that are related to the insufficient rainfall in Myanmar (Thaw 1997).

(b) Rainfall variability and agriculture

As Myanmar is an agricultural country the development of agricultural economy with its growing population is closely related to the availability of water or annual rainfall for crop production. A large proportion of rain water is used for agricultural purposes. Due to this reason, it is important to know whether the available rainfall is adequate or how well distributed it is for crop production in various parts of the country. Abnormalities in the performance rainfall are manifested as flood in one part and drought in the other part of the country which have adverse effects on agriculture, industry, etc, and other related sectors of the economy. Further it is also important to know about the nature of rainfall trends and the statistical analysis of a time series data of rainfall may enable us to understand the long-term behaviour of rainfall.

The seasonal pattern is the general feature of the rainfall distribution over the year. Apart from the monsoon season, agricultural production depends on other sources of irrigation, which are also indirectly influenced by rainfall. This analysis is intended to find out the extra amount of rainwater available, which can be utilized in 4e period of scarcity.

The analysis of rainfall is also used in designing irrigation projects as it tells us f the rainwater availability in a particular catchment area. The rainfall also influences year after year operating efficiency of irrigation projects. It is also an input in designing drainage and land reclamation activity in a project command area.

The cropping pattern of a region depends mainly on the availability of irrigation water. It may be from rainfall or from ground water the analysis of rainfall behaviour of a region helps in considering particular cropping pattern. It also guides other agricultural schedule related to farm operations. Rainfall information is also considered to be an important factor in estimating the agricultural production of a region. The planning for soil water conservation programme cannot be done without an analysis of rainfall because it determines the efficiency of soil and water conservation activity in the country. The field experiments for soil and water conservation also require accurate rainfall information. The agro-climatic regionalization of a state or country is mainly influenced by the climatic factors of the region. Among the climatic factors, rainfall has a predominant role in demarcating the country into various agro-climatic regions.

3.2 Variation in Annual Rainfall of Myanmar

Rainfall variability can be analyzed by the different statistical methods like mean, standard deviation, and coefficient of variation. The statistical values of annual total rainfall for each of the 45 stations are tabulated in Table (3.1) and the distribution of coefficient of variation over Myanmar is shown in Fig (3.2) Fig 3.1a to 3.1.0 show the annual variation of rainfall for each station. The data for this rainfall analysis is collected from Meteorology and hydrology Department, Yangon. Of these 45 stations: Mandalay, Shwebo, Nyaung Oo, Monywa, Minbu, Meiktila, Pyinmana, Yamethin are in Dry Zone and the following stations: Pyay, Toungoo, Thayawady, Bago, Shwegyin,Thaton, Maulamyaine, Hmawby, Yangon, Hinthada, Maubin, Pathein are in the Delta Region.

According to the coefficient of variation, the lowest variability is observed at Putao, the Eastern Highlands, and coastal area of deltaic region and coastal strip of Taninthayi with a value of 10 percent to 15 percent. The region of lowest rainfall variability includes such stations as Putao, Taunggyi, Thayawady, Myeik, Toungoo, Yangon, Hmawby, Bago, Lashio, Pathein, Thibaw, Loilem, and Myintkyina(Fig

Table 3.1 Variability of Annual Rainfall (1950-2000)

Sl. No	Stations	Highest Value	Lowest Value	Range	AVG	STD	CV	SK	KT
01	Putao	5080	3235	1895	4057.93	424.63	10.46	0.46	-0.07
02	Thayawady	2720	1594	1126	2186.96	257.94	11.79	0.07	-0.44
03	Taunggyi	2008	992	1016	1509.10	184.68	12.24	-0.05	0.81
04	Myeik	4966	2607	2348	3923.27	484.09	12.34	-0.41	0.50
05	Hmawby	3104	1865	1239	2524.93	323.69	12.62	-0.23	-0.85
06	Yangon	3523	1995	1528	2686.27	350.35	13.04	0.24	-0.45
07	Lashio	1918	1020	898	1359.36	178.74	13.15	0.55	1.03
08	Thibaw	1756	1016	740	1302.97	171.95	13.20	0.64	0.31
09	Bago	4188	2083	2106	3182.37	437.06	13.32	-0.31	0.05
10	Pathein	3644	1891	1778	2854.63	390.78	13.69	-0.18	-0.34
11	Toungoo	2591	1363	1228	1964.34	275.21	14.01	0.15	-0.02
12	Loilern	1856	994	862	1391.58	200.08	14.38	0.35	-0.09
13	Myitkyina	3153	1475	1678	2176.78	314.72	14.46	0.44	0.84
14	Pinlaung	2564	1398	1166	1988.09	301.59	15.17	-0.05	-0.69
15	Sittway	5917	2737	3180	4639.60	708.52	15.27	-0.23	-0.09
16	Dawei	7578	3034	4564	5342.67	817.47	15.30	0.23	1.28
17	Mawleik	2228	929	1299	1732.80	265.43	15.32	-0.62	1.02
18	Maubin	3674	1552	2122	2345.62	365.49	15.58	0.83	2.48
19	Bhamo	2460	1255	1335	1804.04	284.15	15.75	0.22	-0.23
20	Kawthoung	5725	3033	2692	4020.73	635.72	15.81	0.67	0.10
21	Kalaywa	2385	970	1415	1661.10	264.53	15.93	0.18	1.06
22	Thaton	8144	3802	4347	5401.65	869.87	16.10	0.97	1.74
23	Mawlamyaine	6908	3437	3471	4790.92	774.84	16.17	0.94	0.84
24	Ye	1973	3215	3758	5112.22	830.60	16.25	-0.14	0.19
25	Thandwe	7678	3691	3987	5470.00	924.57	16.90	0.40	-0.10
26	Falam	2117	1074	1043	1558.23	271.05	17.39	0.10	0.58
27	Hpa-an	5973	2367	3606	4263.48	757.22	17.76	-0.29	0.16
28	Loikaw	1537	630	907	1073.42	194.20	18.20	0.24	0.13
29	Kyaington	1928	593	1335	1263.12	235.55	18.65	0.23	2.61
30	Gangaw	1672	773	899	1285.49	240.09	18.68	-0.07	-0.76
31	Pyinmana	1990	871	1119	1342.84	252.58	18.81	0.36	0.01
32	Hinthada	3691	1489	2202	2288.98	439.07	19.18	0.93	1.79
33	Pyay	1758	734	1025	1240.58	238.75	19.25	-0.02	-0.37
34	Yamethin	1072	493	579	834.10	161.34	19.39	-0.14	-0.95
35	Hkamti	5883	2339	3544	3867.93	772.04	19.96	0.57	0.58
36	Kyaukpyu	8912	2819	6093	4611.10	955.62	20.72	2.33	9.87
37	Mindat	2341	1056	1285	1492.20	313.59	21.02	1.11	0.93
38	Katha	2307	910	1397	1528.31	322.97	21.13	0.31	-0.26
39	Mandalay	1405	483	922	851.31	197.68	23.22	0.81	0.62
40	Meiktila	1345	441	904	825.06	198.99	24.12	0.32	-0.11
41	Shwebo	1369	464	705	854.23	206.12	24.13	0.40	0.28
42	Shwegyin	7175	2240	4935	5339.05	903.54	25.39	2.20	1.62
43	Monywa	1375	407	968	769.88	204.26	26.53	0.87	0.86
44	Nyaungoo	923	248	675	598.47	165.40	27.64	0.03	-0.06
45	Minbu	1260	337	923	790.98	222.28	28.10	0.30	-0.10

von.2000.

AVG ~ Average, STD = **Standard Deviation,** CV= Cumulative Variations =Skewness, KT= Kurtosis

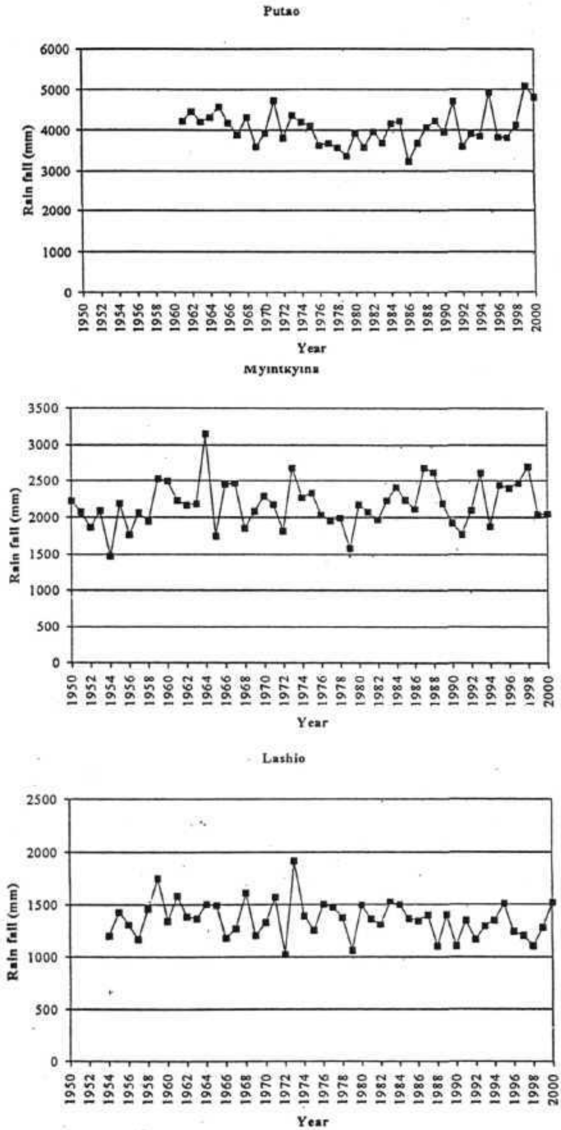


Figure 3.1.a Annual Variation of Rainfall (mm) for Putao, Myintkyina & Lashio

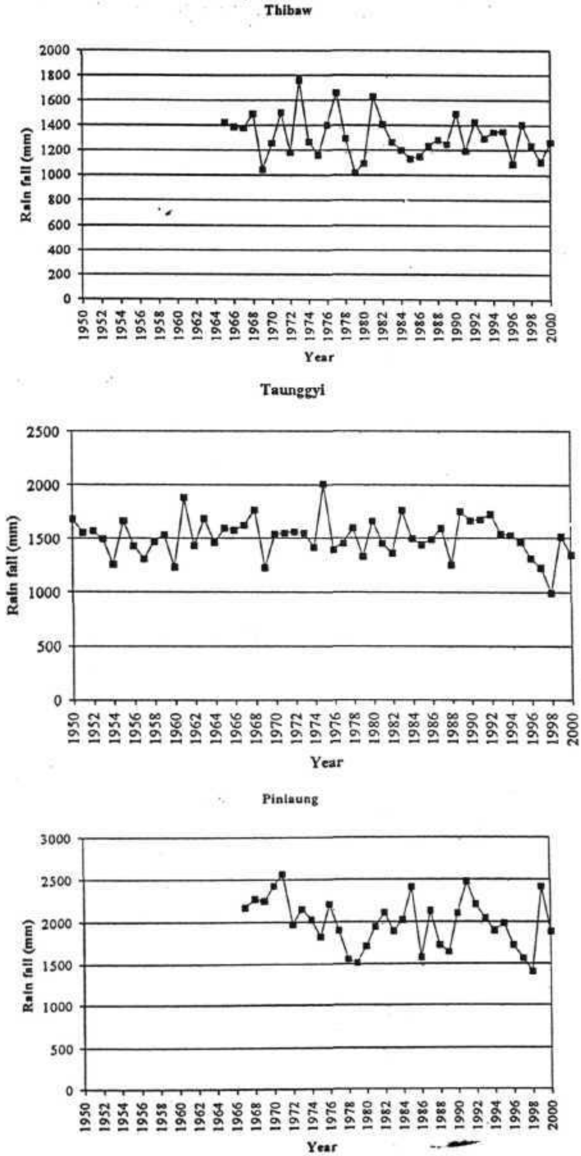


Figure 3.1.b Annual Variation of Rainfall (mm) for Thibaw, Taunggyi & Pinlaung

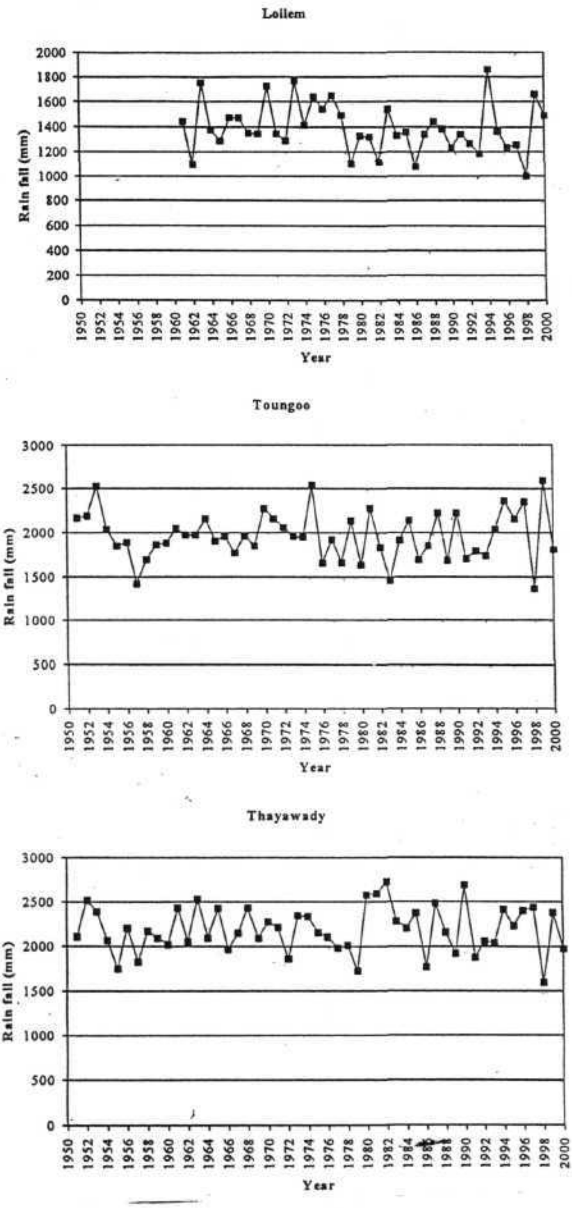


Figure 3.1.c Annual Variation of Rainfall (mm)
for Lollem, Toungoo & Thayawady

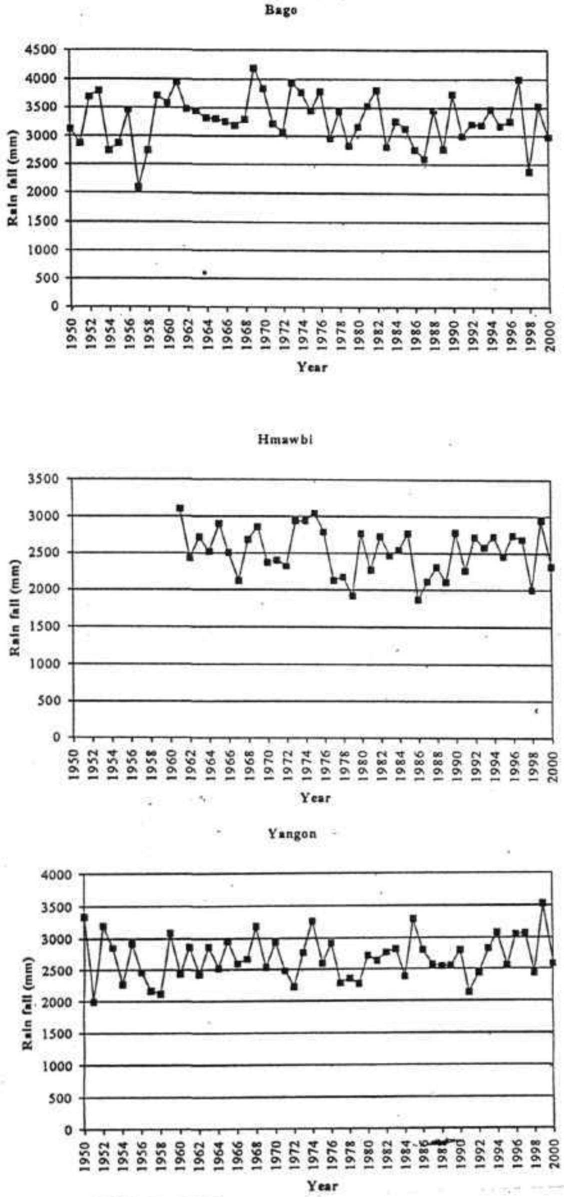


Figure 3.1.d Annual Variation of Rainfall (mm) for Bago, Hmawbi & Yangon

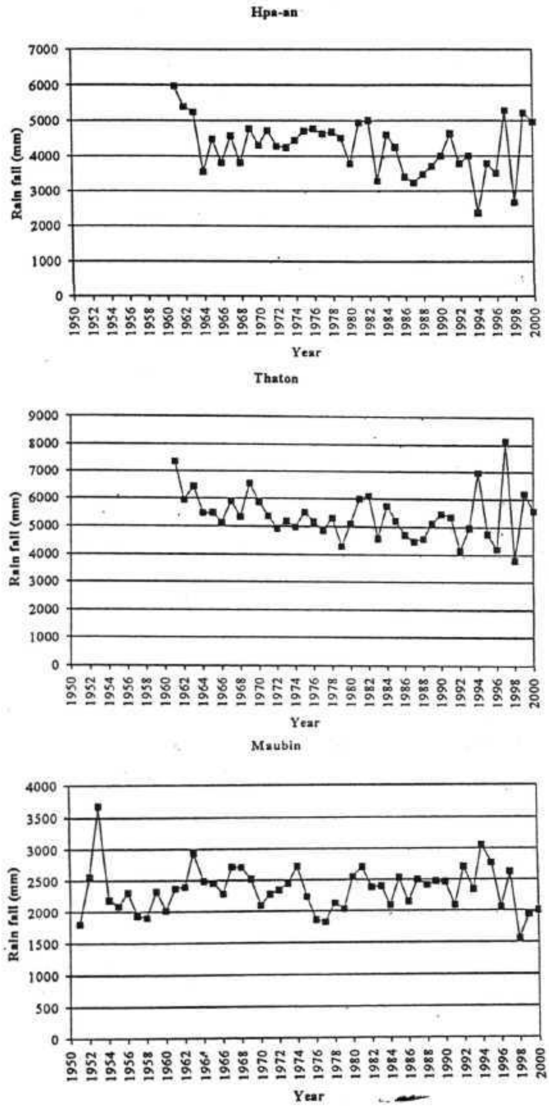


Figure 3.1.e Annual Variation of Rainfall (mm) for Hpa-an, Thaton & Maubin

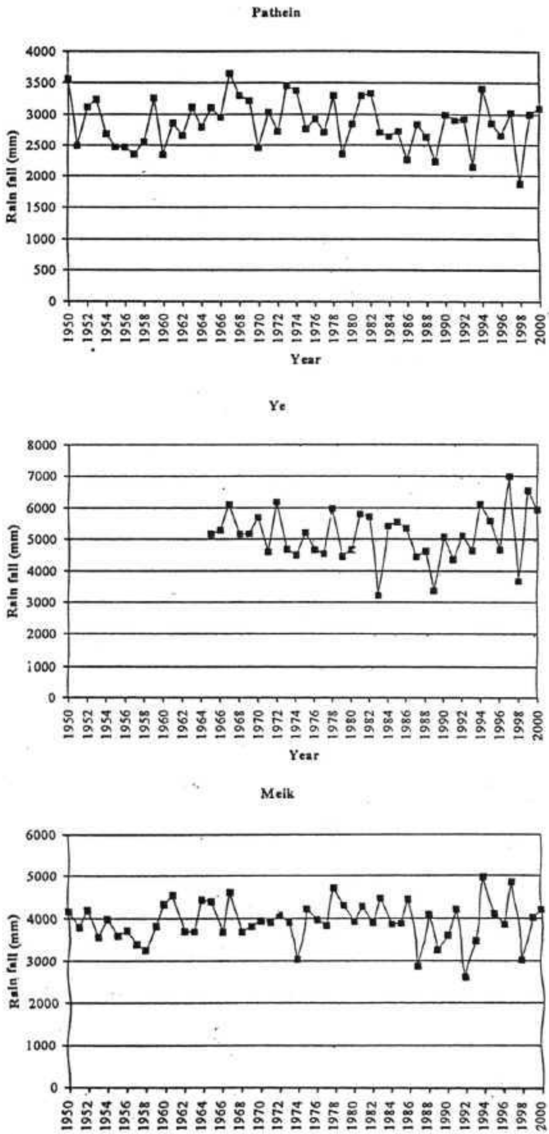
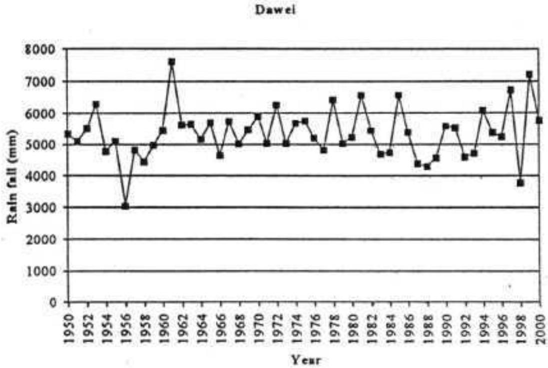


Figure 3.1.f Annual Variation of Rainfall (mm) for Pathein, Ye & Meik



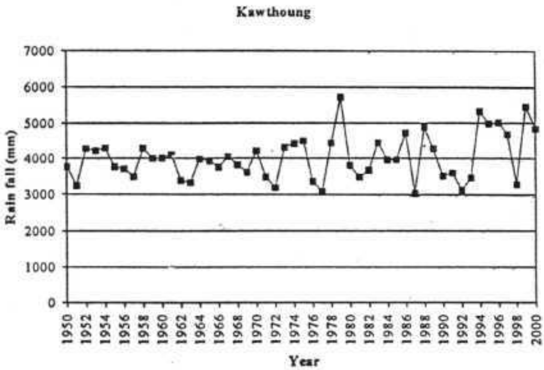


Figure 3.1.g Annual Variation of Rainfall (mm) for Dawei & Kawthoung

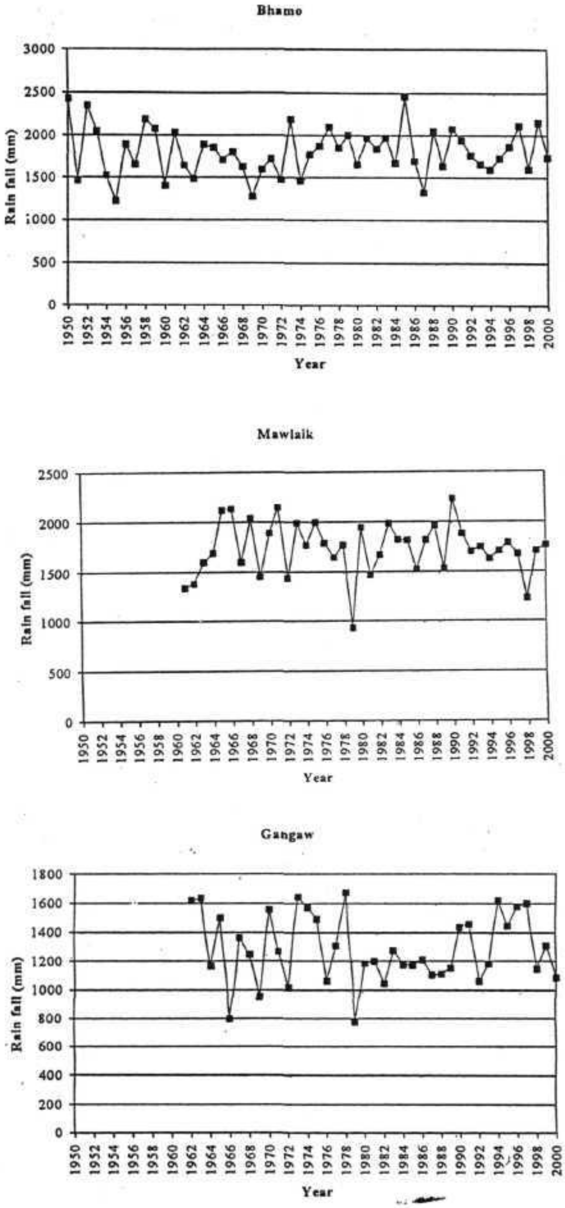


Figure 3.1.h Annual Variation of Rainfall (mm) for Bhamo, Mawlaik & Gangaw

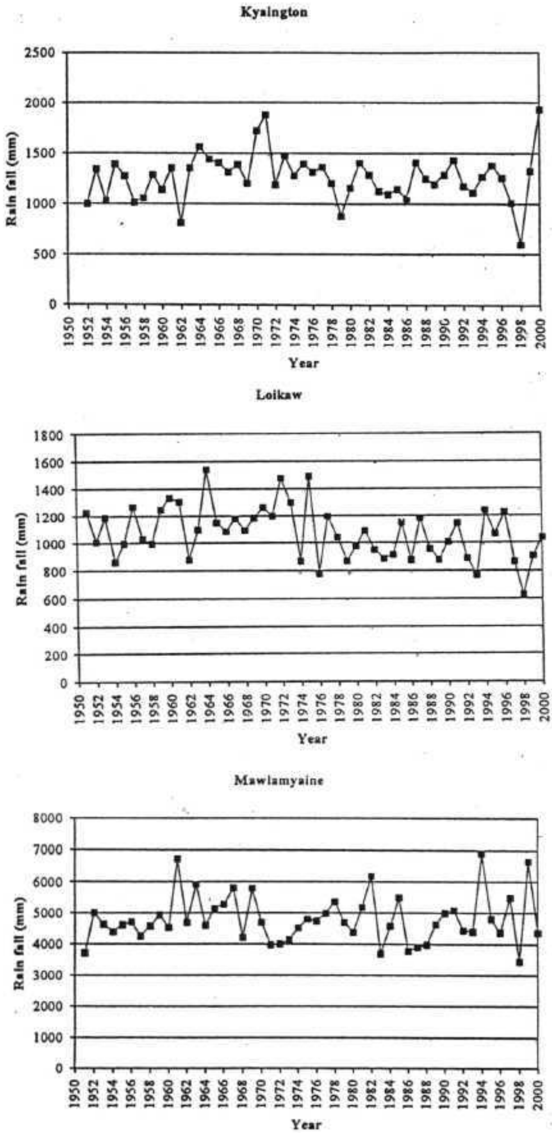


Figure 3.1.i Annual Variation of Rainfall (mm) for Kyaington, Loikaw & Mawlamyaine

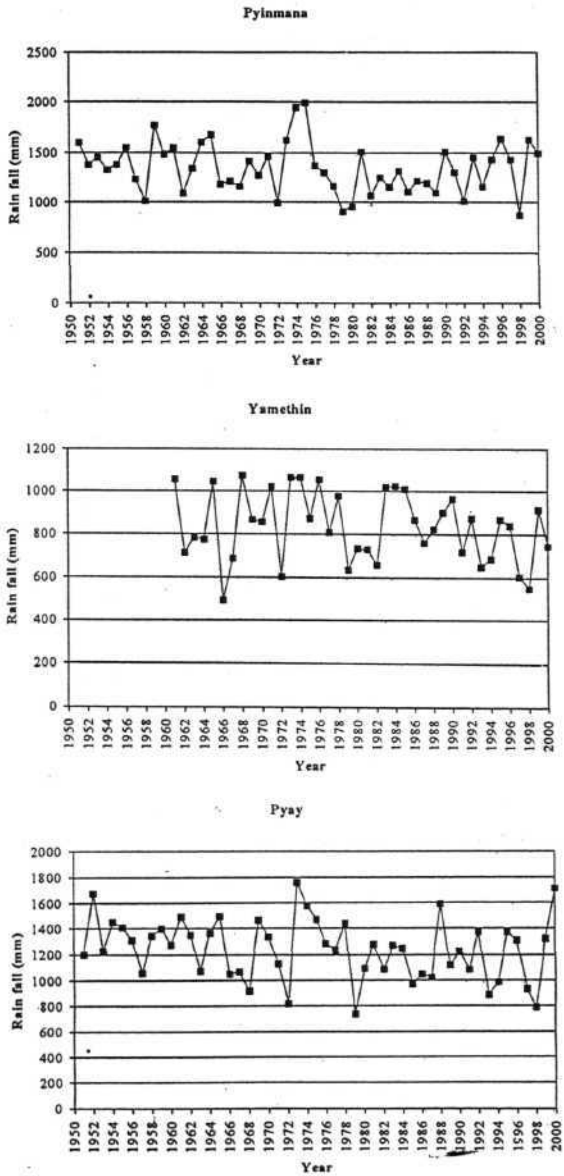
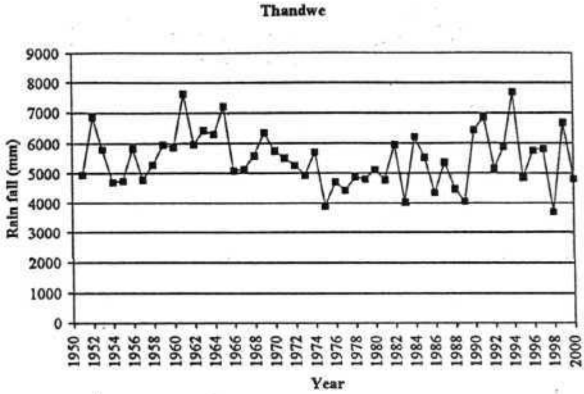
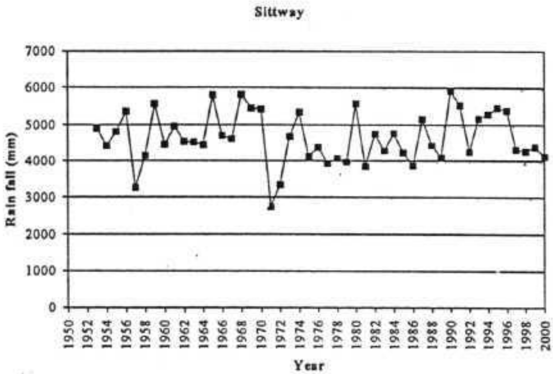


Figure 3.1.j Annual Variation of Rainfall (mm) for Pyinmana, Yamethin & Pyay





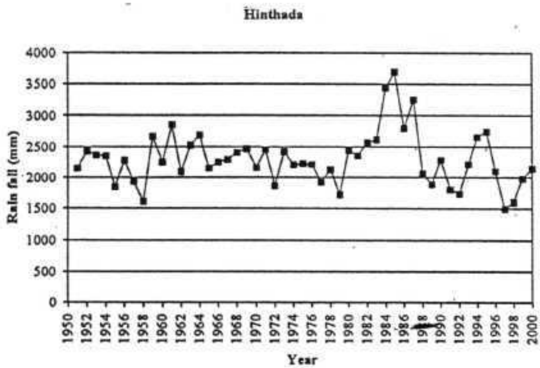
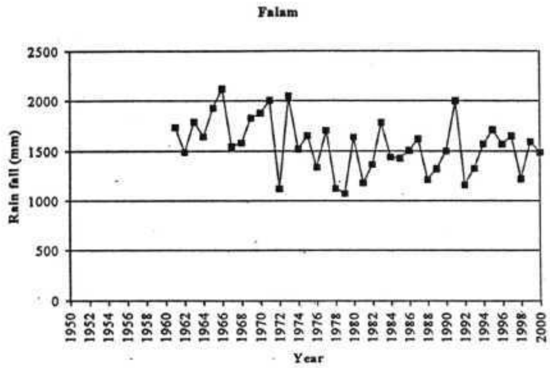


Figure 3.1.k Annual Variation of Rainfall (mm) for Thandwe, Sittway & Hinthada



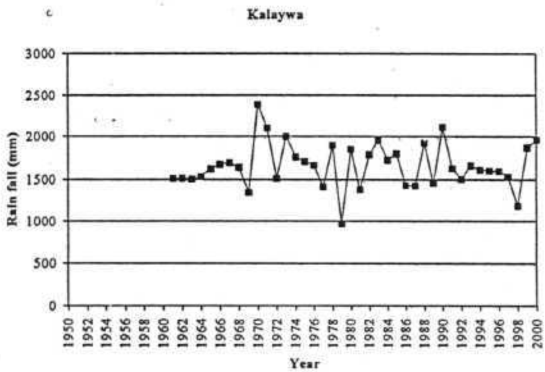


Figure 3.1.1 Annual Variation of Rainfall (mm) for Falam & Kalaywa

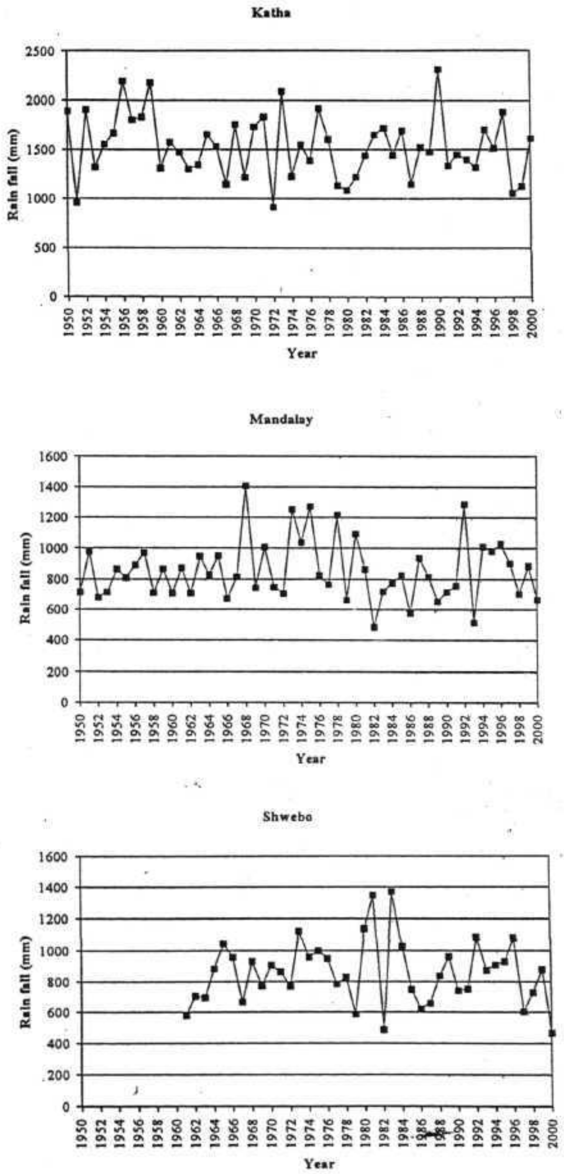


Figure 3.1.m Annual Variation of Rainfall (mm) for Katha, Mandalay & Shwebo

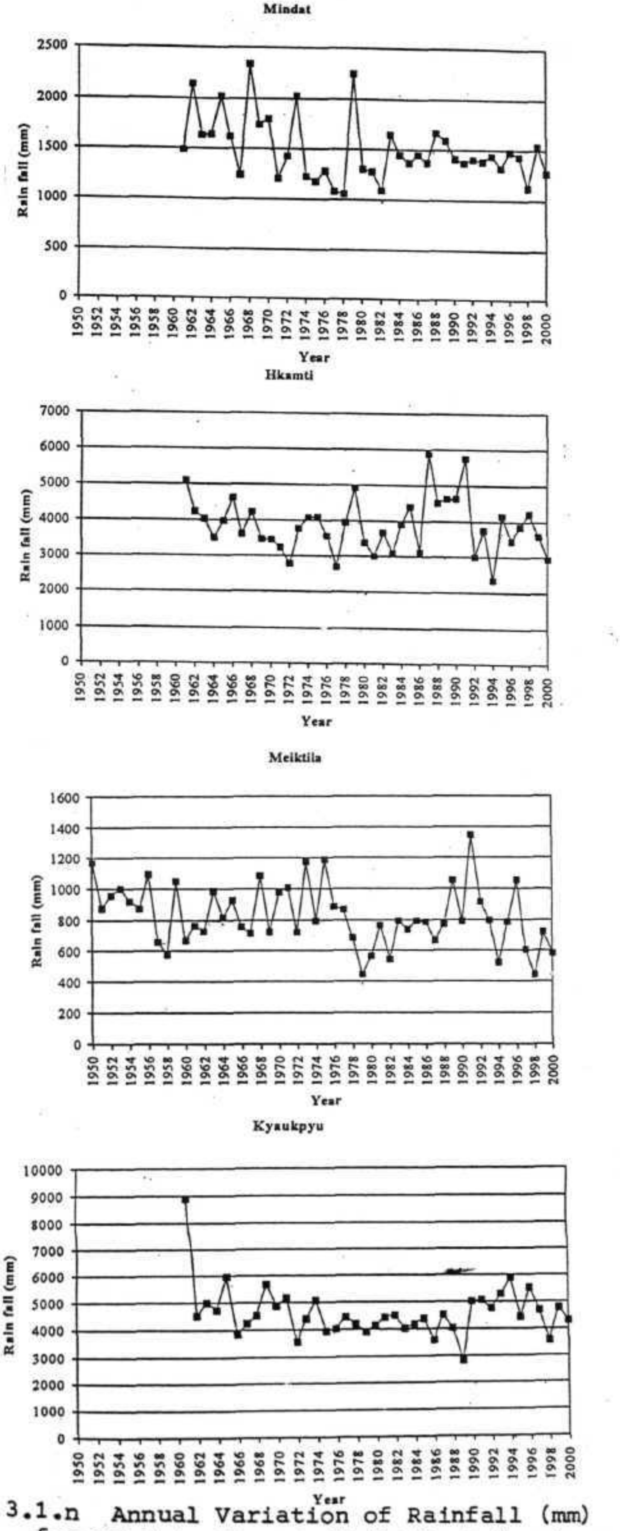
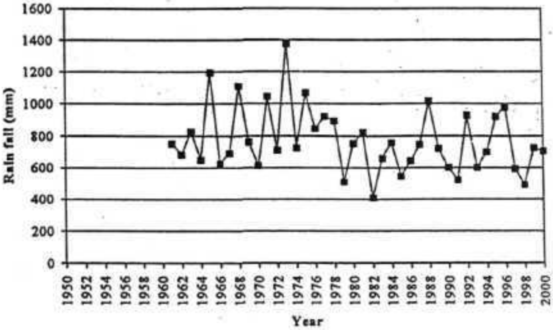
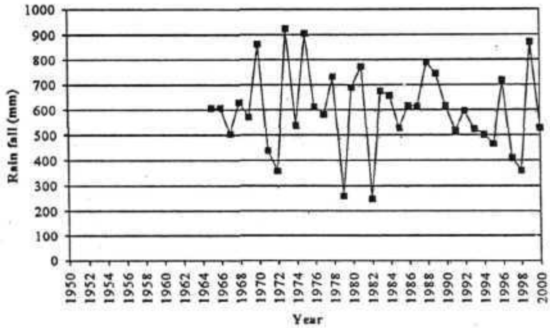


Figure 3.1.n Annual Variation of Rainfall (mm) for Mindat, Hkamti, Meiktila & Kyaukpyu

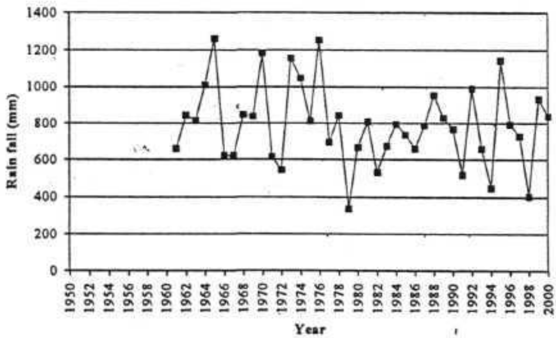
Monywa



Nyaung-Oo



Minbu



Shwegyin

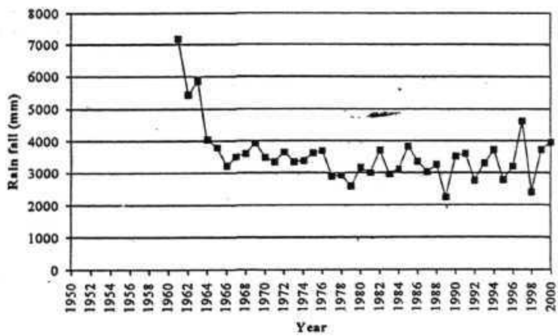
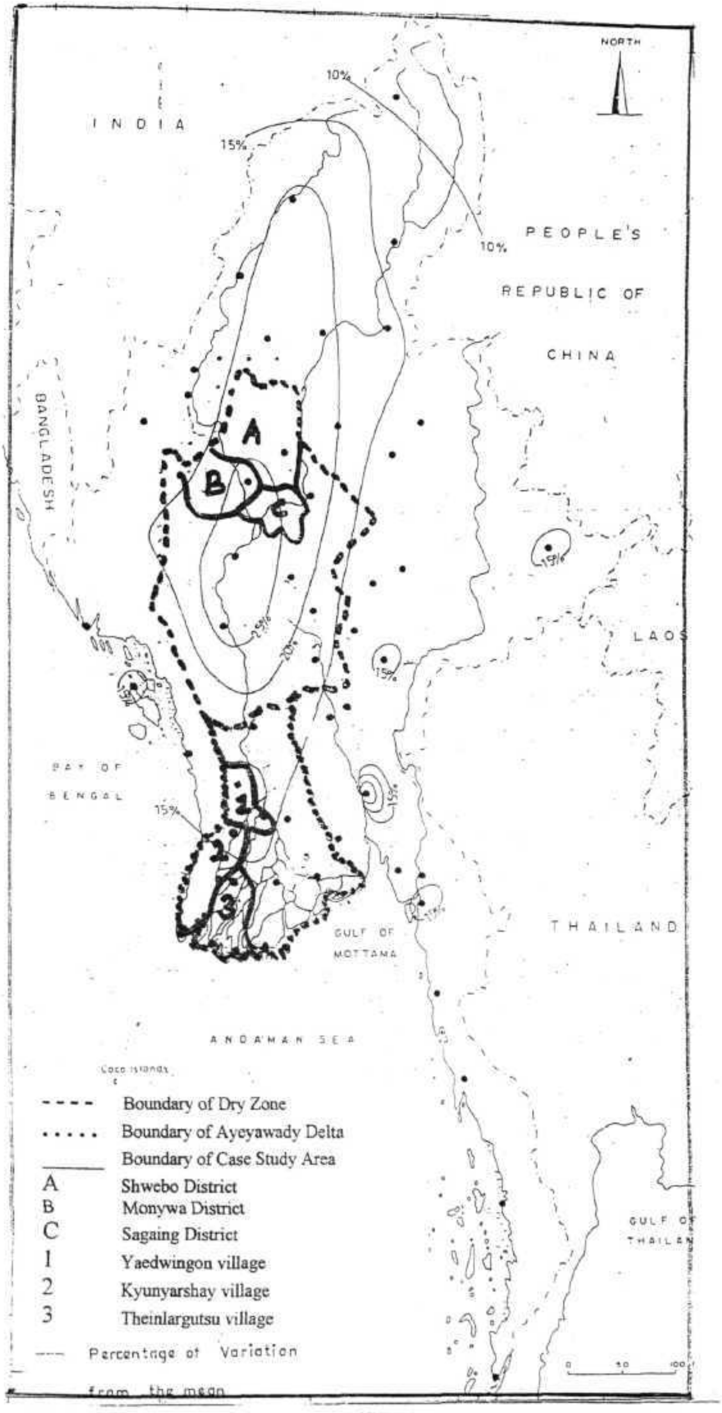


Figure 3.1.o Annual Variation of Rainfall (mm) for Monywa, Nyaung-Oo, Minbu & Shwegyin

3.1.a to 3.1.g). The regions which received the rainfall variability of 15 percent to 20 percent are coastal areas of Rakhine state except Kyaukpyu; Chin state, Western part of Sagaing Division, lower part of Kachin state, Eastern part of Shan highlands, upper part of Ayeyawady and Bago Divisions and Kayah state. The stations are Pinlaung, Ye, Dawei, Kawthoung, Thaton, Mawlamyaine, Hkamti, Mawlaik, Sittway, Kalaywa, Kyaington, Bhamo, Thandwe, Loikaw, Falam, Hinthada, Maubin, Pyay, Pyinmana, Yamethin and Gangaw (Fig 3.1 .h to 3.1.1).

In the middle part of Sagaing Division, Western part of Magway Division, and upper two third of Mandalay Division experience the values of the coefficient of variation from 20 percent to 25 percent (Fig 3.1). It can be seen that Katha, Kyaukpyu, Mindat, Meiktila, Shwebo and Mandalay are included with is category (Fig 3.1.m to Fig 3!.11). The highest variability is observed with core area of the Dry Zone with a value of more than 25 percent. However there is an exception that is the high value of coefficient variation of Shwegyin (25.66%) which is located in Bago Division, outside the Dry Zone. (Fig. 3. ^illustrated the annual variation of rainfall at Shwegyin. It shows that except 1961, 1962, 1963 and 1997 rainfalls of Shwegyin were less, though the fluctuation of rainfall from 1967 to 1997 is not very great. The high actual rainfall for 1961, 1962, 1963, and 1997 of Shwegyin influence the percentage of variation occurred at Shwegyin. Fig *(33-)* shows that rainfall variability is greatest in the central areas (core areas) and it decreases towards all directions. Low variability implies that the mean rainfall at a given location is reliable with high variability implies wide fluctuations about the mean value (Ayoade, 1983). Generally, it is obvious that there is an inverse relationship between rainfall amount and rainfall variability. Annual rainfall is most variable in dry areas. Notable examples are stations of the dry zone. Even within the dry zone, the rainfall variability varies from place to place the highest percentage of variation is observed in the centra] core area, that is the middle portion of the Ayeyawady valley. Rainfall variability is small in the wet region. The region of small variability coincides especially with the uni-model rainfall pattern except in Taninthayi Division.



Figure(3.2) Distribution of Rainfall variation over Myanmar

3.3 Rainfall with Abnormal conditions

As Myanmar is predominantly a monsoon region, wet and dry seasons are more or less distributed throughout the year. But in between these wet and dry seasons, sometimes there are spells of abnormal weather condition occur which may have disastrous effects especially in the agriculture and its related economy of the country. For instance, in some years, even during monsoon season when normally most of the places in the country are getting abundant rains, periods of dry spell may set in and rainfall less than the normal amount may be widespread. Such dry spell may sometimes produce drought condition in Myanmar on the other hand, when the monsoon rain exceeds the normal value, widespread flooding may occur. Such occurrences of droughts and floods greatly affect the agricultural product and various sectors of country's economy.

The annual rainfall for each station can be classified into three categories namely, below normal and above normal or the basis of percentage criterion when these values of annual rainfall deviate between + / -20% from mean annual, it is considered as "normal". If they are greater then +20% and -20%, it is termed as above normal and "below normal" respectively by(Kyaw, 1985). The rainfall condition for each station is shown in table (3.2).

(Fig. 3.4.a to 3.4.o) illustrates the abnormal conditions for the weather stations and they are arranged in descending order of magnitude according to their coefficient of variations shows normal rainfall every year. For the whole country 1952,1959,1961,1965,1970,1971,1973,1985,1988, 1989 and 1999 were the wettest years while 1957, 1958, 1972, 1977, 1979, 1983, 1986, 1987, 1991,1992,1993,1994, 1997 and 1998 were the driest years (see Fig 3.3). In 1952, stations with above normal rainfall were Bhamo, Thandwe, Pyay and Katha. (see Fig.3.4.i, k, 1). In 1959, Lashio, Pyinmana, Katha, and Meiktila received rainfall of above normal condition (see Fig 3.4, d, k, 1) and Fig 3.4. e, f, g, i, j , k , 1 ,m , o) show the stations of above normal condition in 1961 they were Hmawby, Thaton, Dawei, Hpa-an Mawlamyine, Thandwe, Hinthada, Yamethin, Hkamti, Kyaukpyu, and Shwegyin. In 1965, the stations obtained rainfall of above normal are Mawlaik, Sittway, Thandwe, Falam, Pyay, Pyinmana, Yamethin, Kyaukpyu, Mindat, Shwebo, Monywa and Minbu (see

Fig 3.4, h, i, j, k, m, n, o).

Table 3.2 Years of Normal, Below Normal and Above Nonnal Rainfall in 45 Stations in Myanmar

Stations	Year above Normal	Year below Normal	Normal Year	Total of Years
Putao	2(1995,99)	1 0986)	37	40
Taunggyi	3(1960,75,98)	2(1960,98)	46	51
Thavawady	2 (1982, 90)	2(1979,98)	46	50
Mveik	3(1978,94,97)	4(1974,87,92,98)	44	51
Toungoo	2(1953,75,99)	3(1957,83,98)	45	50
Yangon	4(1950,74,85,99)	3(1951,58,91)	44	51
Hmawby	2(1961,75)	3(1979,86,98)	35	40
Bago	2(1969,97)	3(1957,87,98)	46	51
Thaton	4(1961,69,94,97)	2(1979,92,96,98)	31	40
Lashio	2(1959,73)	5(1972,79,88,90,98)	40	47
Pathein	4(1950,69,73,94)	4(1986,89,93,98)	43	51
Thibaw	3(1973,77,81)	5 (1969,79, 88, 90, 98)	31	36
Pinlaung	4(1971,85,91,99)	5(1978,79,86,97,98)	25	34
Dawei	6(1961,78,81,85,97,99)	2(1956,98)	43	51
Loilem	4(1963,70,73,94)	5 (1962, 79, 82, 86, 98)	31	40
Ye	5 (1967, 72, 94, 97, 99)	3(1983,89,98)	28	36
Kawthoung	6(1979,88,94,95,96,99)	4(1972,77,87,92)	41	51
Hpa-an	5(1961,62,63,97,99)	6(1983,86,87,88,94,98)	29	40
Myintkyina	6(1964,73,87,88,93,98)	5(54,56,85,79,91)	40	51
Maubin	3(1953,63,94)	4(1951,76,77,98)	43	50
Mawlamyaine	7(1961,63,67,69,82,94,99)	5(1951,83,86,87,98)	38	50
Mawlaik	4(1965,66,71,90)	4(1961,62,79,98	32	40
Sittway	5 (1959,65, 68, 80, 90)	3(1957,71,72)	40	48
Kalaywa	4(1970,71,73,90)	3(1969,79,98)	33	40
Kyaington	4(1964,70,71,2000)	4(1951,62,79,98)	43	49
Bhamo	5(1950,52,58,73,85)	4(1955,60,69,87)	42	51
Thandwe	6(1952,61,65,91,94,99)	5(1975,83,86,89,98)	39	50
Loikaw	5(1960,61,64,72,75)	9 (1954, 62, 74, 76, 79, 87, 93, 97, 98)	36	50
Falam	6(1965,66,70,71,73,91)	7(1972,78,79,81,88,92,98)	27	40
Hinthada	6(1961,84,85,86,87,95)	8(1955,88,72,79,91,92,97,98)	36	50
Pyay	7(1952,61,65,73,74,88,2000)	8 (968, 72, 79, 85, 93, 94, 97, 98)	35	50
Pyinmana	9(1951,59,64,65,73,74,75,96, 99)	8(1958,62,72,79,80,82,92,98	33	50
Yamethin	10(1961, 65, 68, 71, 73, 74, 78, 83, 84, 85)	7 (1966, 72, 79, 82, 93, 97, 98)	22	40
Gangaw	9 (1962, 63, 70, 73, 74, 78, 94, 96, 97)	4(1966,69,72,79)	26	39
Hkamti	7(1961,66,79,87,89,90,91)	8 (1972, 77, 81, 83, 86, 92, 94, 2000)	25	40
Katha	10(1950,52,56,58,59,71,73,77, 90,97) •	9 (1951, 67, 69, 72, 74 80, 87, 98, 99)	32	51
Kyaukpyu	5(1961,65,69,94,96)	4(1972,86,89,98)	31	40
Mindat	6(1962,65,68,70,73,79)	6(1971,75,77,78,82,98)	28	40
Meiktila	12(1950,53,56,59,63,68,71, 73,75,89,91,96)	11 (1957, 58, 60,79, 80, 82, 87, 94, 96, 98, 2000)	28	51
Shwebo	7(1965,73,80,81,83,92,96)	8 (1961,67, 79, 82, 86, 87, 97, 2000)	25	40
Mandalay	10 (1968,70, 73, 74, 75, 78, 80, 92, 94, 96)	9 (1952, 66, 78, 82, 86, 87, 93, 2000)	32	51
Nyaung-oo	9 (1970, 73, 75, 78, 81, 88, 89, 96, 99)	7(1971,72,79,82,95,97,98)	10	36
Monywa	10(1965,68,71,73,75,77,88, 92, 95, 96)	9 (1970, 79, 82, 85,90, 91,93, 97,98)	21	40
Minbu	10(1964,65,70,73,74,76,88, 92, 95, 99)	9 (1966, 67, 71, 72, 79, 82, 91, 94, 98)	21	40
Ljmvegyin	3(1961,62,63,97)	7 (1977, 78, 79, 89, 92, 95, 98)	36	40

Source: Rainfall Data from Meteorology& Hydrology Department, Yangon, Myanmar.2000.

Figure 3.3 The Wettest years and the Driest years of Myanmar (1950-2000)

The Wettest years	The Driest years
1952	1957
1959	1958
1961	1972
1965	1977
1970	1979
1971	1983
1973	1986
1985	1987
1988	1991
1989	1992
1999	1993
	1994
	1997
	1998

Source: Meteorology & Hydrology Department, Yangon, 2000.

Loilem, Kalaywa, Kyaington, Falam, Gangaw, Nyaung-oo and Minbu experienced the above normal condition in 1970 (see Fig 3.4, h, i, j, 1, n, o). In 1971, the rainfall of above normal condition occurred at Pinlaung, Mawlaik, Kyaington, Falam, Yamethin and Monywa (see Fig. 3.4, e, h, i, j, k, o). In 1973 stations with above normal condition were Lashio, Pathein, Thibaw, Loilem, Myinkyina, Bhamo, Falam, Pyay, Pyinmana, Yamethin, Gangaw, Katha, Mindat, Meiktila, Shwebo, Mandalay, Nyaung-oo, Monywa and Minbu, (see Fig. 3.4 . d , e , g, i, j , 1, m , n , o).

In 1985, the stations obtained above normal rainfall are Putao, Bhamo, Yamethin, Hinthada, Yangon and Dawei (see Fig.3.4.a,b,e,I,j,k) and in the year 1988, Myintkyina, Monywa, Nyaung-Oo, Minbu, Kawthoung received above normal rainfall (see Fig.3.4.g,f,n,o). The stations above normal conditions in 1999 are Minbu, Nyaung-Oo, Pyinmana, Hpa-An, Mawlamyaine and Thandwe (see Fig.3.4.a, g, f, I, k, n, o).

In 1957, below normal conditions of annual rainfall occurred at Toungoo, Bago and Sittway in (see Fig, 3.4. b, c, h). In 1972, stations with below normal were Lashio, Sittway, Hinthada, Pyay, Pyinmana, Yamethin, Hkamti, Katha, Kyaukpyu, and Minbu (see Fig 3.4, d, h, j, k, 1, m, and o). In 1977, this condition (below normal) occurred at Kawthoung, Maubin, Hkamti, Mindat, Nyaung-Oo and Shwegyin (see Fig. 3.4, f, g, 1, m, n, o). Thayawady, Hmawby, Gangaw, Katha, Meiktila, Shwebo, Mandalay, Nyaung-oo, Monywa, Minbu and Shwegyin experienced the rainfall of below normal condition in 1979(see Fig 3.4. a, c, 1, m, n, o).

In 1983, stations received below normal condition were Toungoo, Ye, Hpa-an, Mawlamyaine, Thandwe, Loikaw and Hkamti, (see Fig, 3.4.f, g, i, j, 1). Below normal condition occurred at Hmawby, Pathein, Pinlaung, Loilem, Hpa-an, Mawlamyaine, Thandwe, Kyaukpyu, Shwebo, and Mandalay in 1986 (see Fig 3.4 .c, d, e, f, g, i, m , n) and at Myeik, Bago, Kawthoung, Hpa-an, Bhamo, Katha, Meiktila, and Shwebo in 1987 (see Fig 3.4. b, c, f, i, 1, m , n).

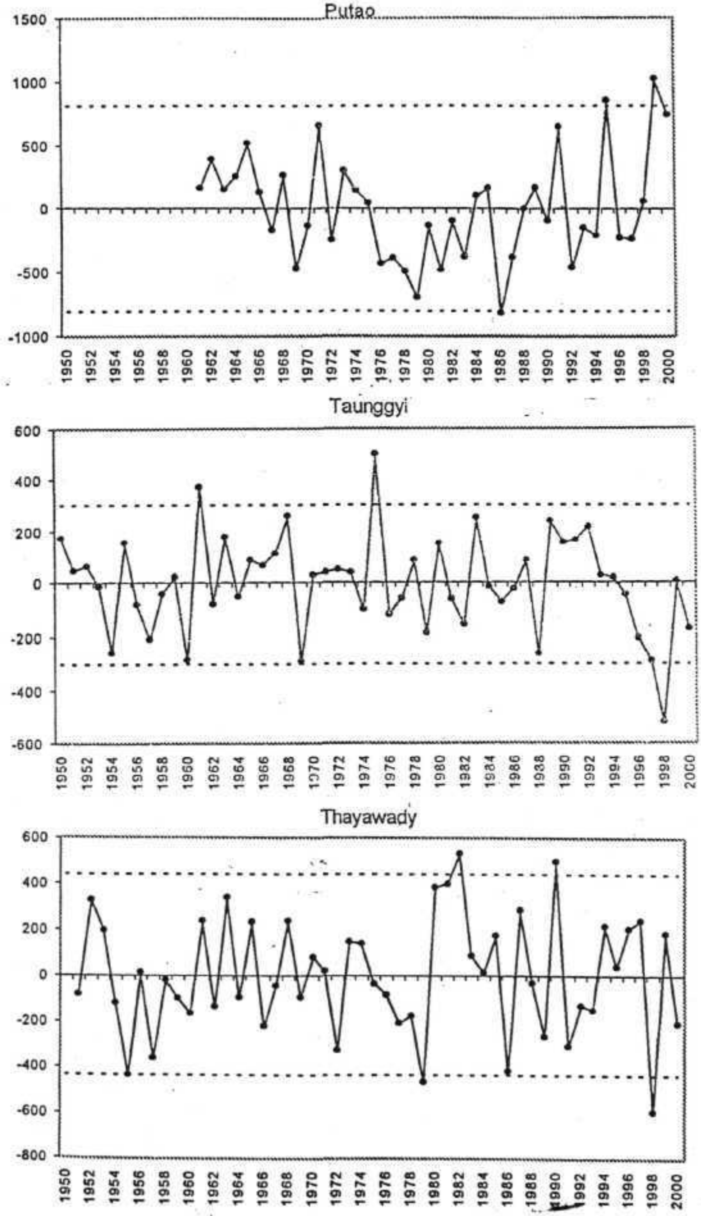


Figure (3.4.a) Annual rainfall of Putao, Taunggyi and Thayawady shown as above normal, normal & below normal

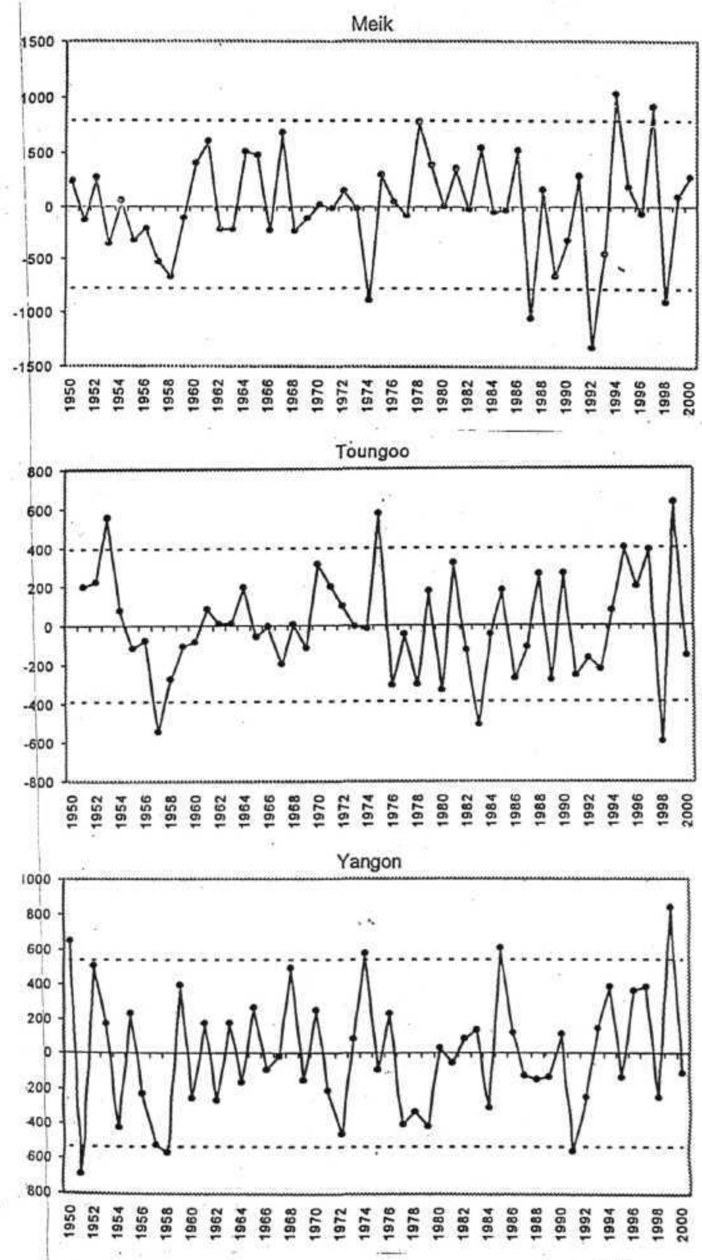
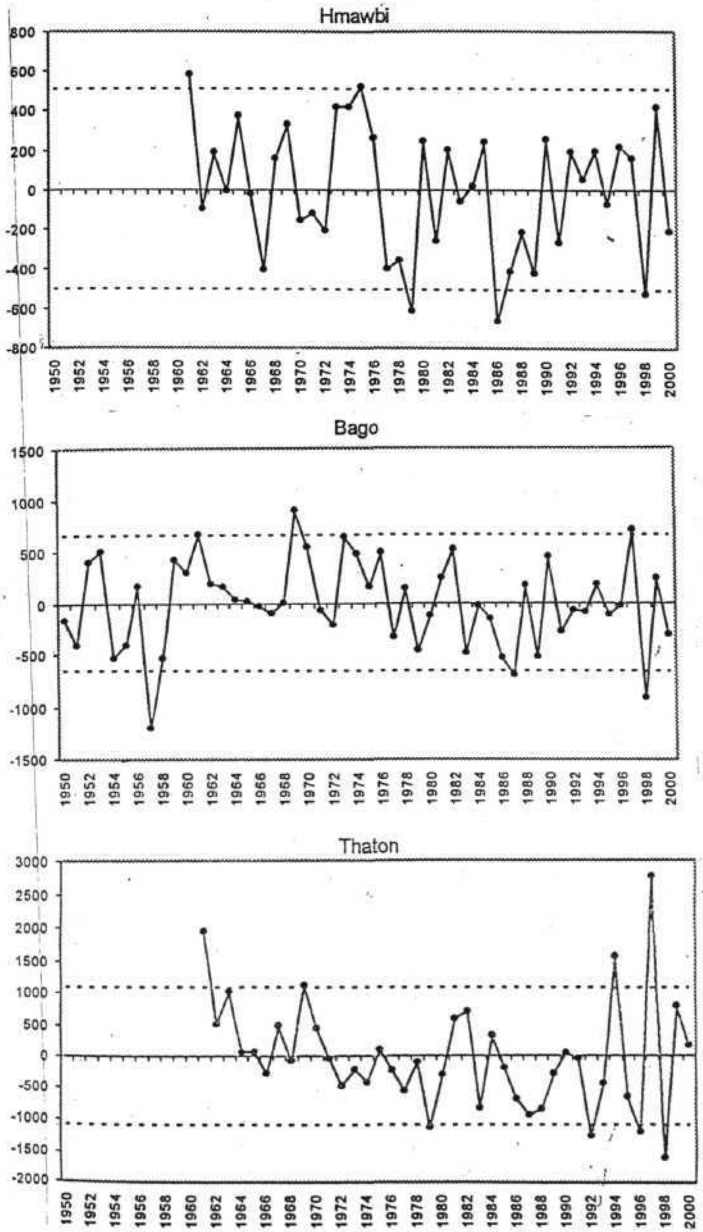
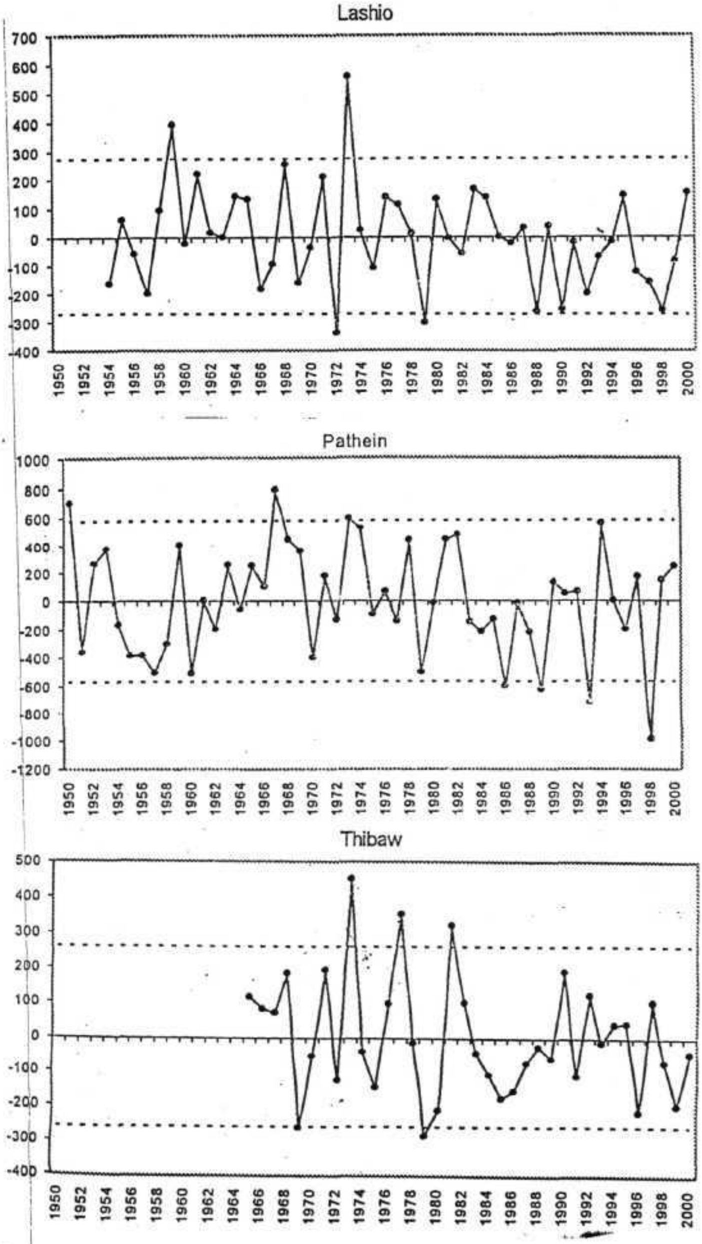


Figure (3.4.b) Annual rainfall of Meik, Toungoo and Yangon
shown as above normal, normal & below normal

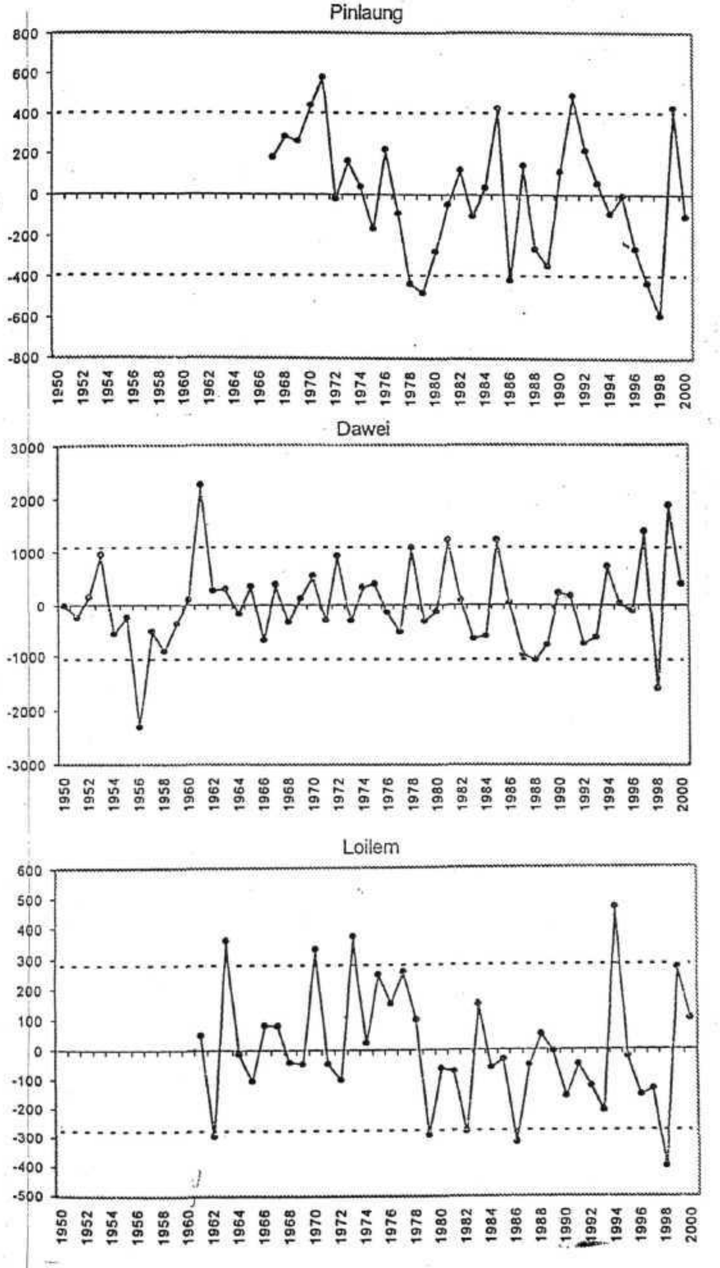


Figure(3.4.c) Annual rainfall of Hmawbi, Bago & Thaton shown as above normal, normal & below normal

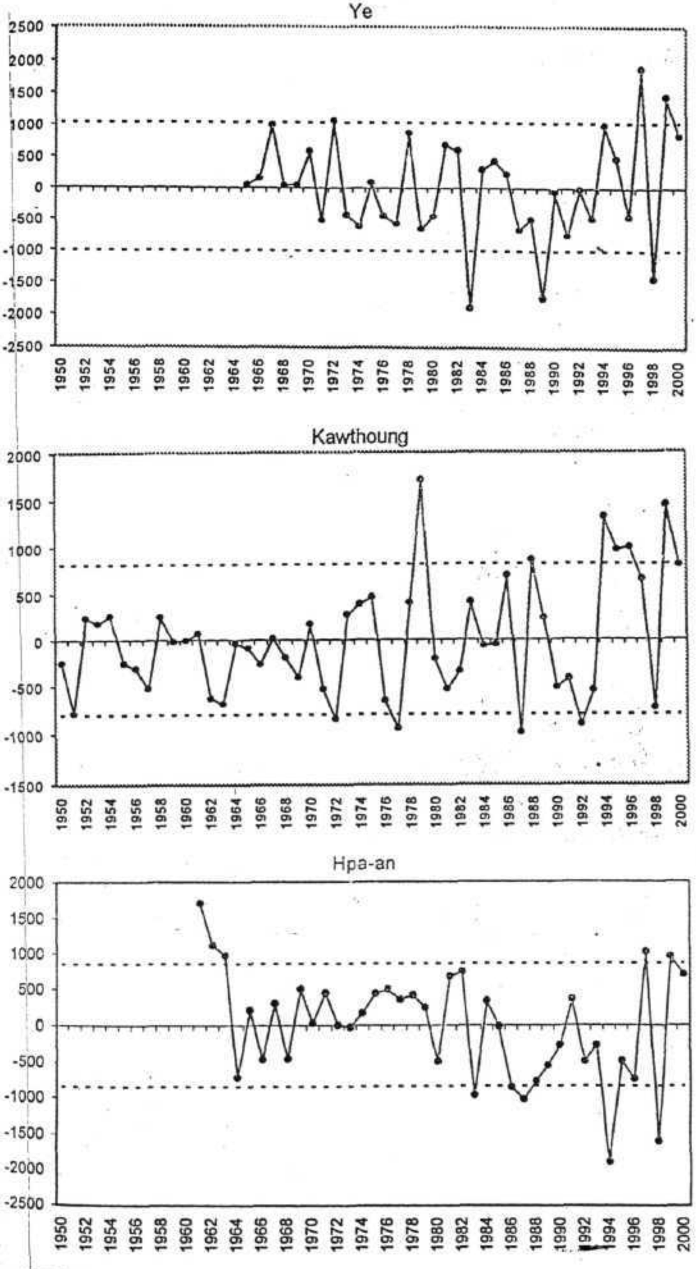


Figure(3.4.d) Annual rainfall of Lashio, Pathein and Thibaw

shown as above normal, normal & below normal



Figure(3.4.e) Annual rainfall of Pinlaung, Dawel and Loilem
shown as above normal, normal & below normal



Figure(3.4.f) Annual rainfall of Ye, Kawthoung and Hpa-an

shown as above normal, normal & below normal

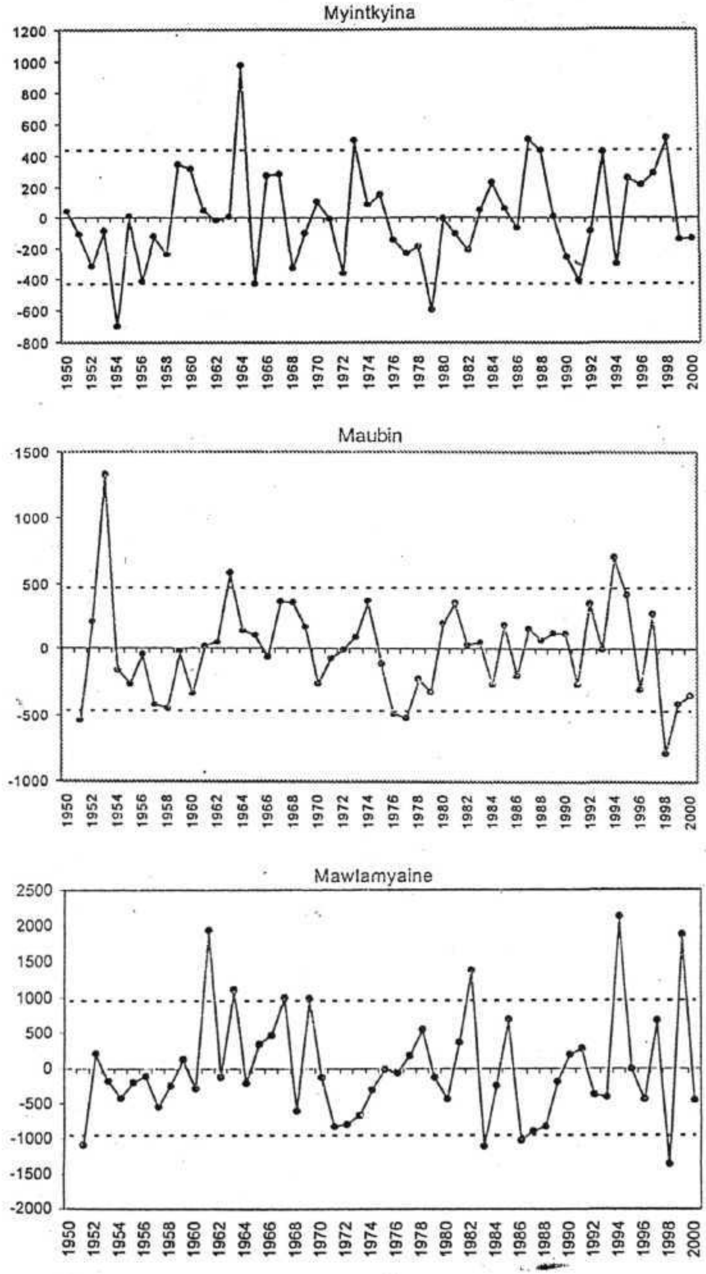
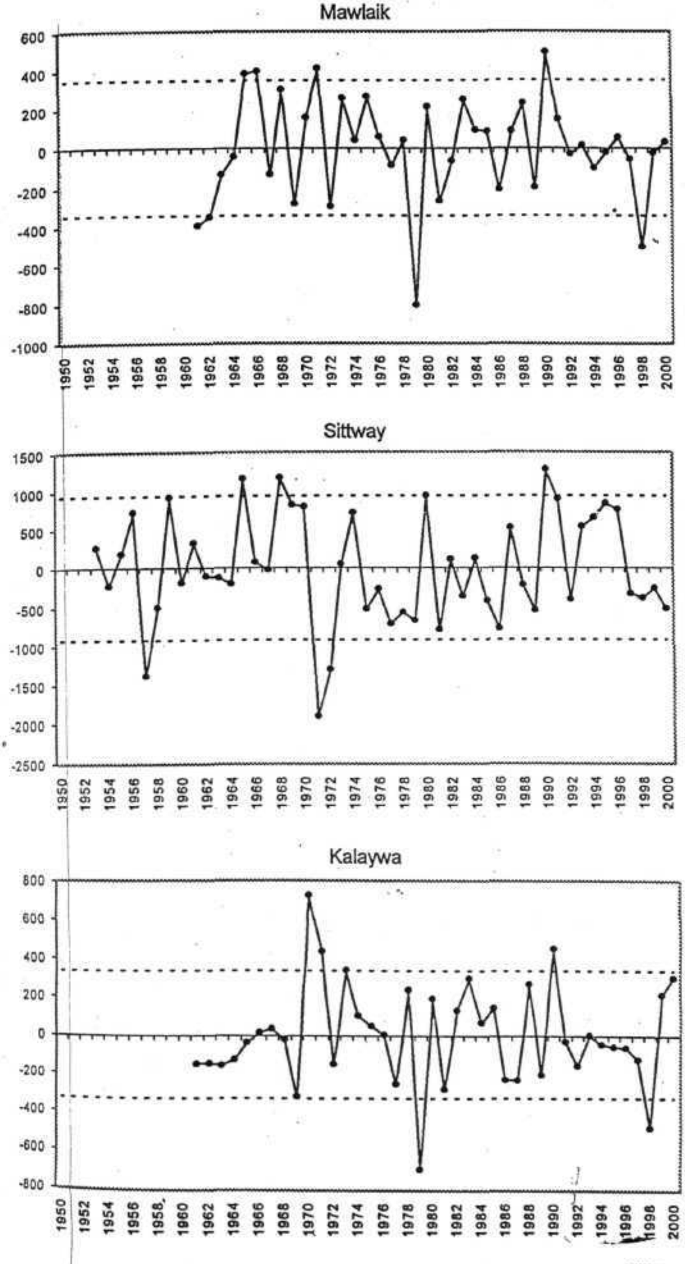


Figure (3.4.g) Annual rainfall of Myintkyina, Maubin and Mawlamyaine shown as above normal, normal & below normal

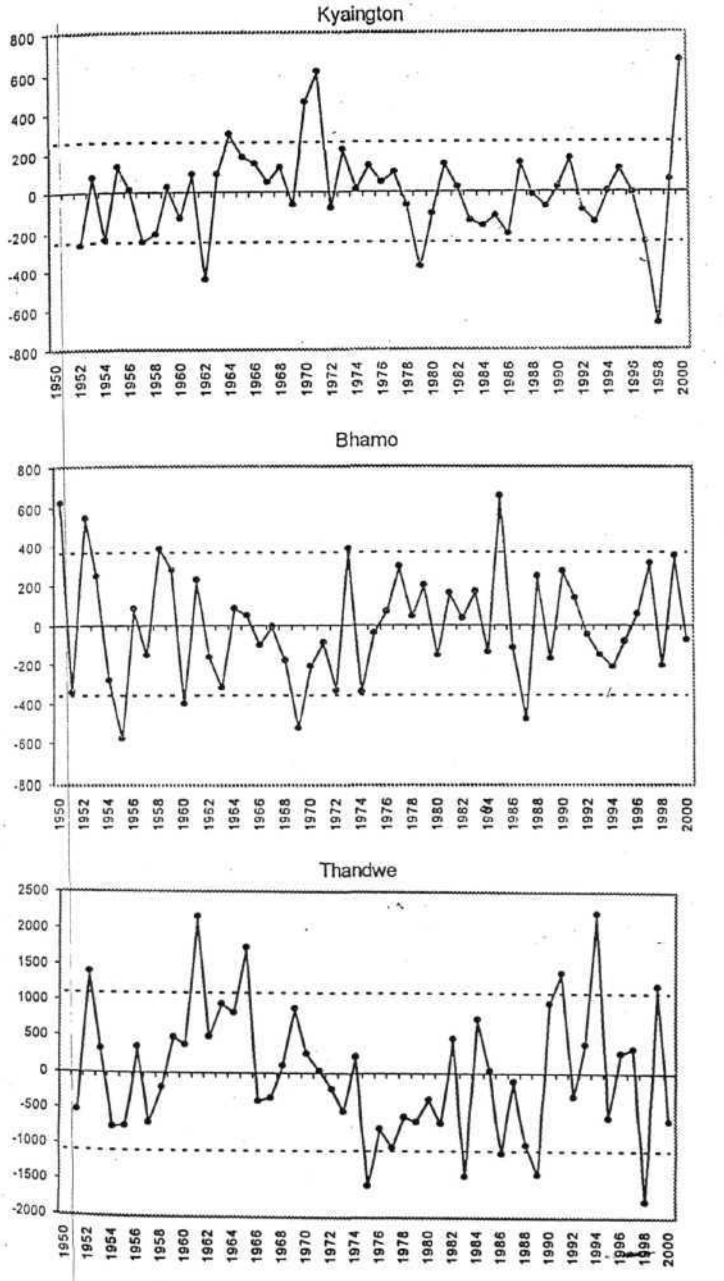


Figure(3.4.h) Annual rainfall of Mawlaik, Sittway and Kalaywa
shown as above normal, normal & below normal

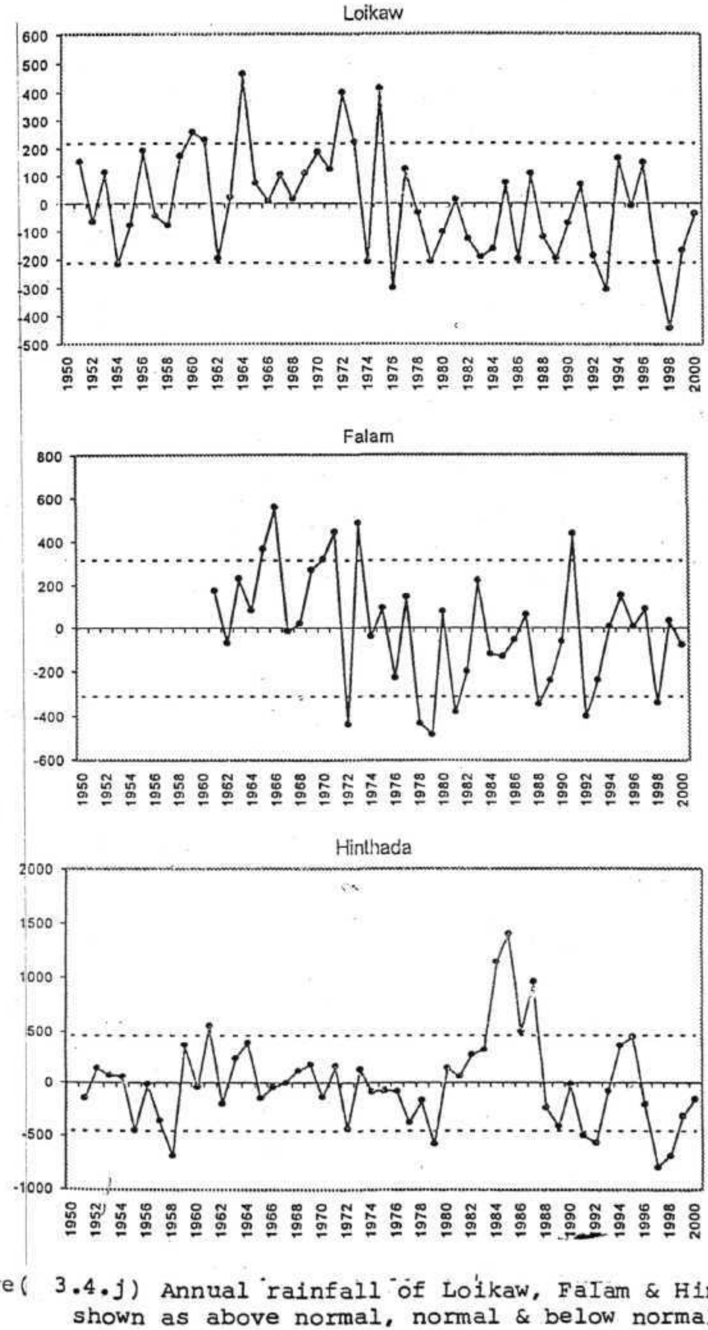
In the year 1991, Minbu, Monywa, Hinthada, and Yangon received rainfalls below normal(see Fig.3.4.b,j,o) and Falam, Hkamti, Pyinmana, Thaton, Shwegyin, Hinthada, Myeik and Kawthoung stations were in the group below normal in]992(see Fig.3.4.b,c,f,j,k,l,o). The stations fall under below normal group of 1993 were Monywa, Mandalay, Yamethin, Pyay and Pathein (see Fig.3.4.k,n,o) while Hkamti, Minbu, Meiktila, Pyay and Hpa-an obtained below normal conditions of rainfall in 1994(see Fig 3.4.k,f,l,m,o).

In 1997 below normal condition can be seen at Nyaung-Oo, Monywa, Yamethin, Loikaw and Pyay (see Fig.3.4.j, k, n, o) and in the peculiar drought year, 1998, almost all the stations of the country fell under below normal of annual rainfall. They are Myintkyina, Katha, Mawlaik, Kalaywa, Falam. Mindat, Lashio, Kyaington, Loilem, Pinlaung, Loikaw, Meiktila, Nyaung-Oo, Pyinmana, Toungoo, Bago, Shwegyin, Yangon, Hmawby, Pyay, Hinthada, Maubin, Kyaukpyu, Thandwe, Hpa-an, Mawlamyaine, Ye, Dawei and Kawthoung(see Fig.3.4.b.c,d,e,f,g,h,I,j,k,Lm,n,o).

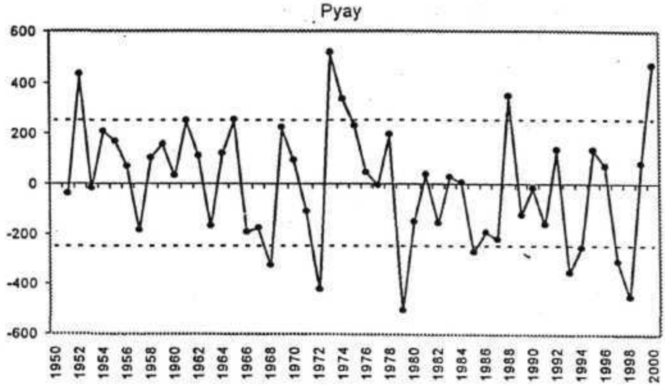
The extreme values obtained for the rainfall condition for each year are found to be connected with certain characteristics of surface preserve anomalies over Southern Asia, the 500 millibar pattern and the disposition of Southern Oscillation (Oo, 1974). The highest and more widespread positive pressure anomaly in the Southern Asian region causes less rainfall over Myanmar. and Vice versa. In the 500 millibar pattern, if a prominent 'High' established itself over Tibet, another 'High' lies over South West Asia, A "Low"' forms over peninsular of India and adjoining Bay of Bengal. Thus, strong monsoon rain follows over Myanmar. Southern Oscillations at atmospheric pressure between the Indian Ocean (with centre of oscillation rear Djakarta) and the Southeast Pacific (with centre near Easter Island) has been observed to have influenced the rainfall of Myanmar to some extent. When the Southern Oscillation is positive, or pressure is high over Indian Ocean and low over Southeast Pacific, positive pressure anomaly is more widespread and persistent over Southern and Southeast Asia, and consequently rainfall over Myanmar is reduced and vice versa.

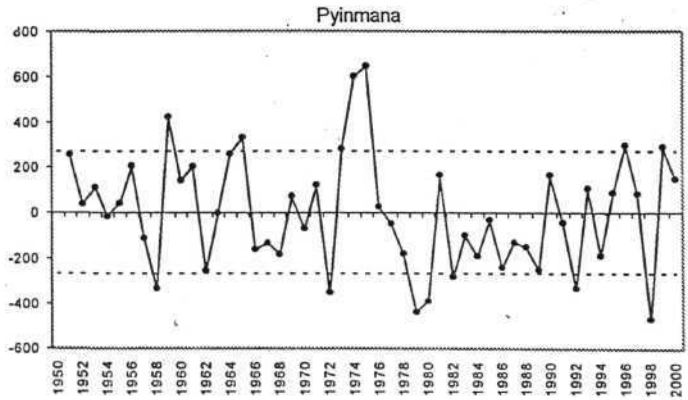


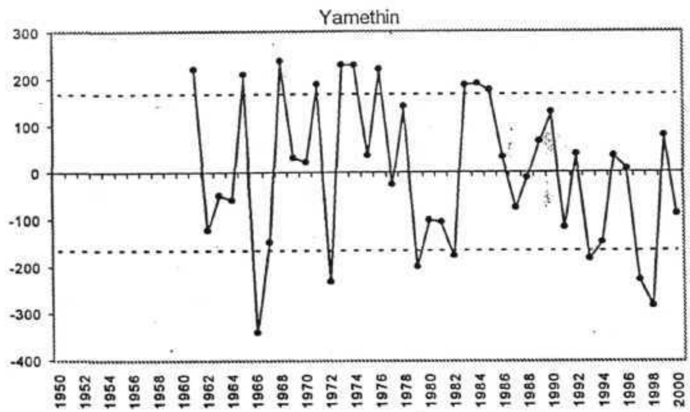
igure(3.4.i) Annual rainfall of Kyaington, Bhamo and Thandwe
shown as above normal, normal & below normal



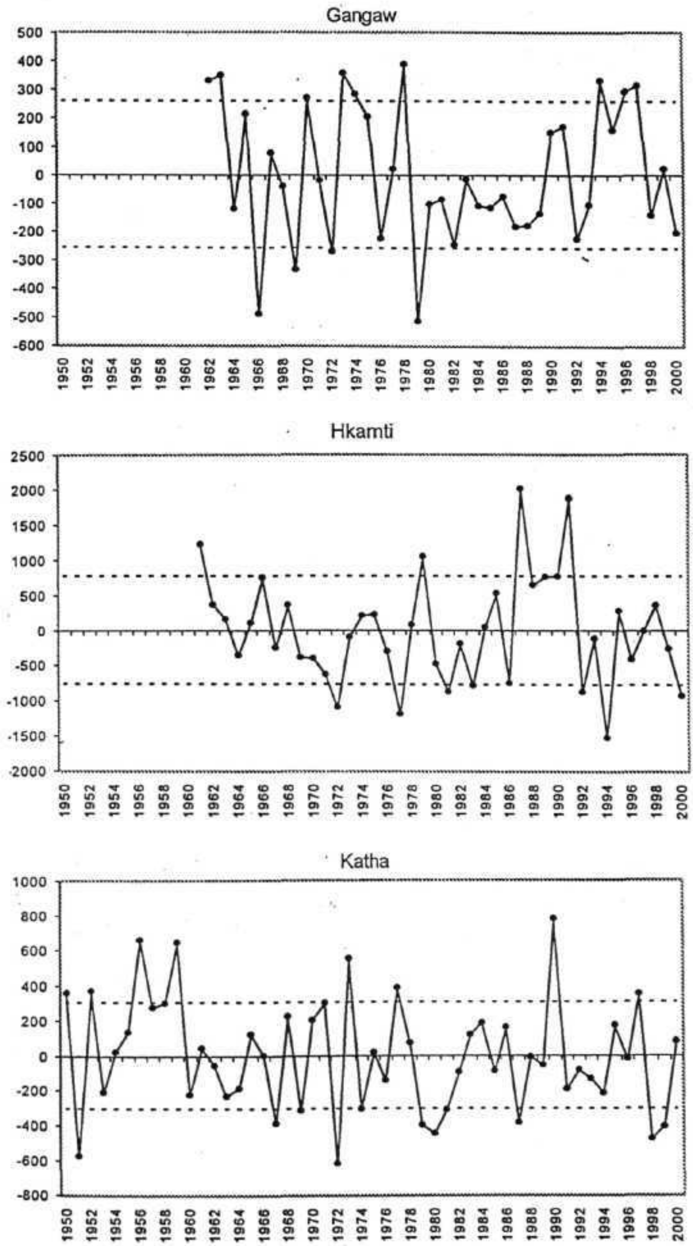
Figure(3.4.j) Annual rainfall of Loikaw, Falam & Hinthada shown as above normal, normal & below normal





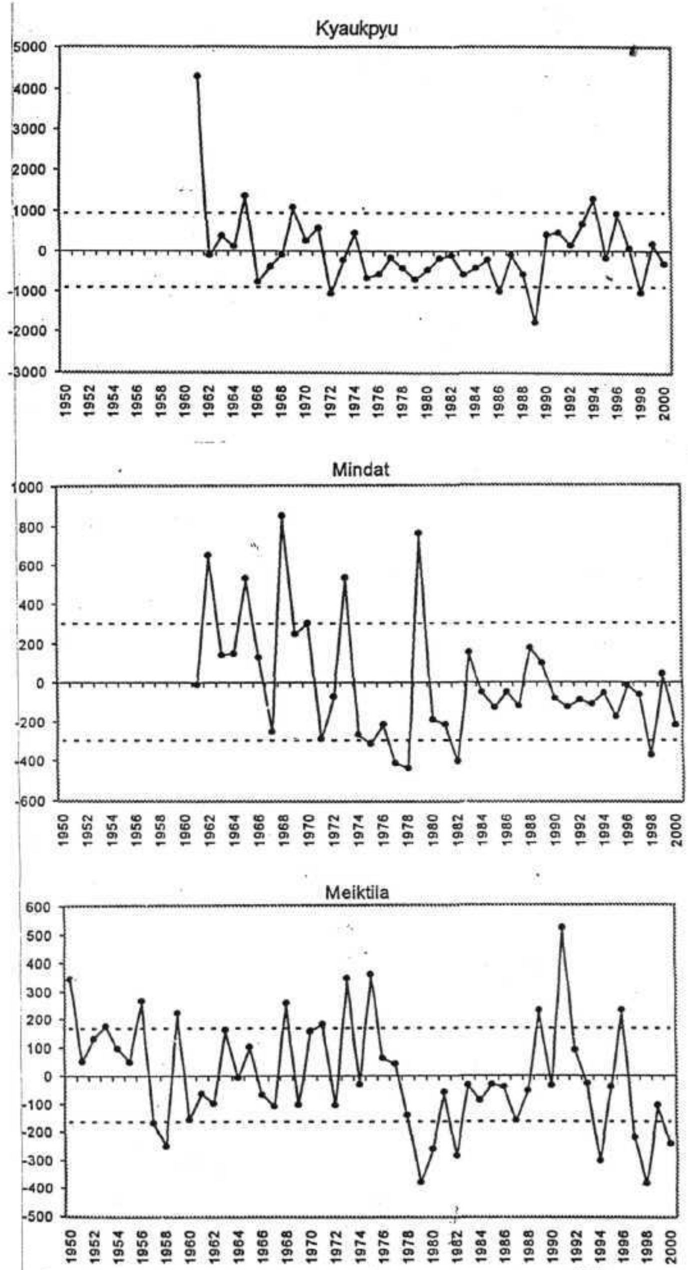


Figure(3.4.k) Annual rainfall of Pyay, Pyinmana and Yamethin shown as above normal, normal & below normal



Figure(3.4.1) Annual rainfall of Gangaw, Hkamti and Katha

shown as above normal, normal & below normal



Figure(3.4.m) Annual rainfall of Kyaukpyu, Mindat and Meiktila shown as above normal, normal & below normal

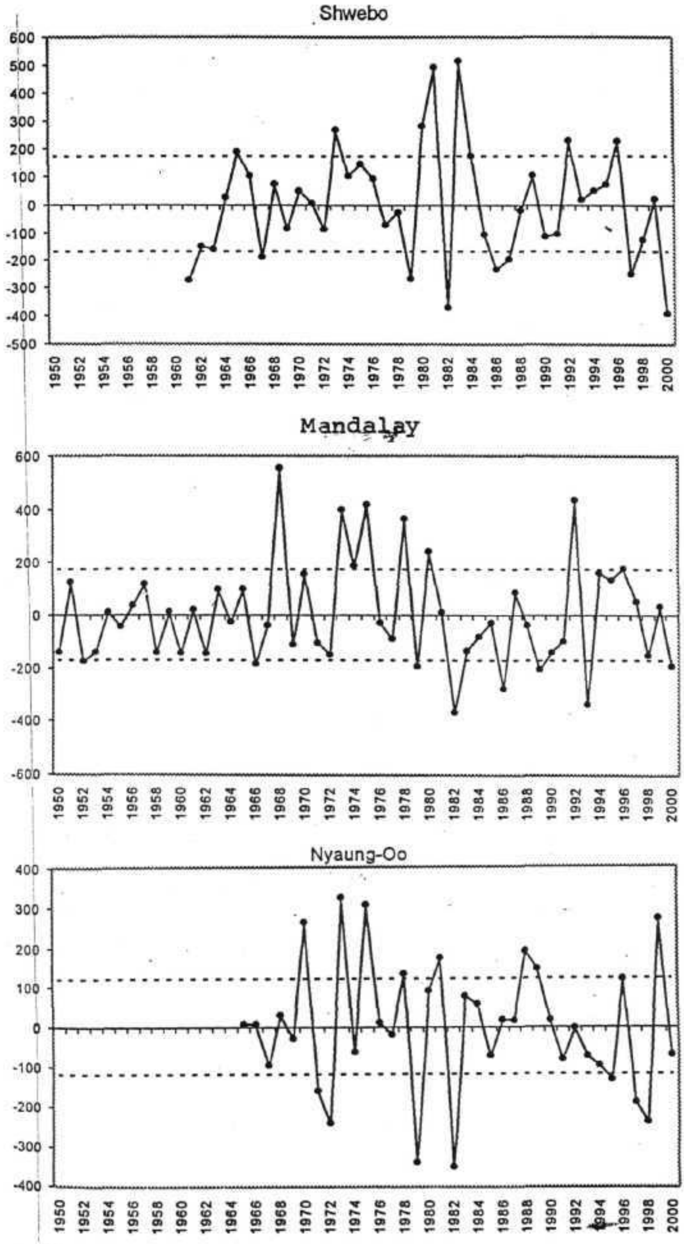


Figure (3.4.n) Annual rainfall of Shwebo, Mandalay and Nyaung-Oo
shown as above normal, normal & below normal

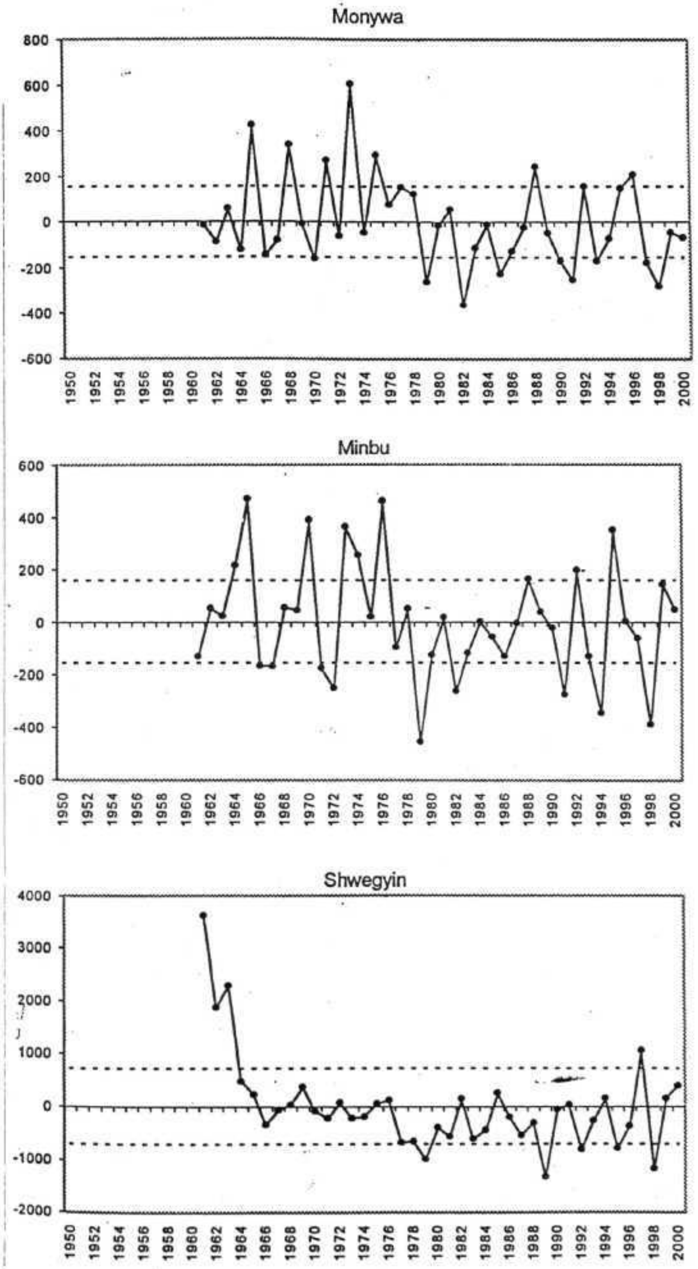


Figure (3.4.o) Annual rainfall of Monywa, Minbu and Shwegyin shown as above normal, normal & below normal

The driest years of the country is found to be related with the phenomena of El Nino and maximum Sun spot (Aung et. al 1984). The driest years of 1957-58, 1972-73,1982-83 and 1986-87, and 1992-93, 1997-98 are associated with strong ENSO (El Nino and Southern Oscillation) years(Aung 1997).Furthermore, the rainfall condition for Myanmar may be correlated with the period of South West Monsoon circulation over Myanmar the dry year is 1979 was due to the failure of the Southwest Monsoon.

3.4 Rainfall Distribution

The detailed study of rainfall distribution in Myanmar can be carried out in two ways, i.e. spatial distribution and temporal distribution.

3.4.1 Spatial Distribution

The spatial distribution of rainfall is illustrated by the isohyet maps, (see Fig 3.5.a to Fig 3.12.a). The distribution of monthly numbers of rain days are shown from Fig (3.5 b) to Fig (3.12.b).The definition of a rain day is far from uniform: most countries of Britain common wealth use a lower limit of 0.25 mm (o.Ol in), but other countries have fixed it at 1, 2 or 5 mm (0.19 in). In Myanmar the rain day is defined by 2.8 mm (0.10 in). The relation of the total rainfall to the number of days with rain is a climatic factor of some importance. It indicates of the type of rainfall and the general impression of dampness or dryness.

The intensity of rainfall during a given period is of vital interest to hydrologists and soil scientists concerned with flood forecasting and prevention and soil erosion control respectively. Rainfall intensity is the rainfall amount divided by storm duration in hours or minutes (Ayoade, 1983). In places where autographic rain gauges or rainfall intensity record are not available, rainfall intensity is given by the amount of rain per rain day. This index known as the mean intensity may be computed for single month or for the whole year. In this study, the mean monthly intensity (monthly mean rainfall per rain day) for the period of May to October **is** Presented in Fig (3.5. c to 3.12.c).

The distributional pattern of rainfall in **May** can be seen in fig. (3.5. a) and the highest peak value of rainfall occurs at Thaton (571 mm 22.48 in) while Nyaung-Oo receives the least amount (63 mm, 2.48 in). With the onset of the monsoon over Myanmar in the last decade of the month, there is a general increase of rainfall in the whole country. The central area of Myanmar is the lowest rainfall region and this is confirmed by 100 mm (3.97 in) isohyet line, and from this area rainfall amount increases outwards. The effect of topography combined with the onset of Southwest monsoon results in the greater difference of rainfall amount between the coastal region and the interior Myanmar.

Most of the country excluding coastal area experiences the monthly rainfall of 100 to 200mm (3.97 -7.87 in) in May. However, there are some exceptions in the areas of Thandaung and Mogok where the values of rainfall are 515 mm (20.28 in) and 350 mm (13.78 in) respectively. It is therefore evident that topography plays a very important role in distribution of rainfall. The amount of rainfall is also higher at Sittway (268 mm, 10.55 in), Kyaukpyu (248 mm-9.76 in), Thandwe 299 mm (11.77 in) Pathein 278 mm (10.94 in), Yangon 303 mm (11.93 in), Hpa-an (412 mm, 16.22 in), Mawlamyaine 317 mm (42.48 in), Ye (500 mm, 19.69 in) Dawei (517 mm 20.35 in) Myeik (431 mm 16.69 in) and Kawthoung 487 mm, 19.17 in). It can be seen that the monthly rainfall values of the coastal strips of Taninthayi is much higher than that of Rakhine region. This may be due to the fact that the South West monsoon current prevails over the Taninthayi area about second week of May which is two weeks earlier than the onset date of the Rakhine areas. The other fact is being a narrow peninsula lying between the Gulf of Thai and the Adaman sea and also the fact that the region is near to the equator favours the occurrence of corrected rain, thus increasing the percentage of monsoon rain received in these areas.

Storms are frequent with the increase of heat and low pressure become more intense during this month of May. As a result, the inflow of sea breezes becomes stronger. Therefore, unsettled weather such as air mass, thunderstorm and tropical storms, which are often severe, these are the characteristics of May rainfall received m central Myanmar, in this month, rainfall of May can be attributed to these disturbances.

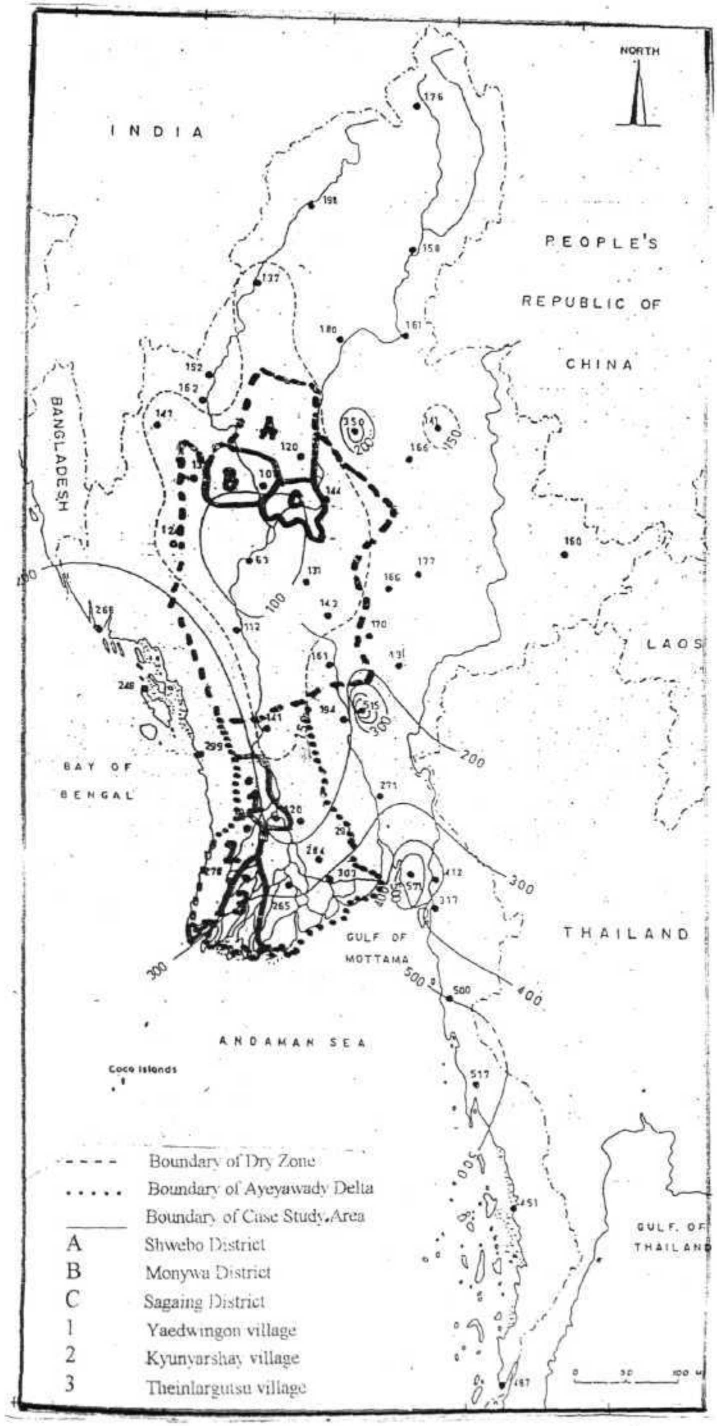


Figure (3.5.a) Distribution of monthly rainfall (mm) in May.

In May, the number of rain days in the Taninthayi coastal strip ranges from 4.1 to 17.5 (see Fig 3.5.b). Over the dry zone, frequency is about 4 to 8 rain days the maximum frequency of rain days to be found at Myeik with 17.5 rain days the region Received more than 12 rain days are Southern Shan hills region, the Deltaic region of Ayeyawady and Bago Divisions and Taninthayi coastal strip.

In May, mean intensity is high as this month is pre-monsoon month (see fig. 3.5 x), it can be seen that even in the dry zone, the mean monthly rainfall per rain day is more than 15 mm (15 mm to 18 mm). The areas less than 15 mm (0.59 in) are the Shan state, Eastern part of Kachin state and the areas west of the Chindwin in Sagaing Division. Some records of mean intensity are 28 mm (1.1 in) at Sittway, 25.8 mm (1.02 in) at Kyaukpyu, 26.7 mm (1.05 in) at Thandwe, 32.8 mm (1.29in) at Thaton, 30.5 mm (1.2 in) at Ye, 32 mm (1.26 in) at Dawei, 25.8 mm (1.02 in) at Myeik , 28.5 mm (1.12 in) at Kawthoung and (29.9 mm - 1.18 in) at Thandaung.

By June, the general pattern of rainfall distribution shows that the lowest rain fall region remains in the central part of Myanmar. The coastal strip of Rakhine and Taninthayi have the highest values (see Fig .3 .6. a) the maximum rainfall amount takes place at Thandwe (1298 mm, 51.1 in) instead of Thaton. The minimum value still exists at Nyaung-Oo with monthly rainfall of 76 mm (2.99 in) the range of maximum and minimum values is 1232 mm (48.5 in) which is twice as much as that of the previous month.

The general trend of rainfall distribution is that the amounts of rainfall values gradually decrease towards the dry zone from the neighboring high topography. The cause of least rainfall over central Myanmar is not because of the lack of moisture in the air. But this can be explained by the fact that central Myanmar lies within the rain shadow area or in the immediate leeward side of the Rakhine Yoma. The absence of high hills or mountains to lift up the moist air enhances the divergent air flow in the low levels over central Myanmar. This results in much fewer chances to get rain (Hla, 1968). The Dry Zone receives its first monsoon rain during the first week of June from the advance of the Inter Tropical Convergence Zone.

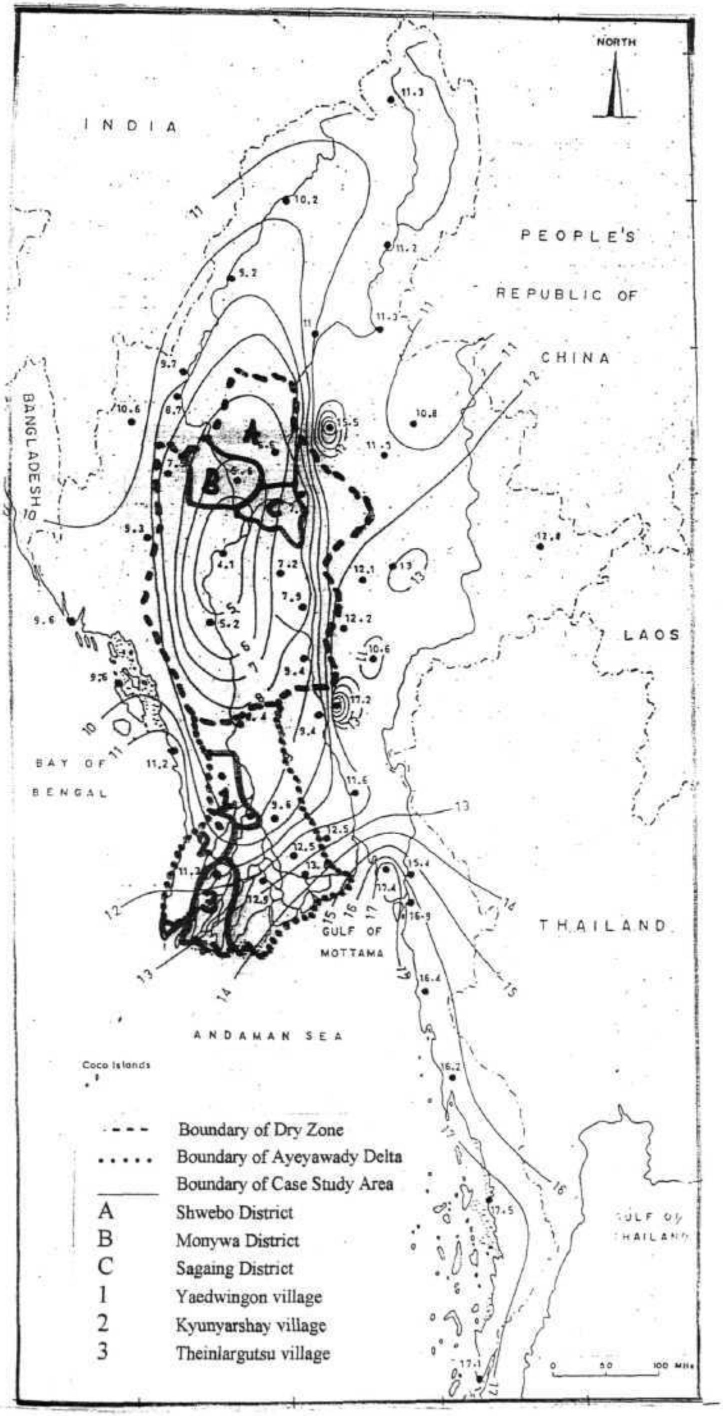


Figure (3.5. b). Distribution of monthly rain day in May.

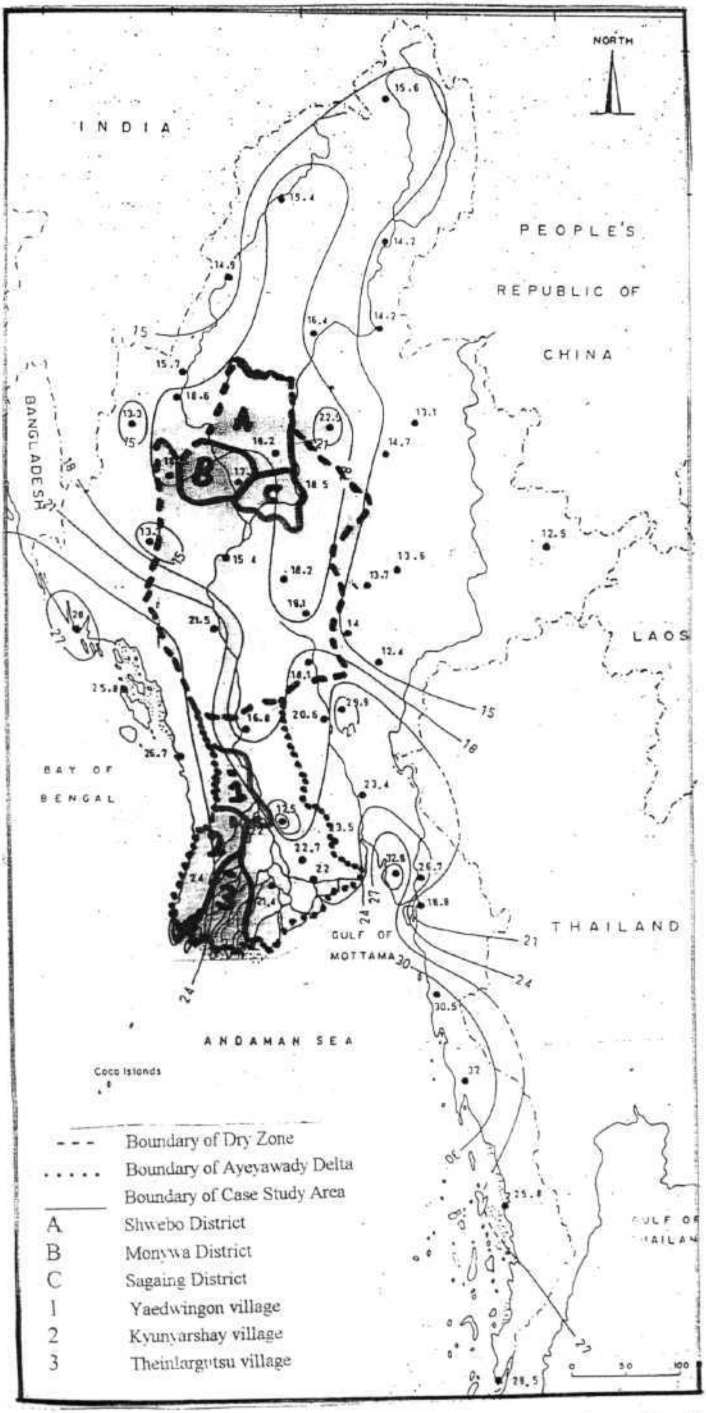


Figure (3.5.c) Distribution of mean intensity of rainfall in May.

The packing of isohyets over Myanmar could be attributed to the steep topographic gradient. In the coastal strips of Rakhine and Taninthayi, the monthly rainfall is more than 1000 mm (about 40 in). Sittway, Kyaukpyu and Thandwe receive 1091 mm (92.95 in) 1011 mm (39.8 in) and 1298 mm (151.1 in) respectively. Thaton receives 1123 mm (44.21 in) ye enjoys 1009 mm (39.72 in), Dawei experiences 1235 mm (48.62 in) and Myeik enjoys 783 mm (30.83 in) and Kawthoung receives 642 mm (25.28 in). The alignment of Rakhine Yoma and Taninthayi Yoma along the coast line and their high elevation also contribute to the cause of getting heavy rain in these regions.

It is also observed that the Northern hills region, the Chin Hills and Shan high lands also experience increase of rainfall. The onset of Southwest monsoon over the Northern hills region occurs at first week of June. As a result, the increase of rainfall over the Northern hills region may be noticed from this month of June. Putao in the far North receives 738 mm (29.05 in) and Hkamti receives 784 mm (30.87 in). The higher amount of rainfall over Chin Hills and Shan highlands may be because of the influence of Southwest monsoon associated with their high elevation. However, some of the stations in the Chin Hills record higher amount of rainfall compared to those in the Shan state. This variable amount of rainfall received at the respective stations is due to the effect of location. Further more, the higher amount of rainfall over the Chin Hills region depend on the direct influence of the Southwesterly air masses. Falam, Mindat and Mawlaik in the Chin hills region have the rainfall amount of 288 mm (11.34 in), 312 mm (12.28 in) and 240 mm (9.45 in) respectively. In the Shan highland, Thibaw receives 263 mm (10.35 in) Taunggyi 217 mm (8.54 in), Loilem 191 mm (7.51in) and Kyaington 175 mm (6.89 in). The deltaic regions of the Ayeyawady and Bago Division enjoy about 500 mm (19.69 in) of rainfall-

The distribution of rain days in June differ from the previous month (see Fig 3-6. b). Southwest monsoon covers the whole of the country and causes the increase °f frequency of rain days. The general trend of rain days in this month is not different from that of monthly rainfall in June. The highest numbers of rain days are to be found at Northern hills region, the coastal strips of the Rakhine and Taninthayi, and the values decrease towards the dry zone. There are 8-14 rain days per month in the

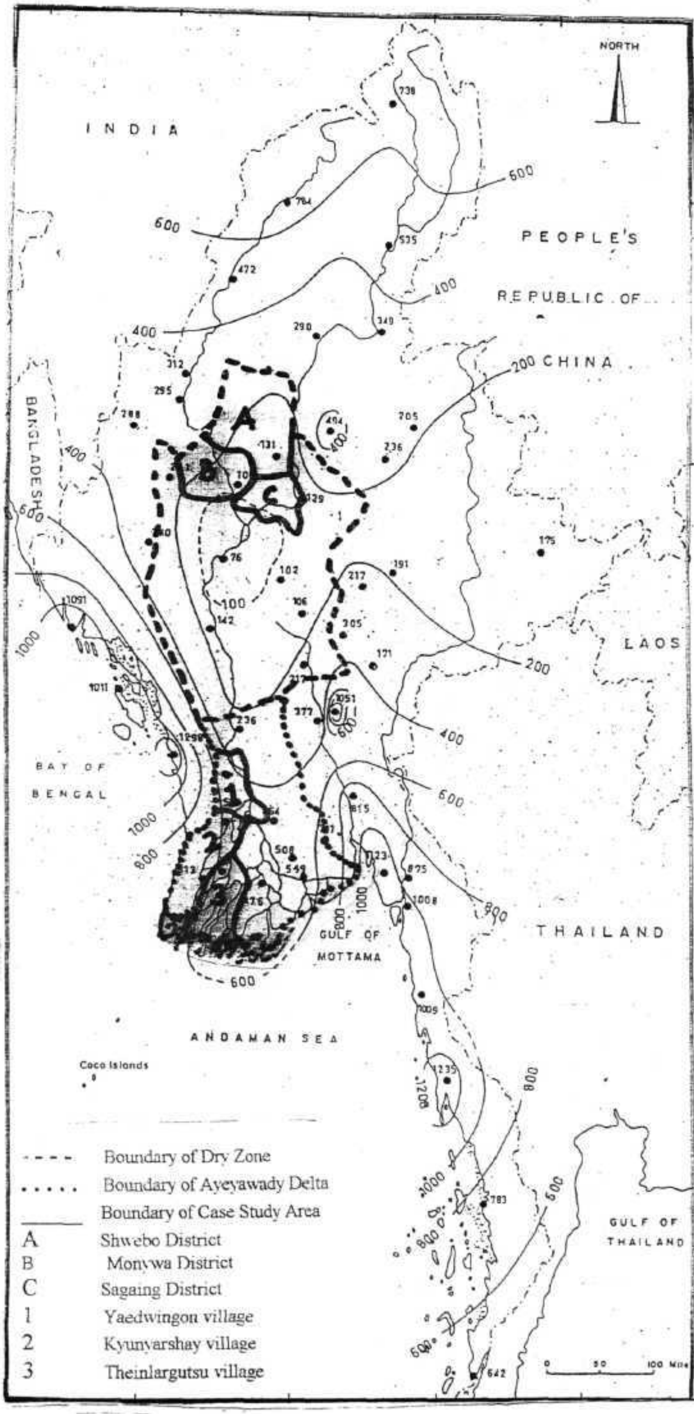


Figure (3.6.a) Distribution of monthly rainfall (mm) in June.

dry zone, 22 to 24 in the Northern hills, 24 to 26 in the Rakhine coastal region and 26 to 28 in the Taninthayi coastal region. Other noticeable values are 27.8 at Thandaung, 25.4 Pinlaung and 23.4 at Mogok.

In June, mean of rainfall or rain day is increasing in amount. However, there is an exception which is the decrease of mean intensity over the dry zone when compared to the previous month of May (see Fig 3.6. C). Hkamti and Putao area, the coastal strips of Rakhine and Taninthayi, and Thandaung experience the intensity more than 30 mm (1.18 in). The rest of the country receives 15 mm (0.59in) to 30 mm (1.18 in). The distribution pattern of mean intensity in June is very similar to the distribution pattern of rainfall in June.

In July, although the spatial distribution of rainfall is similar to that of June, the maximum value has shifted to Thandwe 1482 mm (58.35 in) and the minimum value remains at Nyaung-Oo with the rainfall of 38 mm (1.5 in) (see Fig 3.7.a). The range between them is 1444 mm (26.85 in) is greater than that of the previous month. In almost all parts of the country, stations receive much more rain than the previous month of June. But all the values of central Myanmar are lower than those of the previous months. The amount of rain received during this month varies in amount according to their various geographical locations and also due to the frequency of waves and depressions traveling West along the Inter Tropical Convergence Zone.

It is noticeable that the rainfall values of central Myanmar decrease from the previous month of June and these values are the least amount of rainfall over the country. During this month the amount of moisture in the air is not different from the early months of rainy season (May and June). The main cause of less rain during this month in the Dry Zone is the absence of uplifting of the moistened air. During this period the Southerly currents blow at high speed. The tracks of the Easterly waves locate North of the Central Dry Zone and there is less frequency of waves crossing in this month. Thus, divergent air flows in the low levels prevail over central Myanmar.

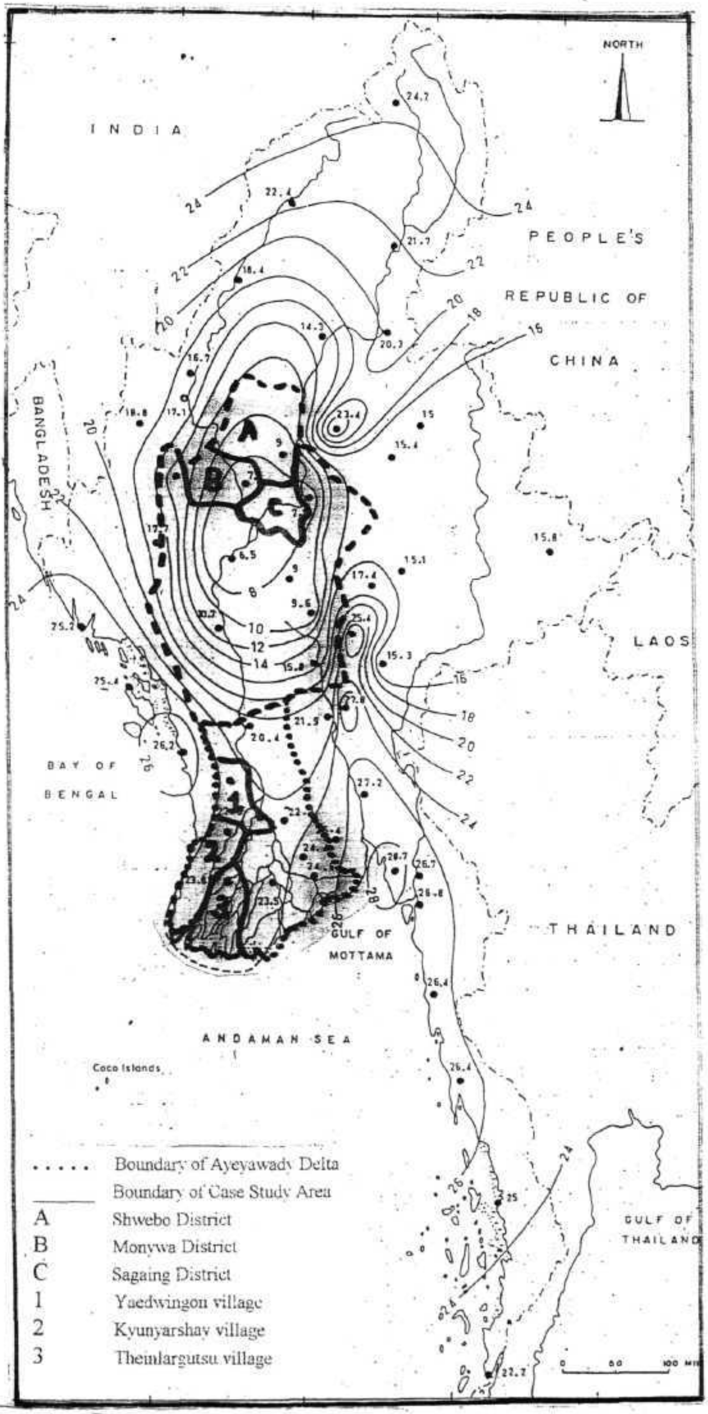


Figure (3.6.b) Distribution of monthly rain day in June.

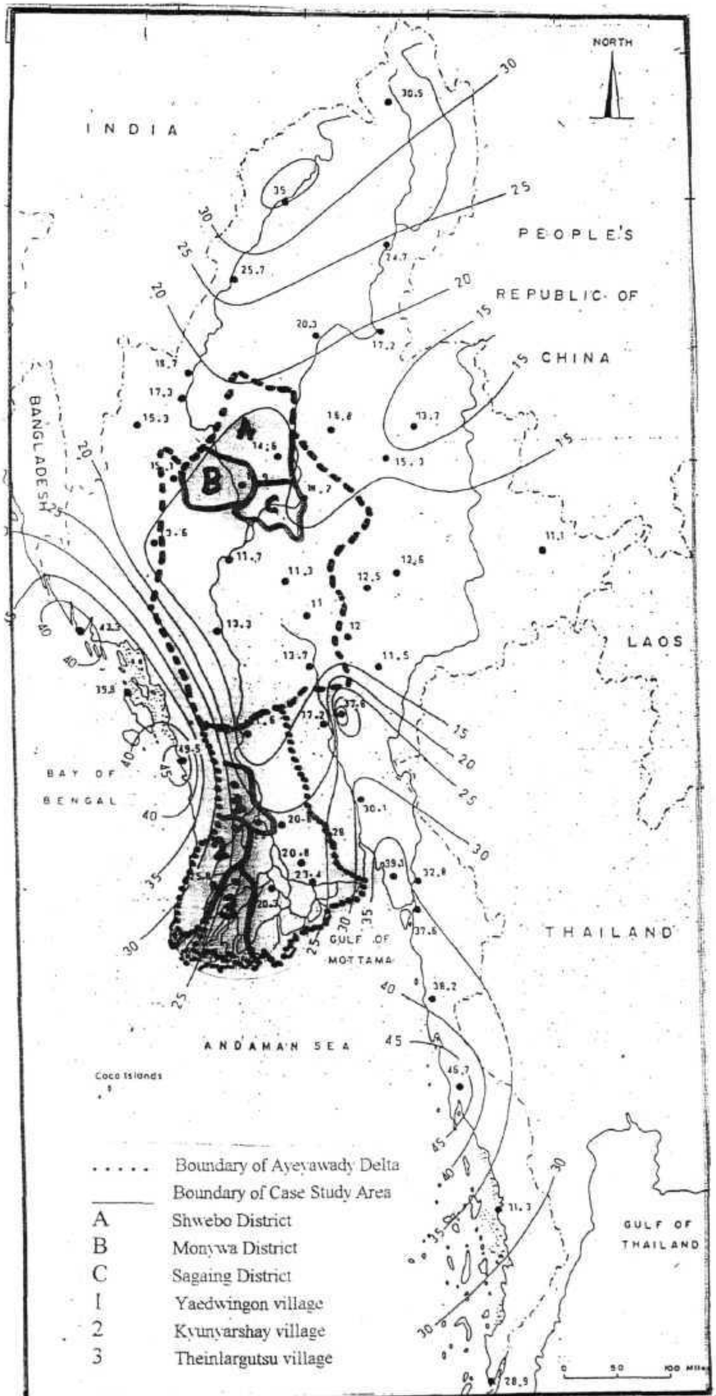


Figure (3.6.c) Distribution of mean intensity of rainfall in June

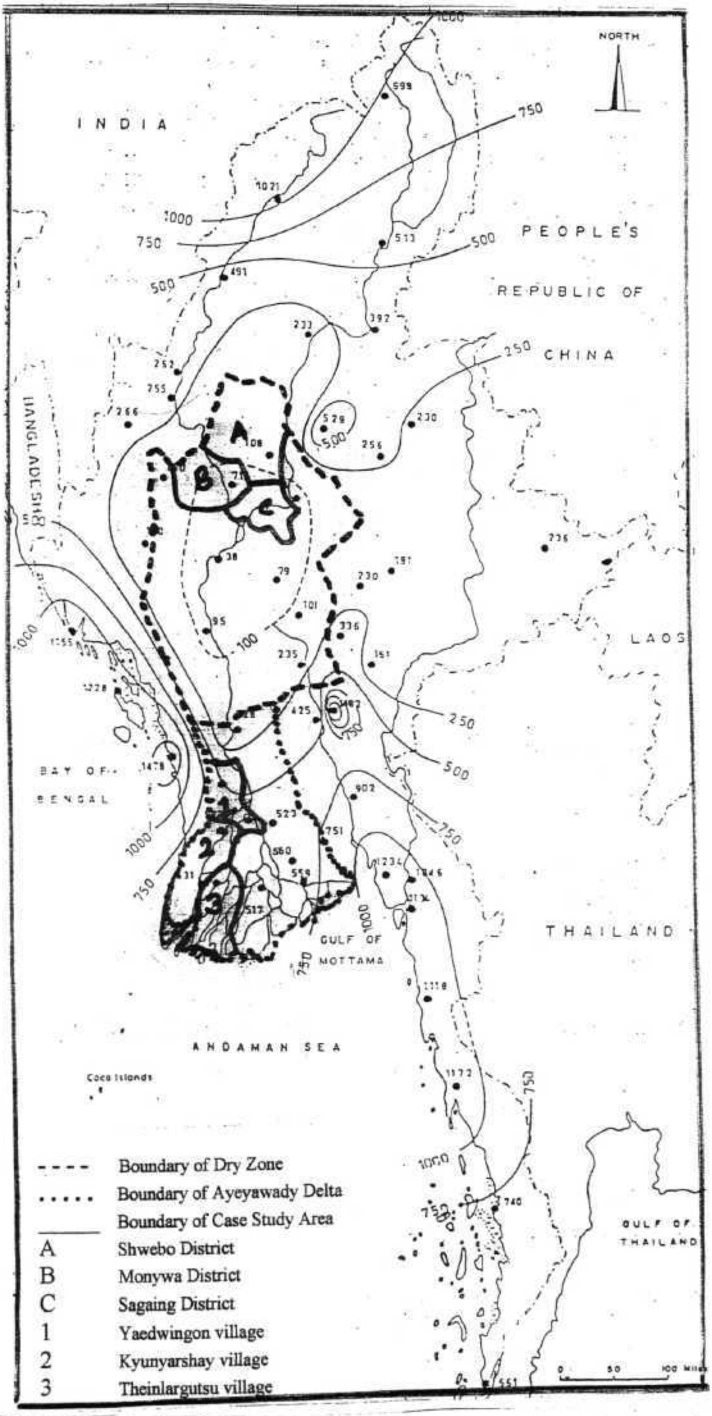


Figure (3.7.a) Distribution of monthly rainfall (mm) in July.

In this month of July, heavy rain is to be found along the coastal strip. The alignment of the Rakhine and Taninthayi Yoma along the coastline and their high elevation also contribute to the cause of getting very heavy rain in those regions. And then, monsoon is very vigorous and this situation receives greatest amount of rain. Among the stations of the coastal strips, Myeik and Kawthoung receive less of rainfall. Because these two stations situated closer to the equator and facing the Islands, they receive less rainfall than the other coastal regions. Thandaung, situated on the Western side of the Rakhine Yoma is in more Southerly location compared to the others, and closer to the path of the storm tracks traveling northwards, has better chances of getting heavier rainfall. Thandwe receives 1478 mm (58.19 in) of rainfall, Sittway 1155 mm (45.47 in) and Kyaukpyu 1228 mm (48.35 in). Along the Taninthayi coastal strip, Thaton records 1234 mm (48.58 in), Mawlamyaine 1134 mm (44.65 in) Ye, Dawei, Myeik ;and Kawthoung receive 1128 mm (44.02 in), 1172 mm (46.14 in) 740 mm (29.13 in) and 561 mm (22.09 in) of rainfall respectively.

The distribution of rainfall in July reveals that Northern hills region receives heavy amount of rainfall due to the movement of the tropical convergence zone. Another factor is that when the Southerly winds entered along the channels and reach the Northern hills region, moderate rainfall is received in this month which is much lower than that of the former months, whereas the amount of rainfall over the Shan highland is much more than that of June. In the Northern hilly regions, Putao has the monthly rainfall of 998 mm (39.29 in) Hkamti 1021 mm (40.2 in) and Myintkyina 513 mm (20.2 in). In the Shan high lands Taunggyi receives rainfall of 230 mm (9.06 in) Lashio 230 mm (9.06 in), Thibaw 256 mm (10.08 in) and Kyaington 236 mm (9.20 in). In the Chin Hills, Mindat enjoys 90 mm (7.48 in), Falam 266 mm (1047 in), Kalaywa 255 mm (10.04 in) and Mawlaik 262 mm (10.31 in). The Deltaic regions of Ayeyawady and Bago Division receive monthly rainfall of more than 500 mm (19.09 in).

By July, the feature of spatial distribution of rain days is more or less similar to that of previous month (see Fig 3.7.b). However, the Dry zone has low frequency than those of June whereas the surrounding high land regions have much higher numbers of rain days. This pattern also can be seen from the distribution map of

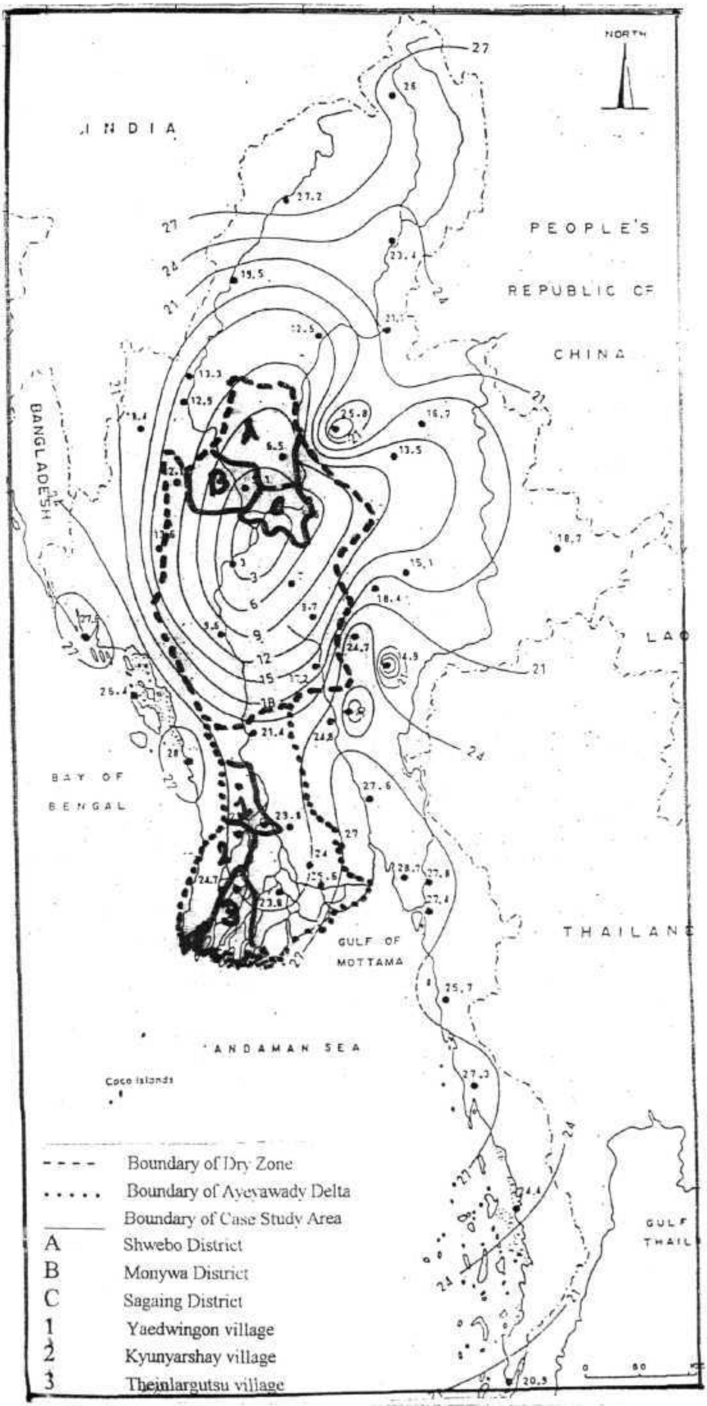


Figure (3. 7. b) Distribution of monthly calm day in July.

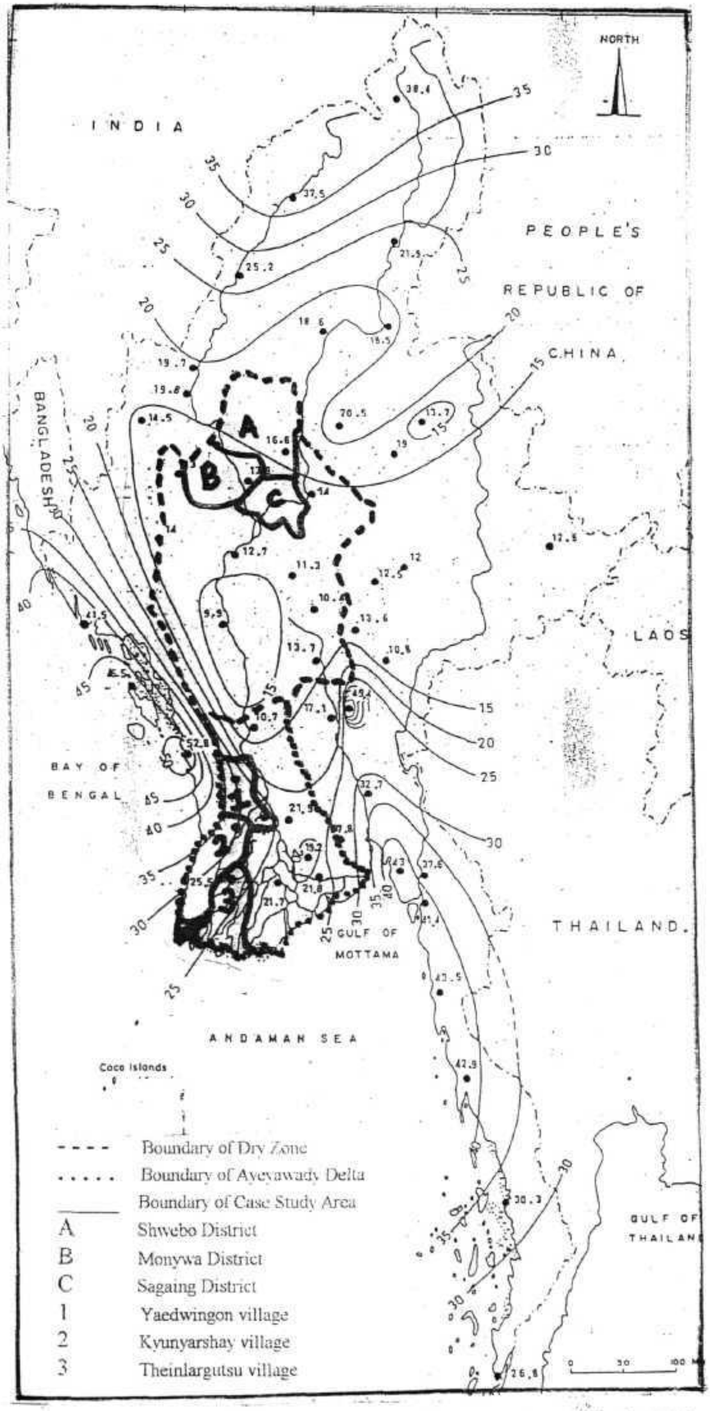


Figure (3.7.c). Distribution of mean intensity of rainfall in July mean monthly rainfall in July. The lowest frequency is to be found at Nyaung-Oo with 3 days. The maximum frequency coincides with the highest monthly rainfall. At Thandaung, the rain falls nearly the whole month of July (30 days) which may be a factor causing the highest value of monthly rainfall in July. The numbers of rain days are 3 to 12 in the Dry Zone, 12 to 21 in the Chin Hills and the Shan highlands and more than 27 in the remaining parts of the country.

In the Dry Zone, the record of rainfall intensity in July is less than that of the previous month of June (see Fig 3.7.c). The least value is to be found at Minbu with 9-9 mm (0.39 in) and the peak value to be found at Thandwe with 52.8 mm (2.09 in) the gradient of isohyets along the West of the Dry Zone is very steep and reflects the role of topography. The remarkable values may be found at Sittway with 41.5 mm (1.63in), Kyaukpyu with 46.8 mm (1.83in), Thandwe with 50 mm (1.97 in), Thaton with 43 mm (1.69 in), Mawlamyaine with 41.1 mm (1.63 in), Ye with 43.5 mm (1.71 in), Dawei with 42.9 mm (1.69 in) and Thandaung with 49.4 mm (1.94 in).

By **August,** the similar spatial distribution pattern of rainfall remains the same over Myanmar with Thandaung having the peak amount of 1416 mm (55.75 in) and Nyaung-Oo the least (83 mm, 3.27 in) the general trend of the distribution is lowest in the interior and increases outwards (see Fig 3.8. a). It is obvious that during the peak monsoon month of July and August, almost all parts of the country receive much of rainfall in the latter month than the former month. The packing of isohyets West of the Dry Zone reveals the steep topographic gradient. It can be seen that the rainfall over central Myanmar increases to about 200 mm (7.87 in). This may be due to the high frequency of Easternly waves in August. Other reason can be due to the shifting of the ITCZ from the Northern Myanmar towards the South.

Rainfall of the coastal strip of Rakhine decreases while the rainfall of the Taninthayi coastal strips increases. However, these coastal strips have heavy rainfall, because they are situated close to the sea and also on the windward side of high mountain ranges. As the heavy moist monsoon air mass sweeps across the Andaman Sea, its effectiveness as a rain producer does not become evident until it meets the Western Yoma.

When the distribution pattern of rainfall in August is compared to that of July, (Fig 3.8.a) shows that rainfall over the Northern hills region declines while that of the Chin Hills and the Shan highland regions increase. This is because of the South wards shifting of the ITCZ over the Northern hills region. The records of rainfall over these regions are 905 mm (35.63 in) at Putao; 650 mm (25.9 in) at Hkamti, 364 mm (14.33 in) at Mawlaik, 348 mm (13.7 in) at Kalaywa, 288 mm (11.34 in) at Falam, 351 mm (13.82 in) at Thibaw, 293 mm (11.54 in) at Lashio and 243 mm (9.57 in) at Kyaingtong.

The deltaic regions of Ayeyawady and Bago Divisions experience the rainfall amount of 500 mm (19.69 in) which is similar to that of the previous two months. The heaviest amount of rainfall over Myanmar is to be found at Thandaung with 1416 mm (55.75 in), Sittway with 1025 mm (40.35 in), Kyaukpyu with 1053 mm (41.46 in), Thandwe with 1401 mm (55.28 in), Thaton with 1326 mm (52.2 in), Ye with 1240 mm (48.8 in) and Dawei with 1342 mm (52.83 in).

In August, the maximum frequency of rain days is at Thandaung with 303 and the least number has shifted to Monywa (see Fig 3.8.b). The number of rain days in the Dry Zone increase in this month where as the coastal region have lower frequency than that of the previous month. The noticeable records are 29.4 rain days at Thaton, 28.3 at Mawlamyaine, 27.8 at Ye, 27.6 at Thandwe and Shwegyin, and 26.9 at Kyaukpyu, 26.2 at Sittway, 26.1 at Bago, 26 at Mogok and 24.6 at Putao.

In August, although most of the country reveals more or less similar values of intensity to that of July, the Dry Zone and some parts of Shan state represent considerable increase of values (see Fig 3.8.c). The packing of isohyets could be attributed to the steep topographic gradient. The distribution of rainfall intensity in August reveals that the least amount is to be found at Pyay and the values increase out wards. The area received the intensity of less than 15 mm (0.59 in) becomes narrower 'n this month. In other words, the area with 20 mm (0.79 in) of intensity becomes extended.

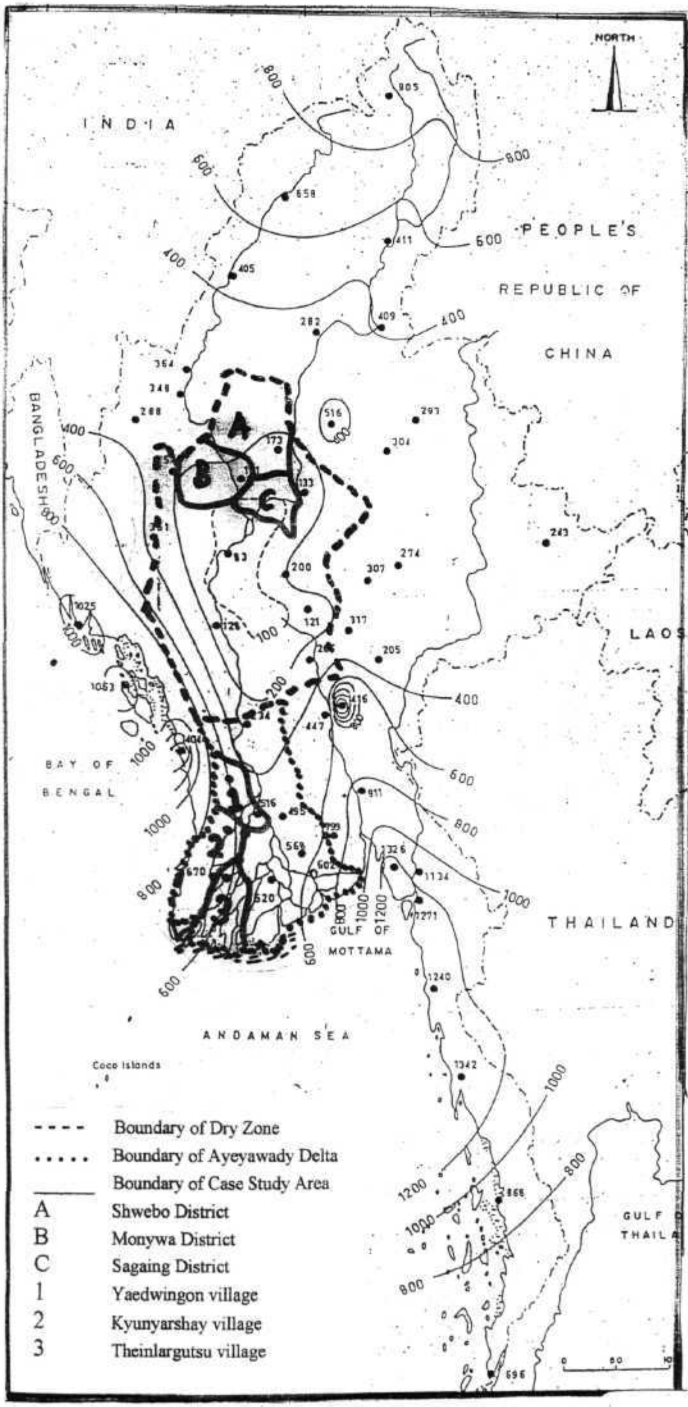


Figure (3. 8. a) - Distribution of monthly rainfall (mm) in August.

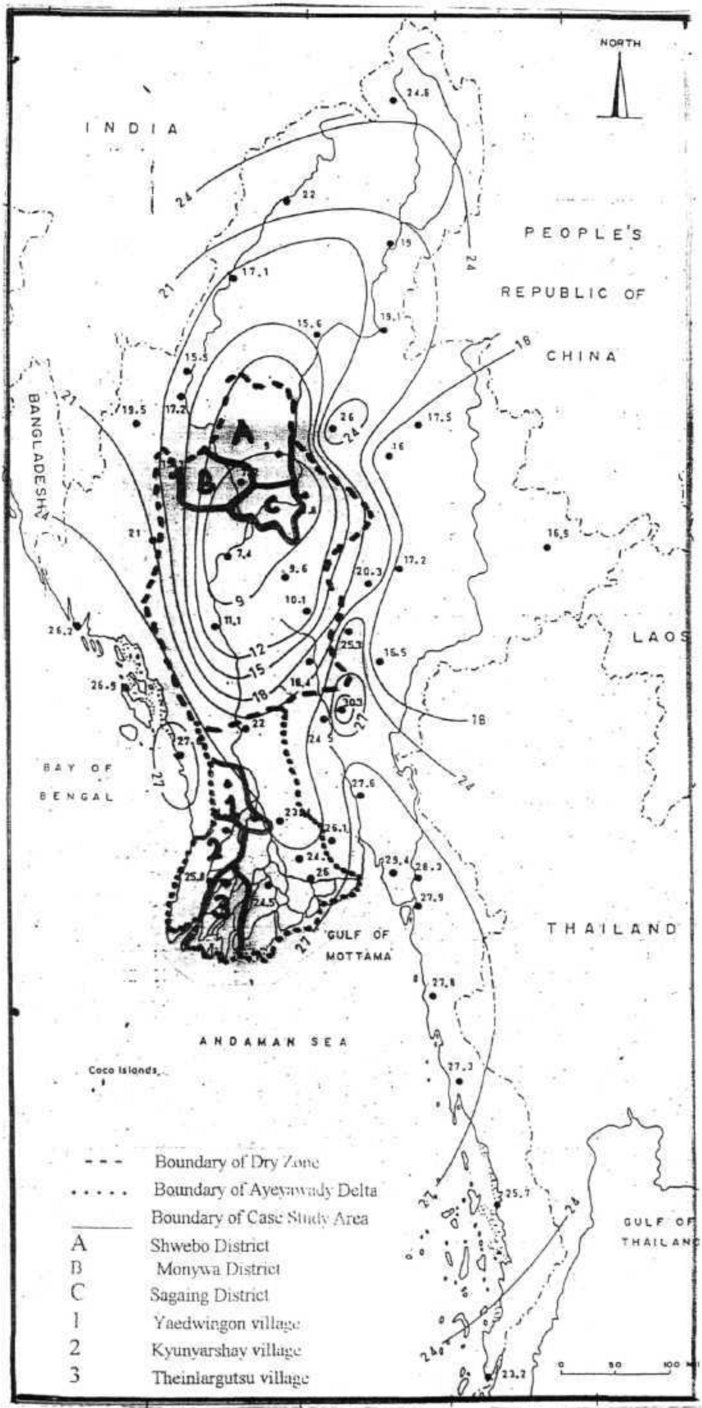


Figure (3. 8. b) Distribution of monthly rain day in August.

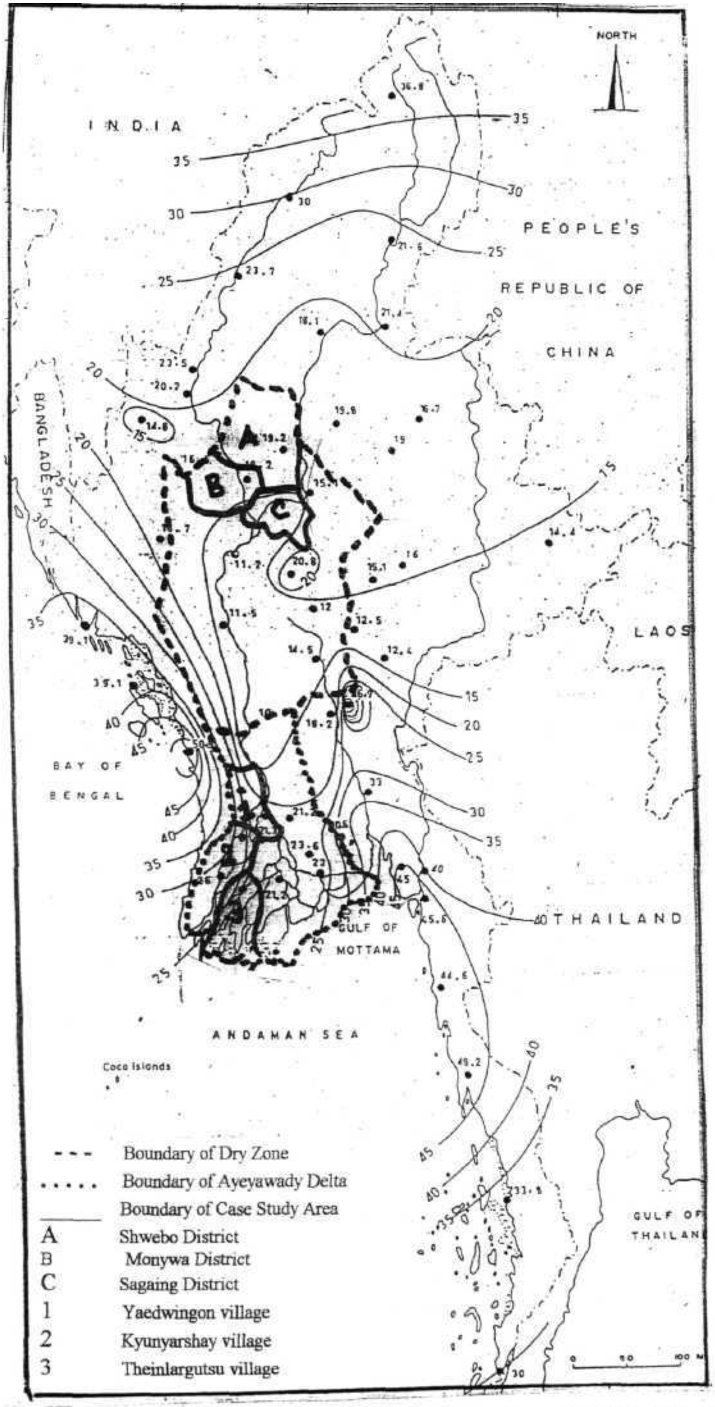


Figure (3. 8. c) Distribution of mean intensity of rainfall in August.

In September, the general features of rainfall distribution are more or less similar to that of the previous three months (see Fig 3.9.a). Although the maximum rainfall has shifted to Kyaukpyu 1109 mm (43.66 in), the least amount of rainfall still occurs at Nyaung-Oo 124 mm, (4.88 in). Rainfall received in the month of September reveals the gradual weakening of monsoon but there is an increase of rainfall over central Myanmar.

In central Myanmar, the values of rainfall amount are higher than that of the month of August. This is due to the intrusion of the remnants of lows, depressions, etc., from South Vietnam crossing Northern Thailand into central Myanmar. By the time they reach central Myanmar, the isobars are no longer distinct but there is still copious rainfall. The frequency of the Easterly waves occurred in September is more than that occurred in August. It is evident that most of the stations in central Myanmar (except Nyaung-Oo and Minbu) receive rainfall more than 150 mm (5.91 in).

The coastal strips of Rakhine and the Taninthayi experience a decrease of rainfall of about 600 mm (23.62 in) when compared to that of the peak monsoon month of July and August. Sittway receives rainfall of 537 mm (21.14 in), Kyaukpyu 1159 mm (46.01 in), Thandwe 614 mm (24.17 in), Thaton 479 mm (18.86 in), Ye 711 mm (27.99 in), Dawei 767 mm (30.2 in) and Thandaung 717 (28.23 in).

The Northern hills region, the Chin Hills and the Shan highland regions also receives decreased rainfall. Putao receives 645 mm (25.39 in), Hkamti 505 mm (19.88 in), Myintkyina 285 mm (11.22 in), Lashio 188 mm (7.73 in), Thibaw 167 mm (6.57 in), Taunggyi 281 mm (11.06 in) and Kyaington 171 mm (6.73 in). Of the deltaic region, Ayeyawady Divisions enjoy about 300 mm (11.81 in) and Bago Division receives more than 400 mm (15.75 in) of rainfall. This also reflects the important role of topography.

By September, the number of rain days all over the country has declined (see Fig 3.9.b) the outer limit of the Dry Zone experiences 10 rain days which is lower than 2 rain days in August. The lowest frequency occurs at Nyaung-Oo (7.0) and the

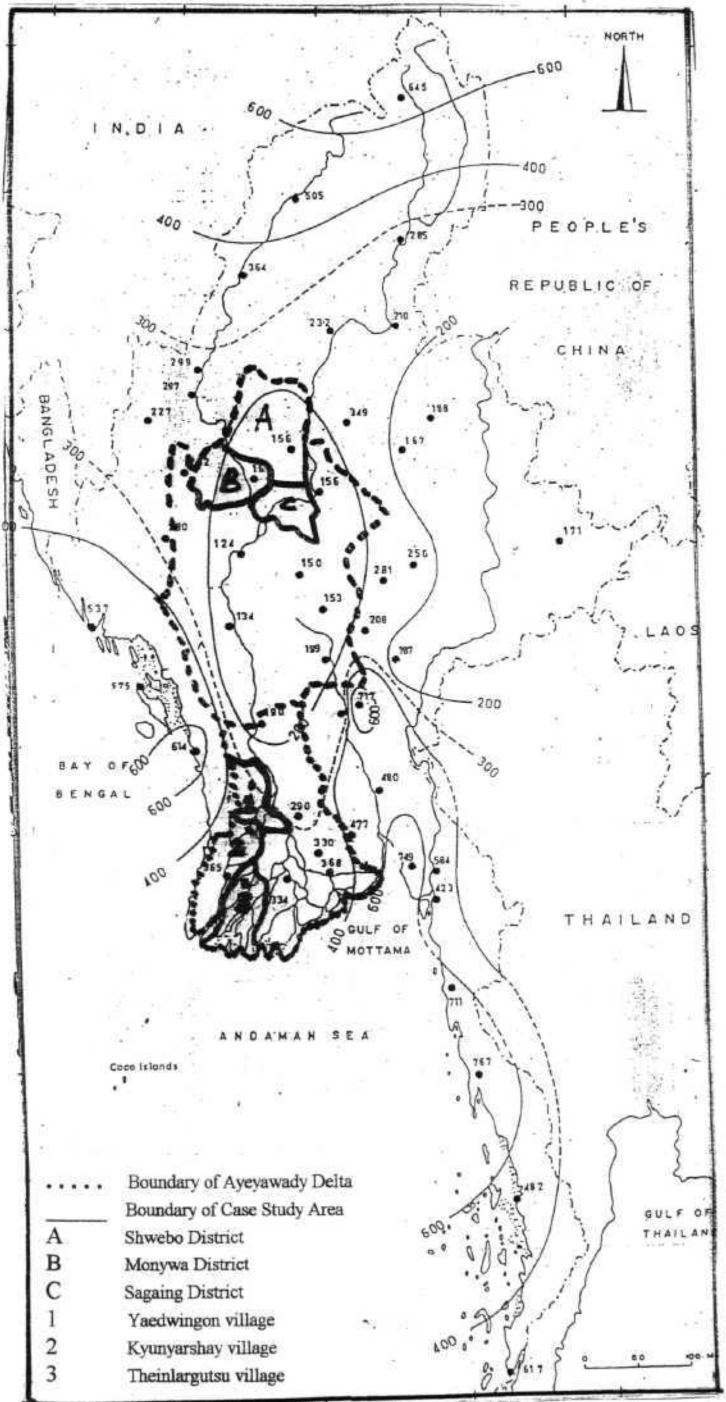
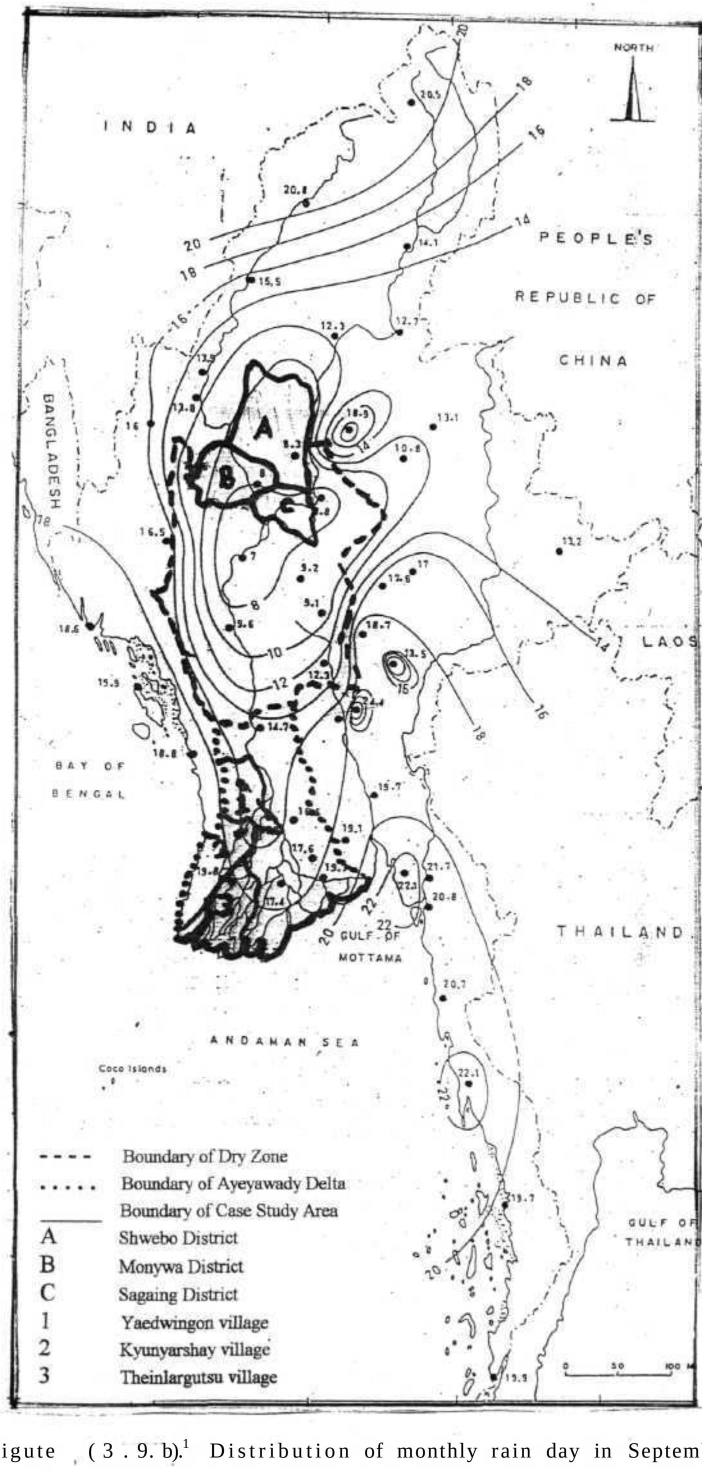


Figure 0.9. a)- Diatribution of monthly rainfall («) "in September.



Figute (3.9. b).[1] Distribution of monthly rain day in September.

highest frequency occurs and Dawei (22.1). Except the Northern hill region and the Taninthayi coastal strip, many parts of the country have 12 to 20 rain days.

In September, the distribution of rainfall intensity is little different from that of previous month of August (see Fig 3.9.c). The regions of the lowest values are the Shan state, the area from North of Minbu to the South of Pyay, and Falam. These regions receive less than 15 mm (0.59 in) of intensity. There is a decrease of values in the region of Rakhine and Taninthayi coastal strips and in the Northern hills region. These regions receive the mean intensity of more than 20 mm (0.79 in) and the rest of the country enjoys between 15 mm to 20mm.

By **October,** the distribution of rainfall is different from the previous month of September. Lowest amount of rainfall region locates in the central Myanmar and the values increase outwards (see Fig 3.10.a). The decrease amount of rainfall over the whole country shows the results of the retreating monsoon. The difference between rainfall of coastal region and the interior begins to decline.

When a comparative study of the distribution of the rainfall in central Myanmar between peak-monsoon and post monsoon is made, one may find in general, that the post monsoon rainfall is about 400 mm (15.75 in) higher than that of the peak monsoon months. Rainfall of about 300 mm (11.81 in) is confined only to the coastal regions of the Rakhine and the Taninthayi. Thandaung and Shwegyin where direct reflection of topography take place receive rainfall more than 300 mm. The amounts of rainfall received in the selected stations during this month of October are as follows:

Sittway 289 mm (11.5in), Kyaukpyu 256mm (10.08 in), Thandwe 207 mm (8-15 in), Thaton 292 mm (11.5 in), Ye 345 mm (13.58 in), Dawei 333 mm (13.11 in), %eik 302 mm (11.89 in), Kawthoung 369 mm (14.53 in) Thandaung 321 mm 02.67 in), Shwegyin 367 mm (14.45 in), Putao 132 mm (5.2 in), Hkamti 217 mm (8,54 in) Taunggyi 200 mm (7.87 in) and Kyaington 128 mm (5.04 in). Deltaic region of Ayeyawady and Bago Division receive monthly rainfall of below and above 200 mm (7.87 in) respectively.

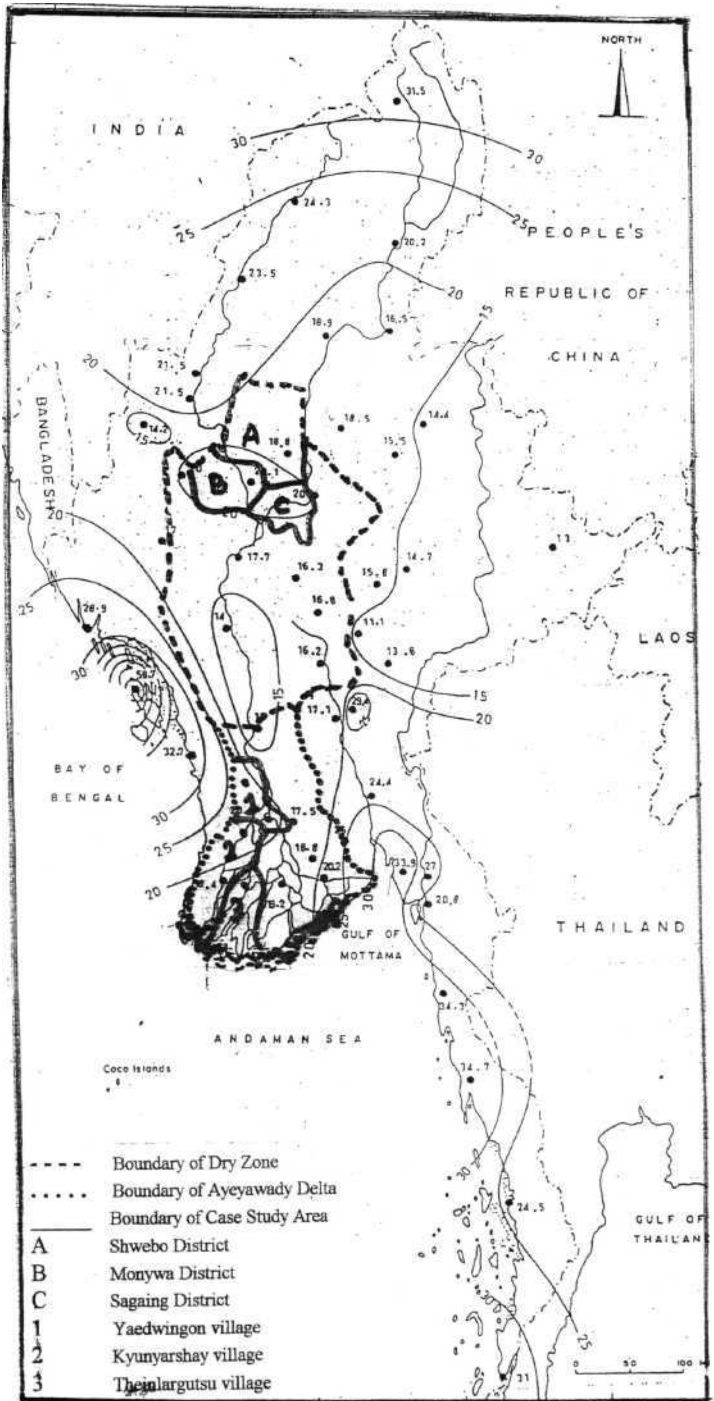


Figure (3.9.c) Distribution of mean intensity of rainfall in September.

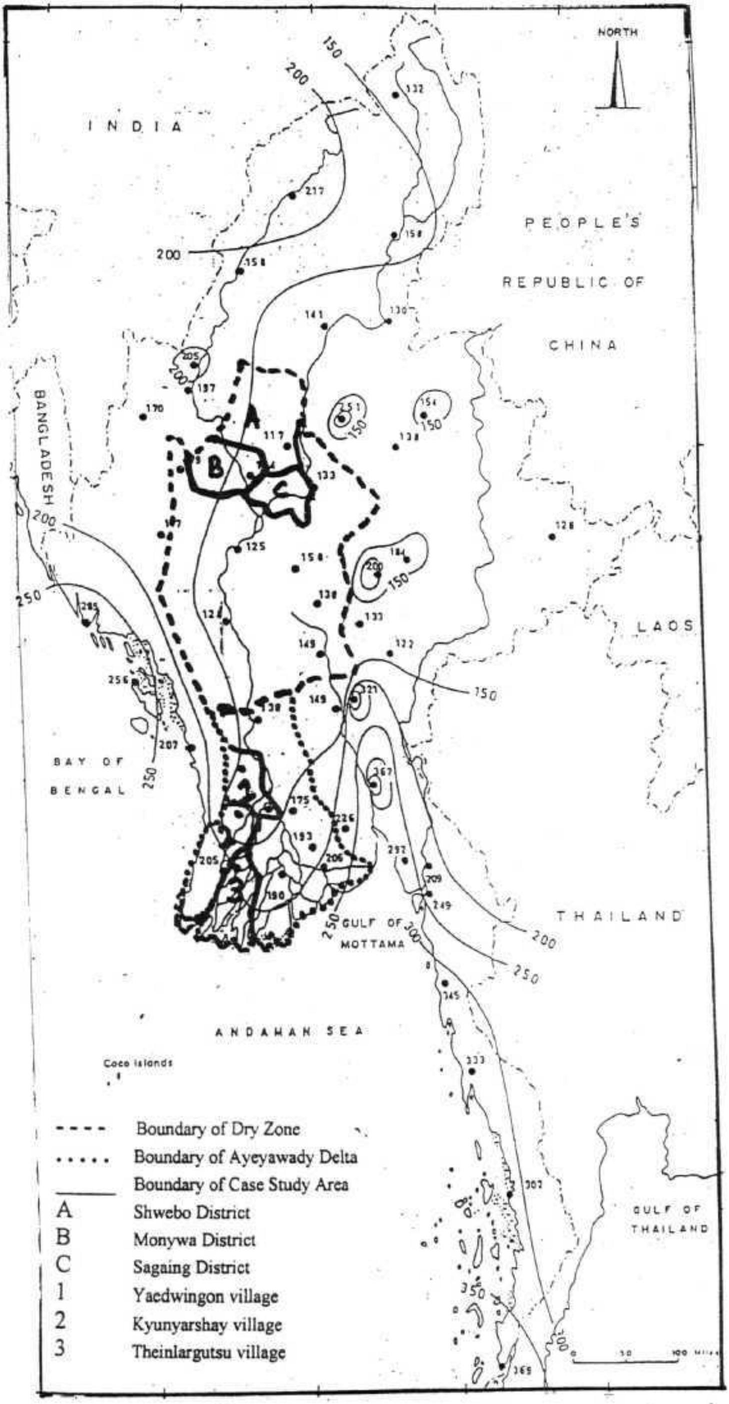


Figure (3. 10. a) Distribution of monthly rainfall (mm) in October

By October, the pattern of rain days has changed (see Fig 3.10.b). The frequency of rain days is still decreasing after the Southwest monsoon has retreated. It is noticeable that the peak frequency is found at Pathein (17.3). This may be due to the result of post monsoon storms. The Northern most part of Myanmar, the Rakhine coastal region (excluding Sittway), the Western part of Shan high land have a frequency of more than 10 rain days. That remaining areas experienced the monthly rain days of less than 10. The number of rain days in the Dry Zone is 5 to 7.

It is obvious that the mean intensity over Taninthayi has decreased considerably in October (Fig. *3.10c) but* an interesting annual feature is noticed over the Chin hills region, with increases of rainfall intensity instead of decreasing. The increase in intensity received in this region *is* due to *two* factors: one being *the* Northeast movement of cyclones from the Bay of Bengal to the Rakhine and Chin states, and *the other, the* storms that occurred in *the gulf of Thailand which move* towards Rakhine state. In general, most of the country experiences the mean monthly intensity between 15 mm (0.59 in) and 20 mm (0.79 in). The regions which receive more than 20 mm are the coastal strips of Rakhine and Taninthayi, Mawlaik, Kalaywa, Hkamti, Nyaung-Oo, Meiktila, Mogok and Thandaung, Putao, Bhamo, Monywa and some stations of the Shan state such as Taunggyi, Loilem, Pinlaung, Loikaw and Kyaington receive mean intensity of less than 15 mm.

The period from November to April is the dry season. Therefore, the amount of rainfall, frequency of rain day and mean intensity of rainfall become less. (Fig 3.11.a) shows the spatial distribution of rainfall in **November,** with the general trend of lowest rainfall in the north and highest in the south of the country. The minimum value is found at Putao with rainfall of 22 mm (0.87 in) and the maximum value at Kawthoung with the rainfall of 153 m (6.02 in). The values of rainfall amount over the whole of the country decrease twice as low as those of former month. This is due to the retreat of Southwest monsoon and prevailing of Northeast monsoon currents. *In* November, the minimum number of rain days shifted to Putao instead of Meiktila (see Fig 3.11.b), and Kawthoung has the highest frequency of *9.6.* In general, the number *of rain days over the whole* country never exceeds JO days.

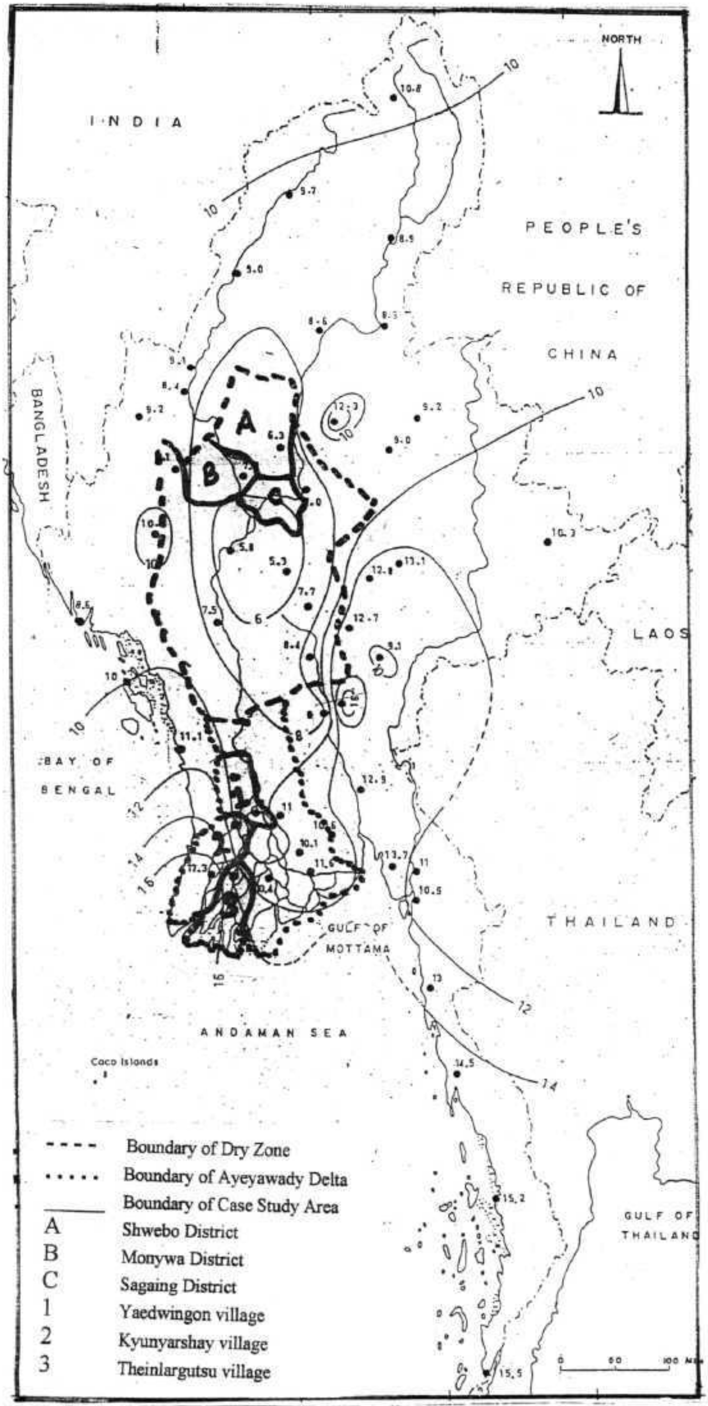


Figure (3.10. b) Distribution of monthly rain day in October.

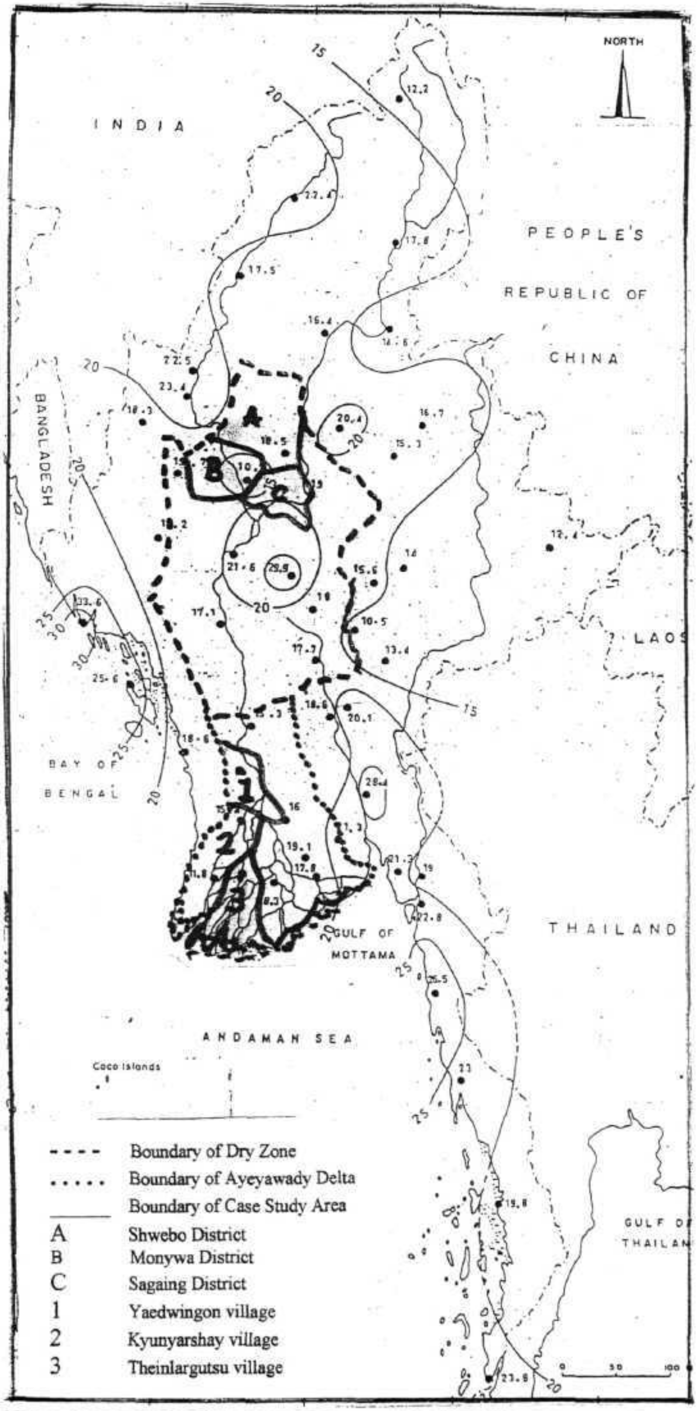


Figure (3. 10, c) Distribution of mean intensity of rainfall in October

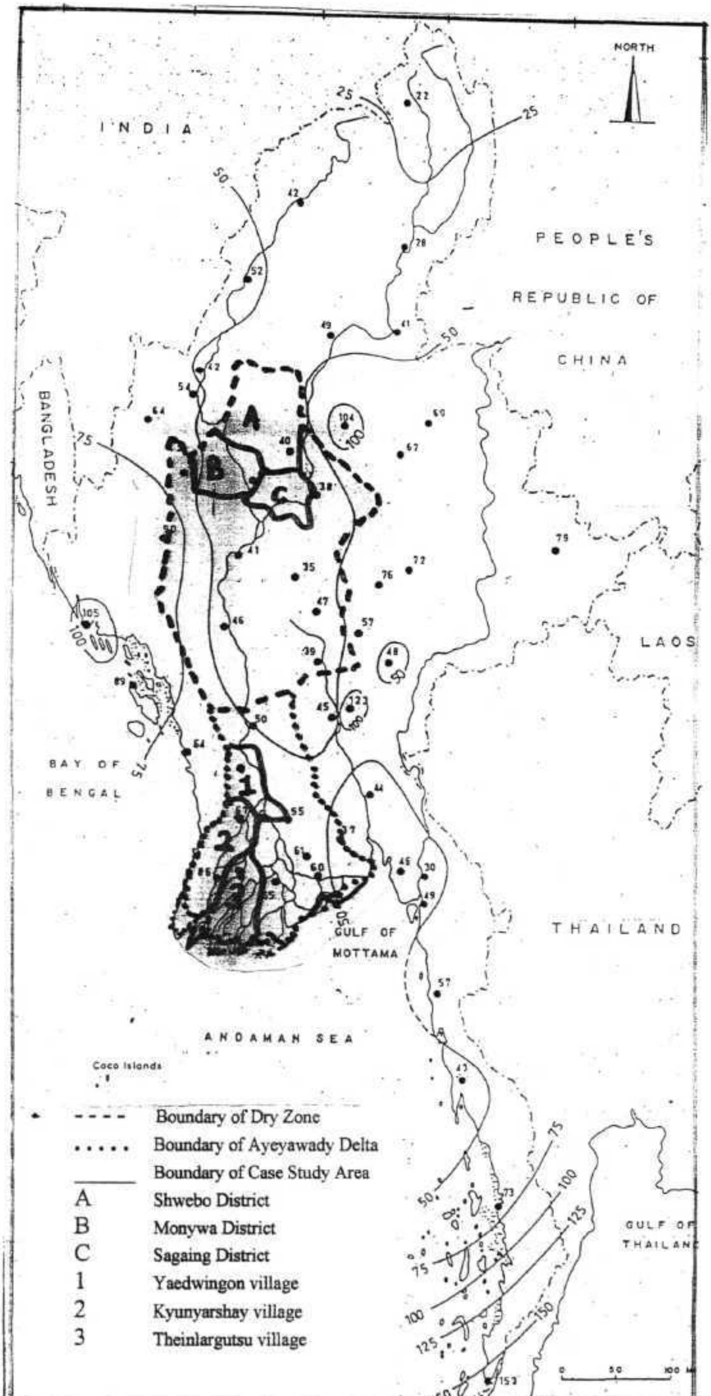


Figure (3.11.a) Distribution of monthly rainfall (mm) in November.

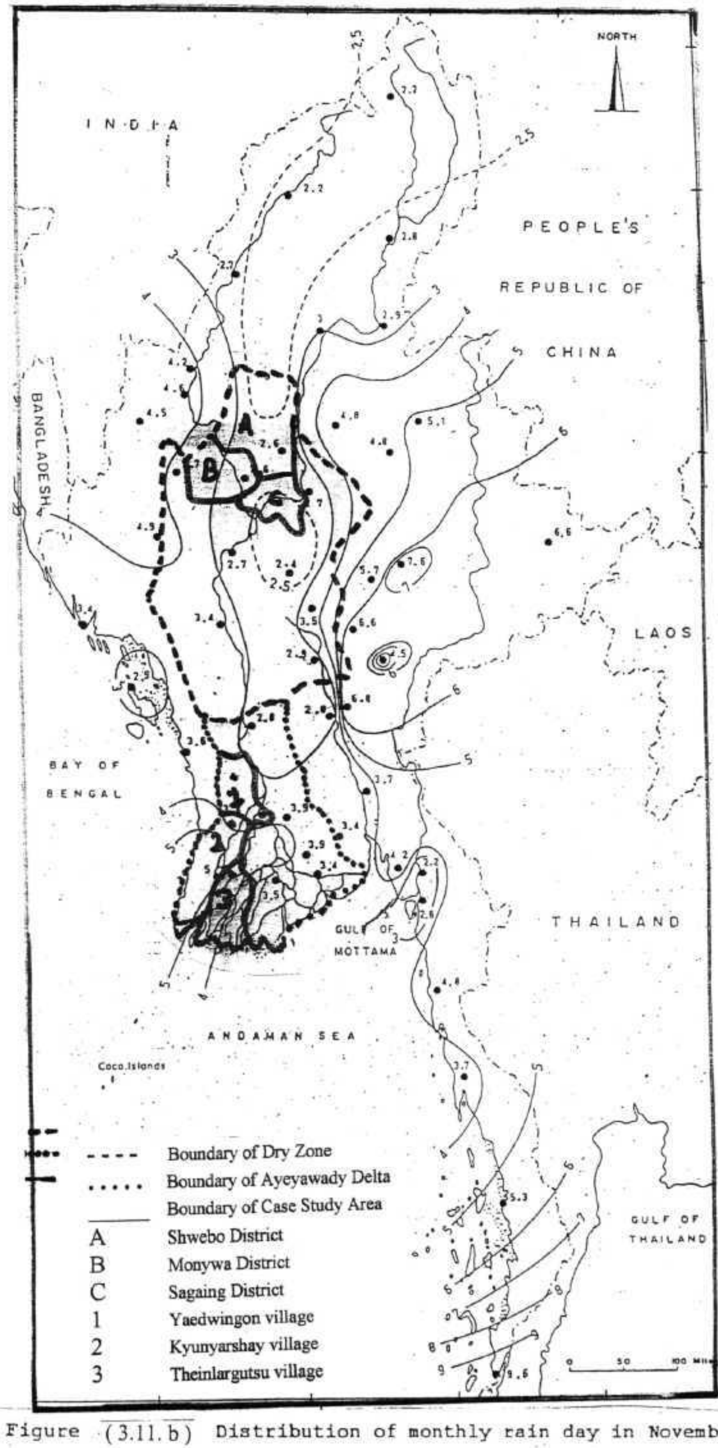


Figure (3.11.b) Distribution of monthly rain day in November.

In December, the maximum rainfall is 19 mm (0.75 in) at Myeik and the minimum is 2 mm (0.079 in) at Mawlaik, Kalaywa, Gangaw, Shwebo, Monywa, Minbu, Pyay and Thandwe. Kachin state, Northern Sagaing Division, Shan state and Taninthayi Division receive rainfall of above 8 mm (0.2 in). The highest frequency of rain days is 1.9 and it is found at Kawthoung.

In **January,** the maximum rainfall is 19 mm (0.75in.) at Myeik and the minimum is 2 mm (0.079 in.) at Maulaik, Kalaywa, Gangaw, Shwebo, Monywa, Minbu, Pyay, and Thandwe. Kachin State, Northern Sagaing Division, Shan State and Taninthayi Division receive rainfall of above 8 mm(0.24 in.). The highest frequency of rain days is 1.9 and it is found at Kawthoung.

In **February,** the maximum rainfall is 51 mm (2.01 in) at Myeik. Kachin state, Northern Sagaing Division and Taninthayi Division receive rainfall above 9 mm (0.35 in) and the highest frequency of rain days is 9.9 and is found at Putao.

In **March,** the maximum rainfall is 75 mm (2.95 in) at Putao. Kachin state, Northern Sagaing Division, Shan state and Taninthayi Division receive rainfall of more than 10 mm (0.39 in). The highest frequency of rain days is to be found at Putao (0.39 in).

In **April,** Kachin state, Northern Sagaing Division, Shan state, Chin state, Mon State and Taninthayi Division receive rainfall of above 45 mm (1.77 in). The maximum rainfall is 147 mm (5.79 in) at Putao and the mimmum is 10 mm (0.39 in) at Pyay. The frequency of rain days is from 8 to 13 in the Northern hills regions and from 4 to 6 in the Southern coastal strip and the Shan state, and from 2 to 7 in Sittway and the Chin Hills. Fig.3.12. a shows the distribution of annual rainfall and it can be seen that the amount of rainfall varies markedly from place to place. Over Central Myanmar the isohyets are presented as concentric ellipses contouring around the confluence of the Ayeyawady and the Chindwin Rivers. The Dry Zone of Myanmar is that part of the country bounded by the 1,000 mm (39.37 in) isohyet of annual rainfall. This area consists parts of Mandalay Division, Magway Division, and lower

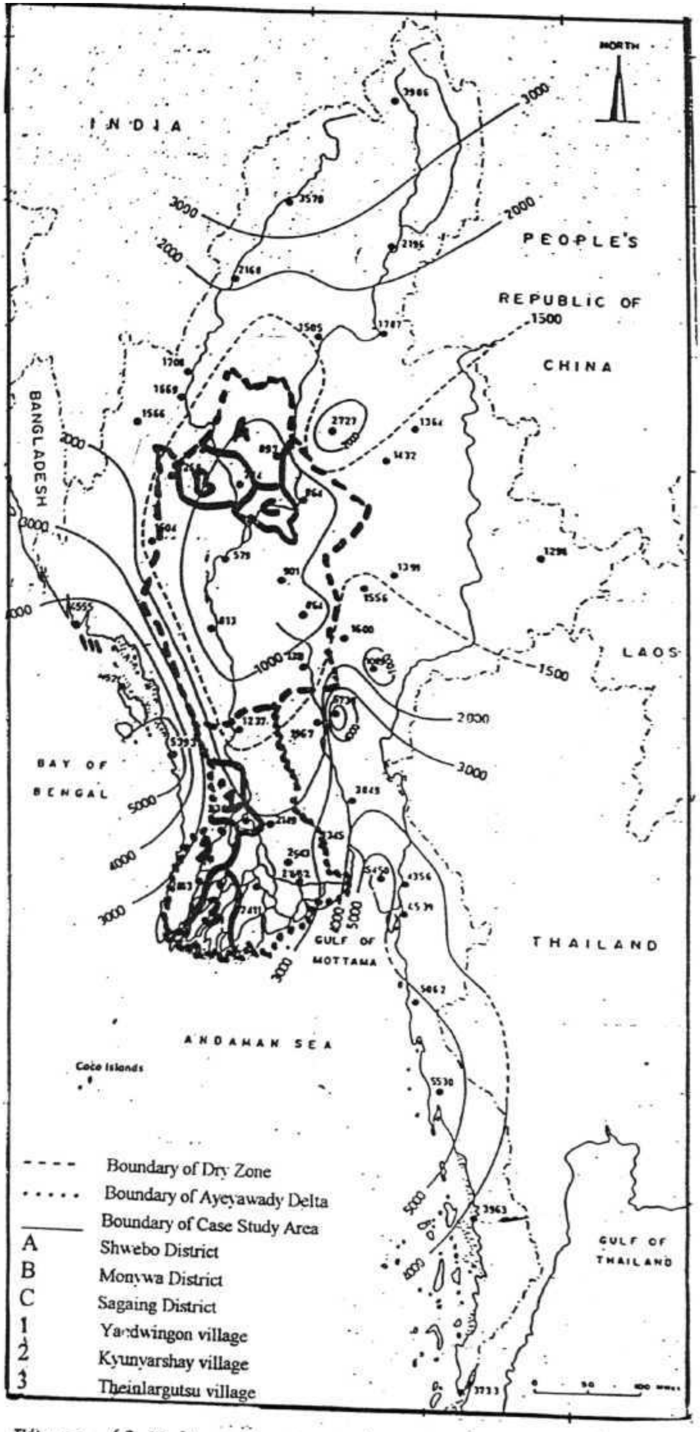


Figure (3. 12. a). Distribution of annual rainfall (mm) in Decemb

Sagaing Division. From year to year, due to the insufficient rain, this region has to depend on an expensive system of irrigation for its agricultural activities.

From the Dry Zone the rainfall gradually increases towards all directions, the gradient of isohyets are steep in the West where the land rises immediately to the Western ranges. The annual rainfall of Rakhine coastal strip is more than that of the Taninthayi coastal strip. It may be clear that the storms, occurring in the Bay of Bengal, constitute the main source of the rainfall received in this region. Another factor is the important role of topography. When the Southwest monsoon carrying much of moisture encounters almost vertically with the Western ranges it precipitates much of the rain over these high land regions and this is also the main factor that causes heavy rainfall over Taninthayi coastal strip.

To the East of the Dry Zone, the isohyets are widely extended up to the bottom of the Eastern highlands. The heights of Shan high lands are between 1500 to 3000 meters. In these regions, there are many mountains, high lands and valleys. It is observed that the amount of rainfall is attributed to the effect of the location of towns in the low valleys of the mountainous region. The height of the stations and their annual rainfalls are as follows:-

Station	Elevation(Height) (metres)	Rainfall (mm)	Rainfall (in)
Thibaw	435.9	1432	36.38
Kyaington	827.2	1298	51.1
Loikaw	895.5	1089	42.87
Loilem	1355.5	1399	55.09
Taunggyi	1436.2	1556	61,26
Pinlaung	1436	1606	63.23

Source: Meteorology& Hydrology Dept. Yangon, Myanmar, 1998.

There is the **exception that** Loikaw has **much** less rainfall when compared to its elevation. This may be due to the surrounding mountain highlands. On the West of Loikaw, the height of the mountain which is situated in the Shan state is generally 900 metres. The noticeable peaks of these mountains are 1818 m in the North -West of Loikaw and 2037 m in the Southwest of Loikaw. Similar to that, there is a range on the East of Loikaw between the Nampung and Thanlwin Rivers. This range is more than 900m and some other peaks with height of 1566 m and 1679 m are in the due East and in the East of Loikaw respectively. Thus, the position of ranges in the East and West of Loikaw could be the main cause of less rain over Loikaw.

To the South of the Dry Zone, the isohyets have a southward deflection in passing the Ayeyawady valley and recurve northward in the Sittoung valley. It is obvious that the rainfall of Ayeyawady valley is relatively lower than that of Sittoung valley. For example, Toungoo which is located on the West bank of the Sittoung river receives 1967 mm(77.44 in)of annual rainfall while Pyay which is located on the East bank of the Ayeyawady, even the same latitude, receives rainfall of 1237mm(48.7in) annually. Both serve as the drainage channels for the Southerly winds into the Dry Zone. Of the two, the Sittoung valley is some what narrower with the Eastern escarpment lying right near the Sittoung River. This physical condition may be the cause for the channeling effect of the Southerly winds resulting in more uplifting and more rains in the Sittoung valley.

There are some places where orography plays an important role in the variability of rainfall. Thandaung which is situated in the Northern fringe of the Shan highlands with its altitude of 1470 meters shows an orographic intensification of rainfall. The general orientation of mountain ranges lying directly in the path of the Southwesterly airflow is particularly favorable for heavy orographic rain. Such being the case, Thandaung receives an annual rainfall of 5738 mm (225.91 in), which exceeds its surrounding place like Toungoo (1967 mm (77.44 in). The same situation is also apparent at Mogok. The packing of isohyets in the areas of Mogok is due to the steep topographic gradient.

One can find Thaton as another heavy rainfall area, because the gulf of Mottama has perturbations which are locally known as "Sumatra's". These disturbances are caused by local thermal convection over warm sea surface and also there is convergence of local breezes from the surrounding coastal areas. Another effect to cause the heavy rainfall over Thaton is due to the steering of Southwesterly air when they enter the Sittoung river channel. It is considered that the surrounding high mountains in the vicinity of Thaton may be one of the factors contributing to the high amount of rain over Thaton.

To the North of the Dry Zone, the values of isohyets become greater. Much of these rains are from orographic rain. During the rainy season, most of the Southwest monsoon winds have freely passed over the Dry Zone, leaving the region with many cloudy but rainless days. When these rain bearing winds encounter with the Northern ranges, air ascends and precipitation occurs over the Northern high lands. The annual rainfall at Homalin is 2168 mm (85.35 in), Myintkyina 2196 mm (86.46 in) Hkamti 3570 mm (140.55 in) and Putao in the far North of Myanmar receives 3906 mm (153.78 in). In general, the distribution of rainfall in Myanmar is determined by the topography of the country. Fig (3.12.b) shows the distribution of annual rain days. It can be seen that the central Myanmar has the least number of rain days. The Isohyets are present as concentric ellipse centering on the Dry Zone, and the number of rain days increases towards the North, East, South and West. The gradients of isohyets around the Dry Zone are steep to the West and to the South. In the East and West of the Dry Zone, the Chin Hills and Shan high land experience the annual rain days of over 100 but not more than 120. The Northern hills region and the coastal strips of Rakhine and Taninthayi have the frequency of more than 120. The maximum number of rain days occurs at Thandaung with 158.2. When rain days is compared to annual rainfall one can find that a strong correlation exists (0.1) between the number of rain days and the total amount of rainfall at the 0.1 percent significant level. However, the Northern hill region are an important exception to this rule- here the number of rain days increases with elevation but the total amount of rainfall gradually decreases.

3.4.2 The Seasonal (Temporal) Distribution

The seasonal or temporal rainfall distribution is of vital importance in human activities especially in agriculture. The temporal (monthly distribution through the year) is often more significant than the annual average. It is the major controlling factor of the calendar of agricultural activities. In many parts of the tropics the times °f the beginning, duration and end of the rainy season are decisive factors in the

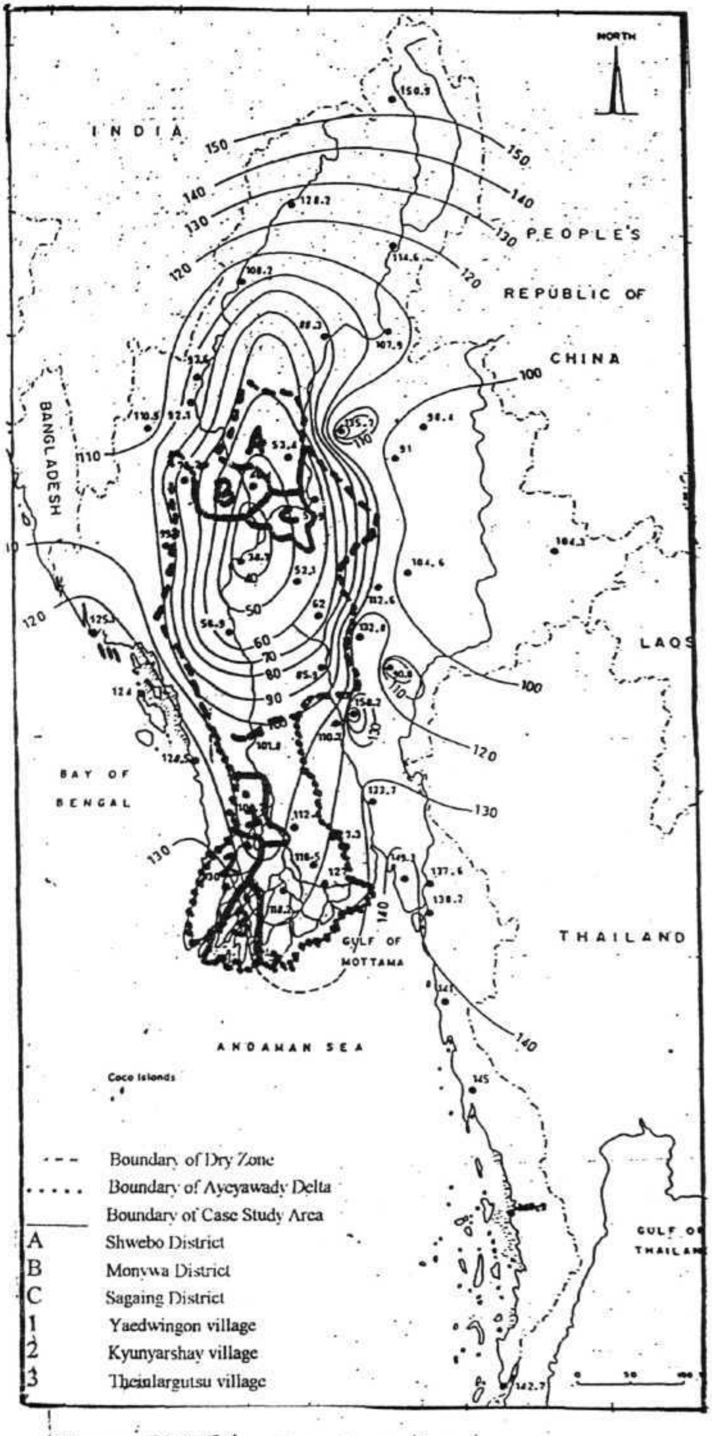


Figure ,(3.12.b) Distribution of annual rain day in December struggle for sufficient food supply. Rainy season also results in variation of temperature, moisture and cloud conditions compared to the dry periods, and rainy seasons they have influenced the general weather condition.

The information on the monthly variation of rainfall in a specific location is also important in the application of agriculture. Seasonal variations of rainfall for each station are shown in (Fig 3.14.a to Fig 3.15.e).

Two types of monthly rainfall distribution can be identified in Myanmar (see Fig. 3.13).

(1) The uni-modal pattern (One maximum)

(2) The Bi-modal pattern (double maximum).

The first type consists of stations where there is only one maximum rainfall period through out the year. This type can be subdivided into two groups. In the first group the peak amount of rainfall occurs in July and the second type has the maximum amount of rainfall in August. This may be due to the condition of monsoon effect and the location of these stations. During July and August, monsoon is vigorous and rainfall is heaviest in these months. However, the amount of rain received during this period may vary in amount according to this various geographical locations and also vary from season to season depending on the frequency of waves and depressions traveling West along the inter tropical convergence zone.

Generally, July has the maximum of rainfall. However, for some stations, August has the highest rainfall and total rainfall is reduced a little in July. And this can be correlated with the higher frequency of typhoons in August. Some of the typhoons of the Pacific Ocean move westward and hit North Vietnam or South China Coast. The remnants of these typhoons continue to move westward as low pressure and reach Myanmar. Therefore, in August the monsoon rain is added with rain produced by waves causing the maximum amount of rainfall.

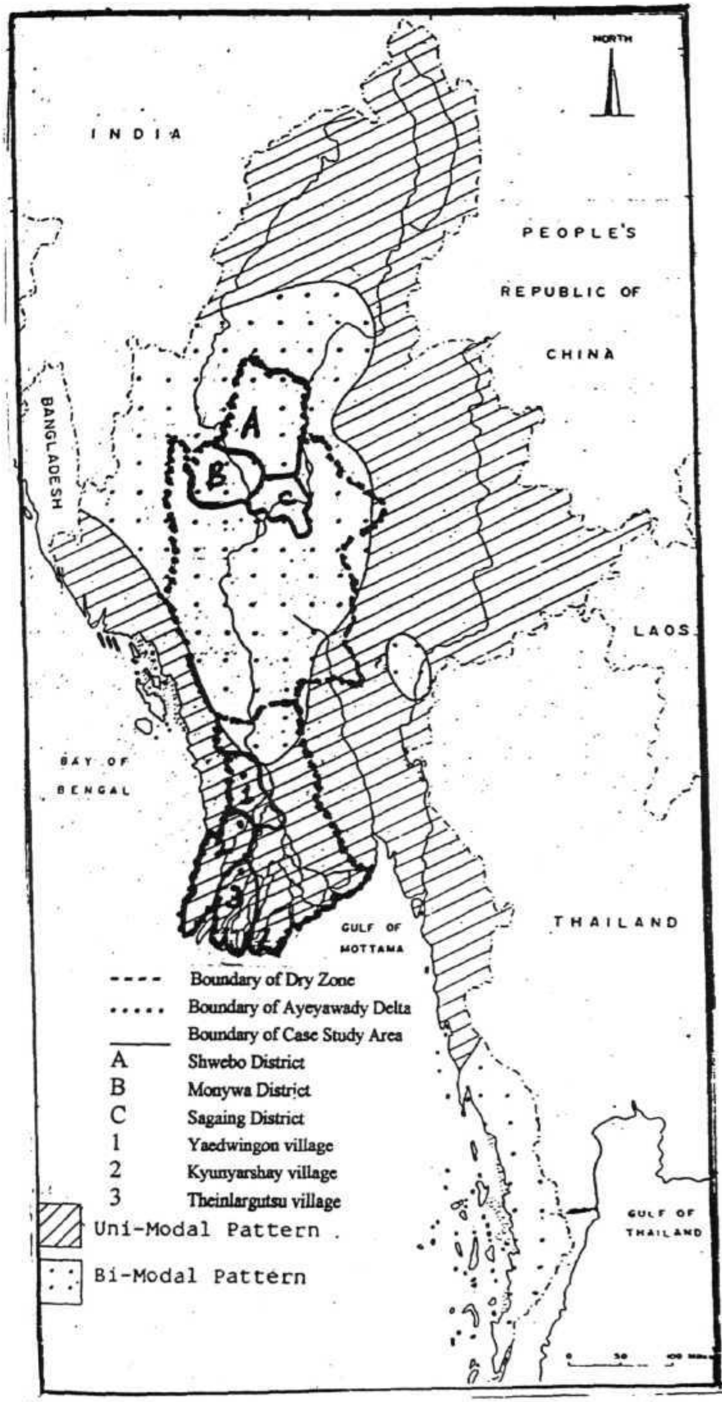


Figure (3.13) Distribution of Rainfall Pattern over Myanmar

The first group of July maximum rain can be found along the coastal areas of Rakhine state, the Ayeyawady valley between the area under Pyay and the area of upper deltaic region, the Northern hills region (upper part of Sagaing Division and Chin state), Mogok, Thandaung and Pinlaung area. Stations included in this group are Sittway, Kyaukpyu, Thandwe, Hinthada, Thayawady, Putao, Myintkyina, Hkamti, Homalin, Mogok, Thandaung and Pinlaung (see Fig 3.14.a to 3.14.c). It can be seen that most of these stations are situated in hilly regions.

In June, July and August, the amount of rainfalls at Thandaung, Thandwe, Sittway, and Kyaukpyu are more than 1,000 m. Putao, Hkamti, Mogok and Hinthada have more than 500 .mm of rainfall, where as Myitkyina, Homalin, Thayav/ady and Pinlaung receive rainfall between 300 mm and 400 mm. The intensity of rainfall among these three months vary slightly at the stations of Thandwe, Sittway, Mogok, Thayawady and Pinlaung and that of the remaining stations are considerable. The frequency of rain days is also highest in the month of July except Kyaukpyu, Hinthada, Mogok and Pinlaung.

The region of the uni-modal pattern with August maxima extends to nearly all of the Shan plateau, Bhamo area, lowest parts Ayeyawady, the Bago Division, the Sittoung valley, and the Kayin and Mon states. In this second group, Thibaw, Lashio, Taunggyi, Kyaington, Loilem, Bhamo, Maubin, Hmawby, Yangon, Bago, Pyinmana, Toungoo, Shwegyin, Thaton, Hpa-an, Mawlamyaine and Ye are included.

During the three months of June, July and August, the rainfall values are more than, 1,000 mm at Thaton, Ye, and Mawlamyaine, more than 800 mm at Hpa-an and Shwegyin, more that 500 mm at Bago, Pathein, Yangon, Hmawby and Maubin, between 200 mm and 400 mm at Toungoo, Bhamo, Pyinmana, Thibaw, Lashio, Taunggyi, Kyaington, and Loilem (see Fig 3.14 d to 3.14 h). Between these three months, the rainfall variations at Pathein, Yangon, Hmawby and Maubin are not significant **whereas the others** are fairly considerable.

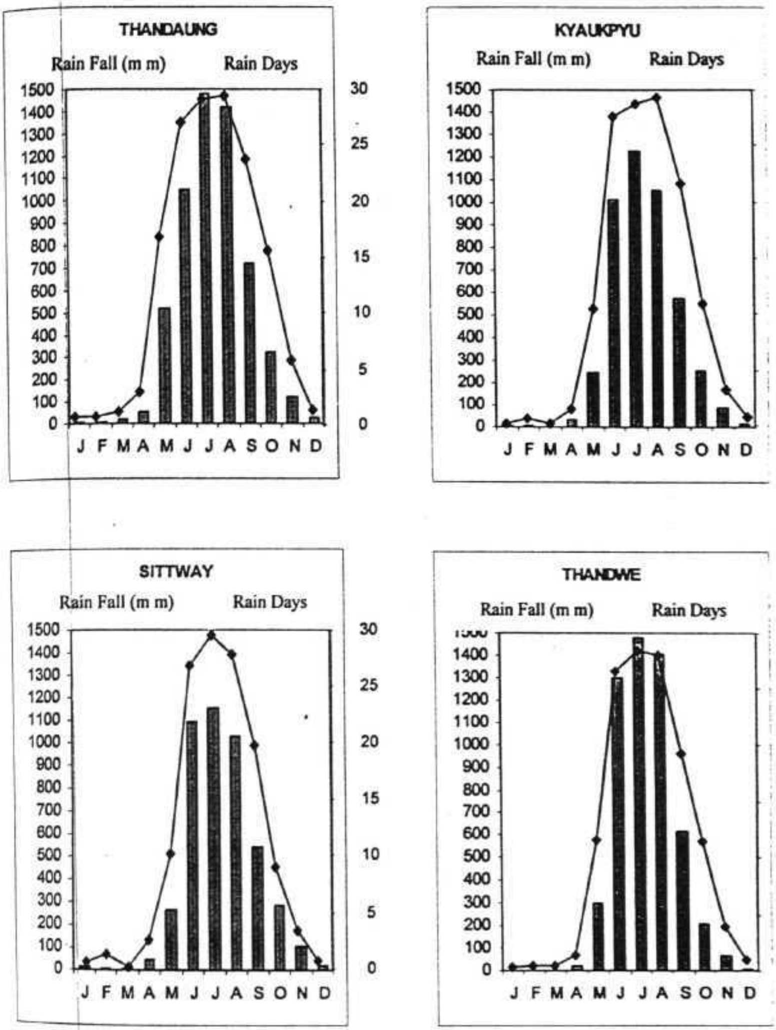
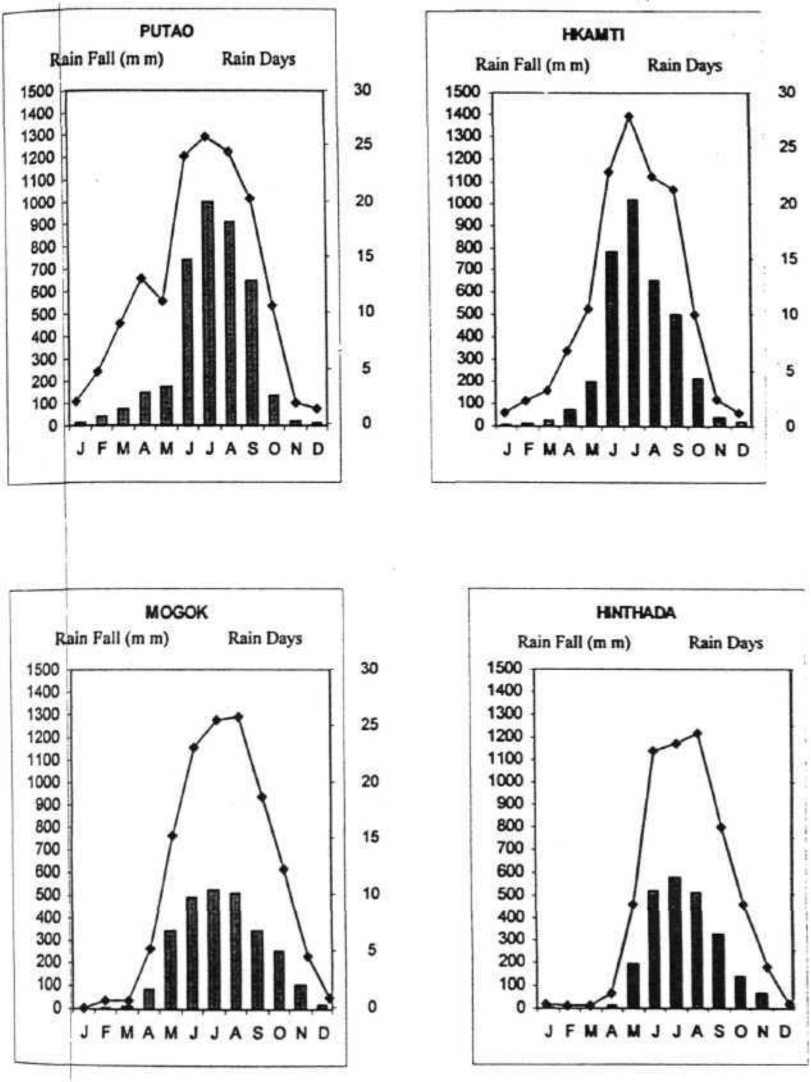


Figure (3.14.a) Monthly distribution of rainfall and rain day for Thandaung, Kyaukpyu, Sittway & Thandwe.



Figure(3.14.b) Monthly distribution of rainfall and rain day for Putao, Hkamti, Mogok & Hinthada.

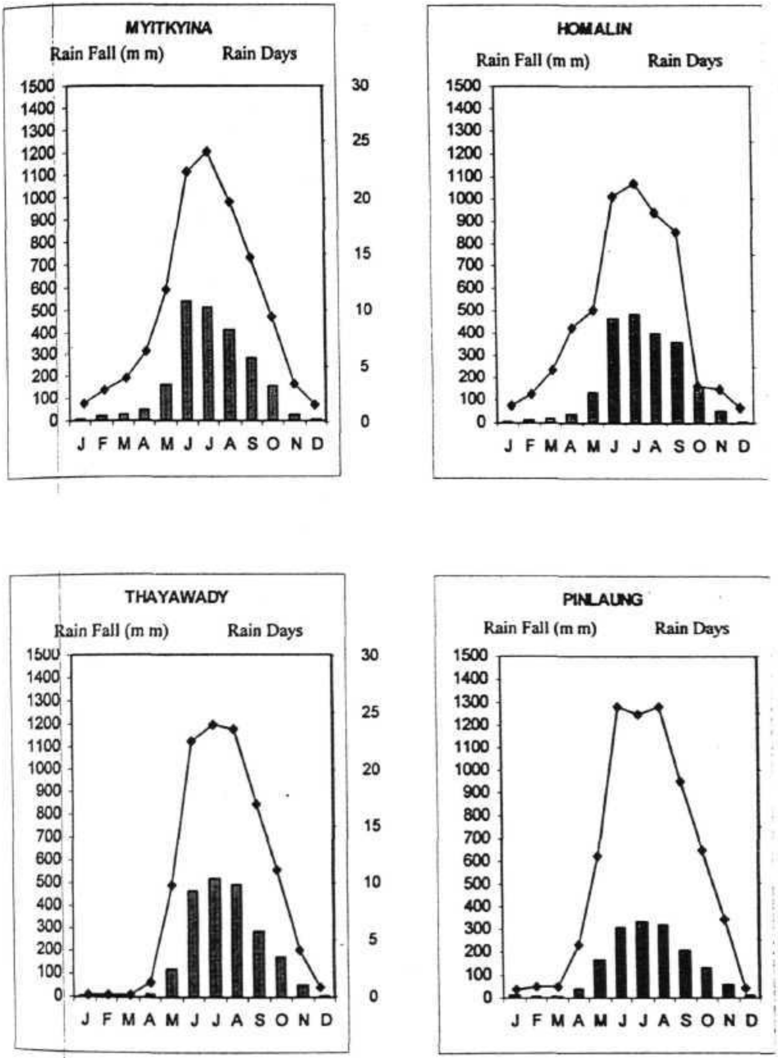
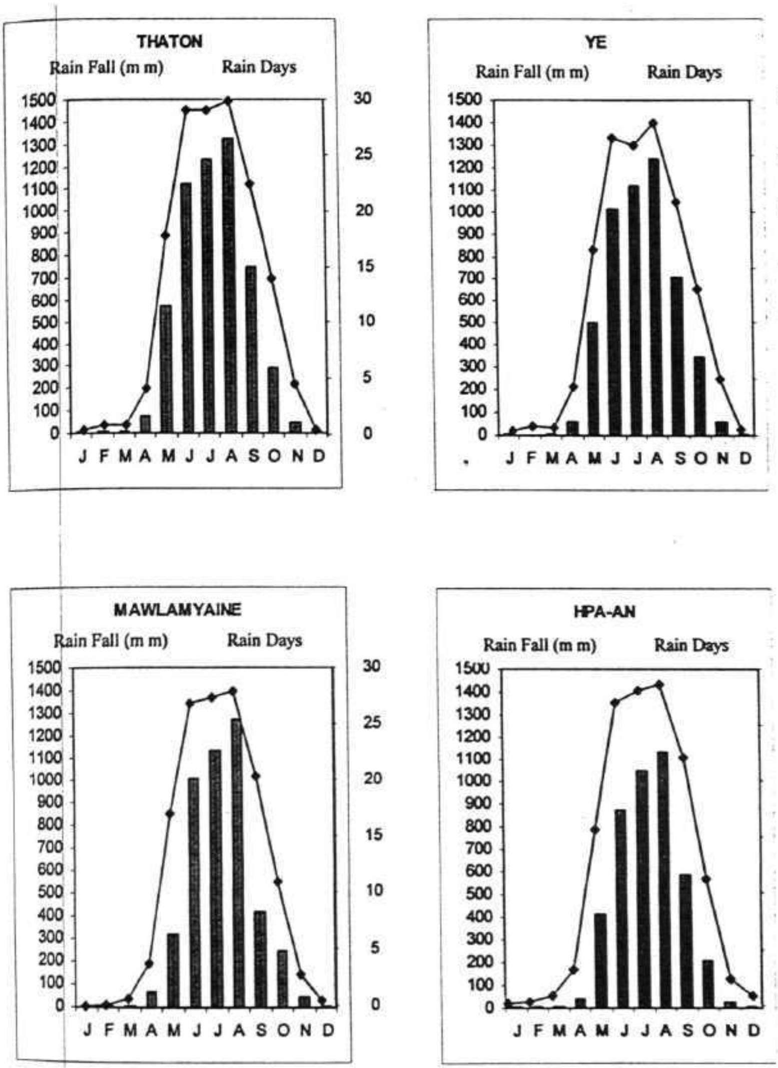
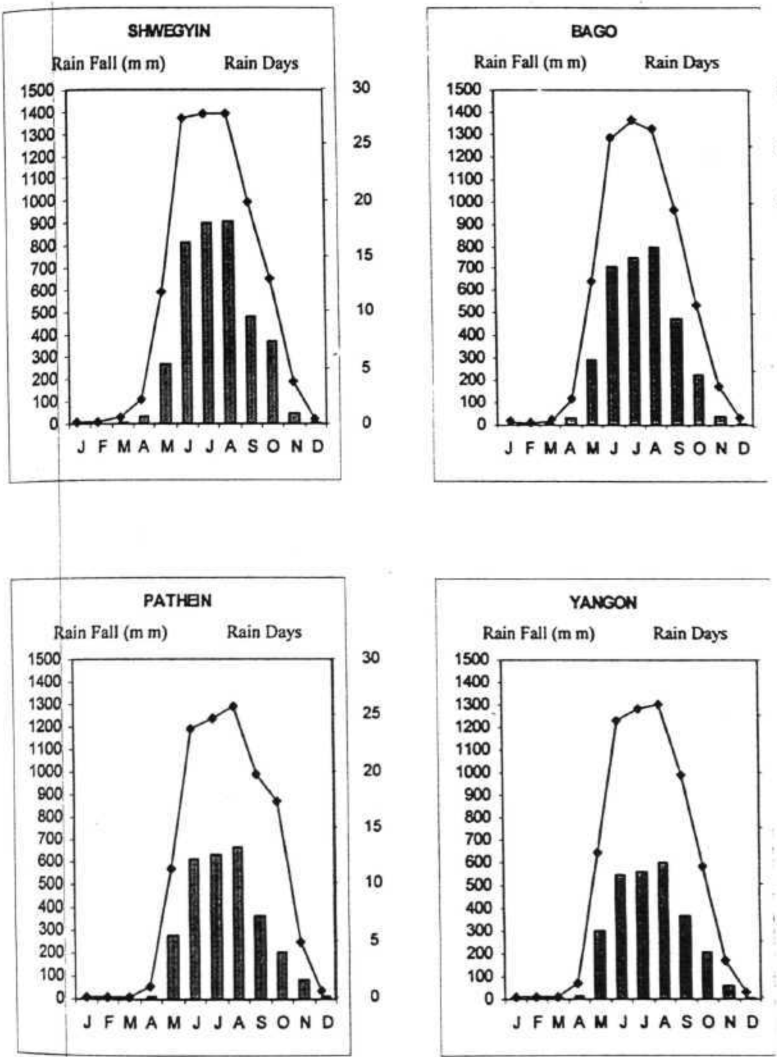


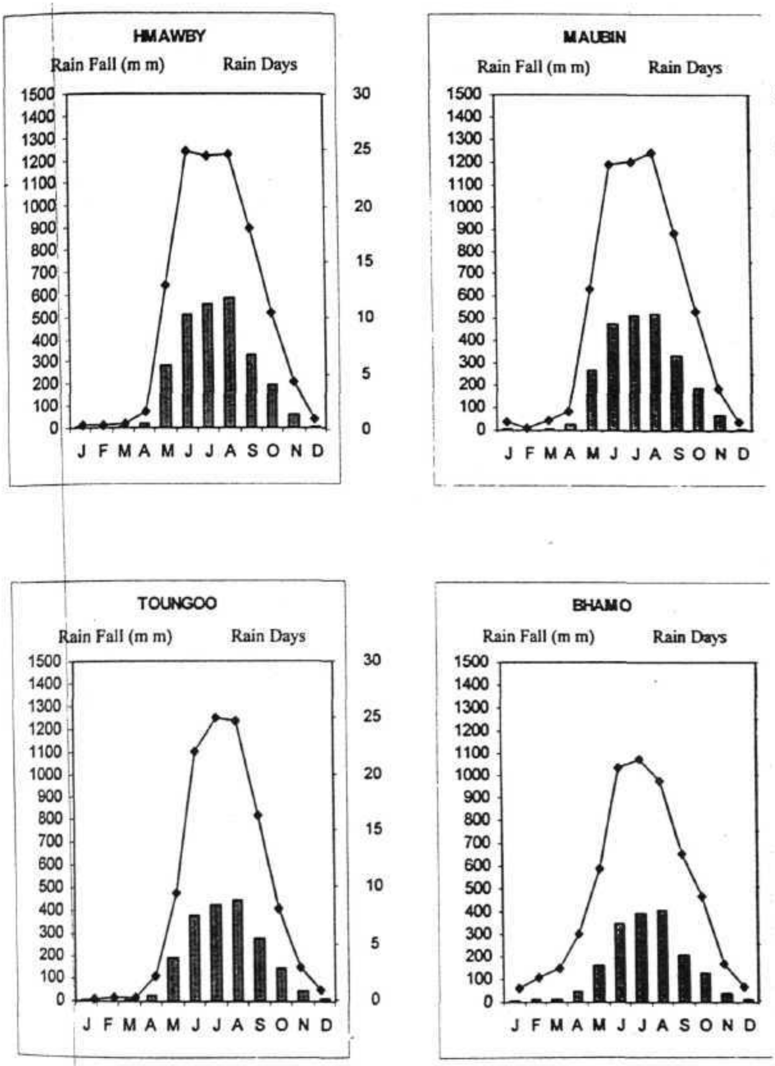
Figure (3.14.c) Monthly distribution of rainfall and rain day for Myitkyina, Homalin, Thayawady & Pinlaung



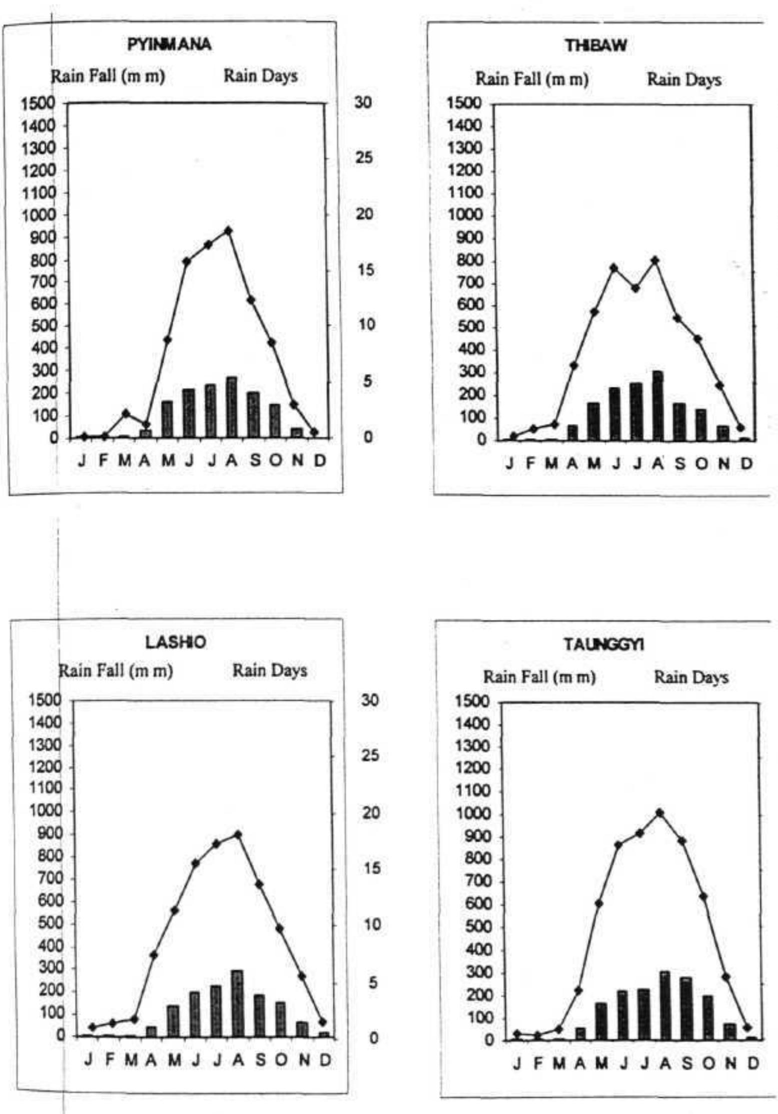
Figure(3.14.d) Monthly distribution of rainfall and rain day for Thaton, Ye, Mawlamyine & Hpa-an.



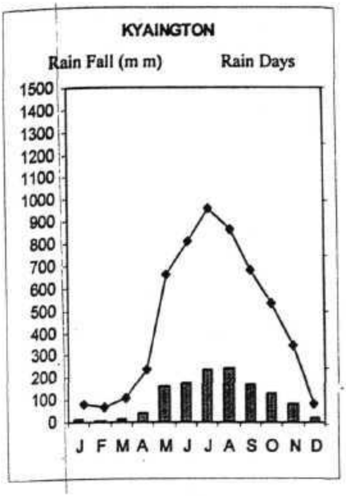
Figure(3.14.e) Monthly distribution of rainfall and rain day for Shwegyin, Bago, Pathein & Yangon

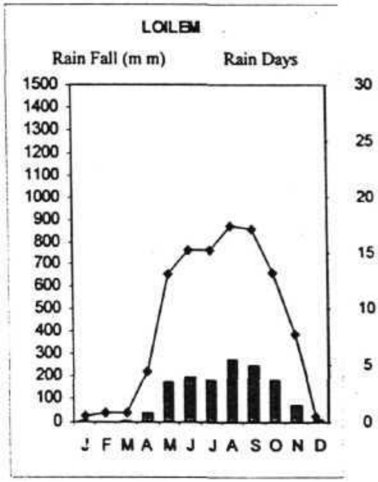


Figure(3.14.f) Monthly distribution of rainfall and rain day for Hmawby, Maubin, Toungoo & Bhamo



Figure(3.14.g) Monthly distribution of rainfall and rain day for Pyinmana, Thibaw, Lashio & Taunggyi





.gure(3.14.h) Monthly distribution of rainfall and rain day for Kyaington & Loilem

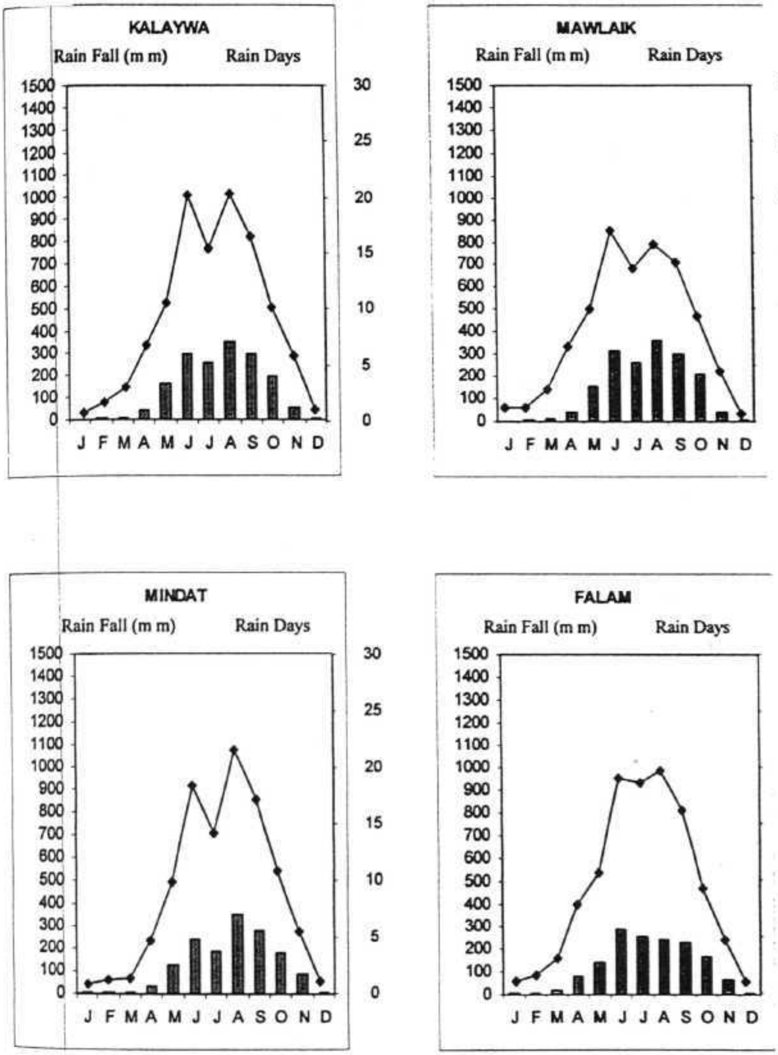
The second type of monthly rainfall distribution indicates bi-modal where double maximum rainfall pattern occurs. The first maximum occurs in the early rainy season in the months of May or June. The Second maximum occurs in the month of August or September (see Fig. 3.15a to 3.15e).

The second type may be subdivided again into two groups based on the total rainfall. In the first group, stations in Sagaing Division, Kachin state, Chin state, the dry zone and the upper part of Bago Division are included. They are Katha, Falam Mawlaik, Kalaywa, Mindat, Gangaw, Monywa, Shwebo, Mandalay, Nyaung-Oo, Minbu, Meiktila, Yamethin, Pyay and Loikaw. In the second group, stations in Taninthayi Division are included and these are Dawei, Myeik and Kawthoung. It can be seen that in the first group, each station has monthly peak values of less than 500 mm. The second group is characterized by the monthly peak values of more than 500 mm.

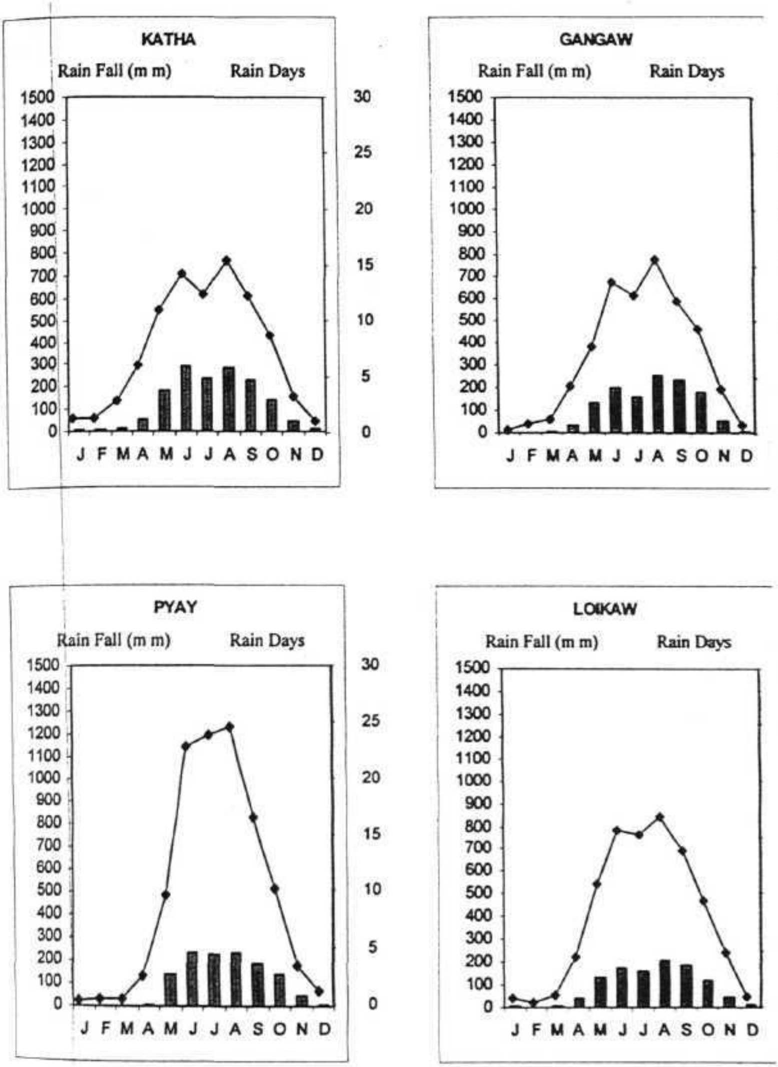
In the first group, the bi-modal pattern may be due to the advance and retreat of the Inter Tropical Convergence Zone (ITCZ). Here, the longest stay of this ITCZ zone is during the first week of June and the last week of September. Between the two maximums occurs a dry spell usually known as "July drought" by agriculturists (Hla, 1983).

The July rainfall amount is approximately 100 mm in the Dry Zone and about 250 mm in the rest of the areas. Although July gets less rain than June and August, the difference is not so great and hence it probably cannot exert a negative effect on agriculture. Generally, in the rainy season (mid May to mid October), the amount of rainfall at these stations vary slightly. (Fig 3.15.a to 3.15.d) reveals that except Pyay and Yamethin the remaining stations indicate the bi-modal distribution of rain day pattern.

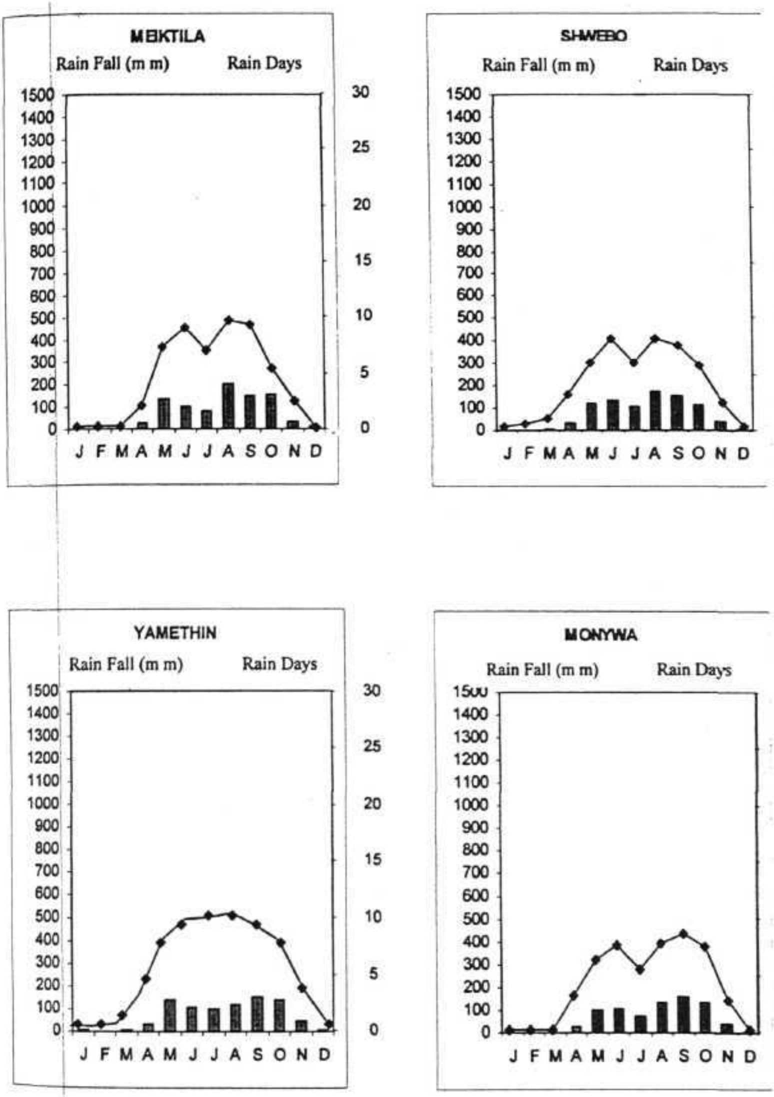
The reasons for double maximum for the Taninthayi Division are different from that of the former region. This may be due to three factors. This region is nearer to the equator and so early rain received from the onset of Southwest monsoon may



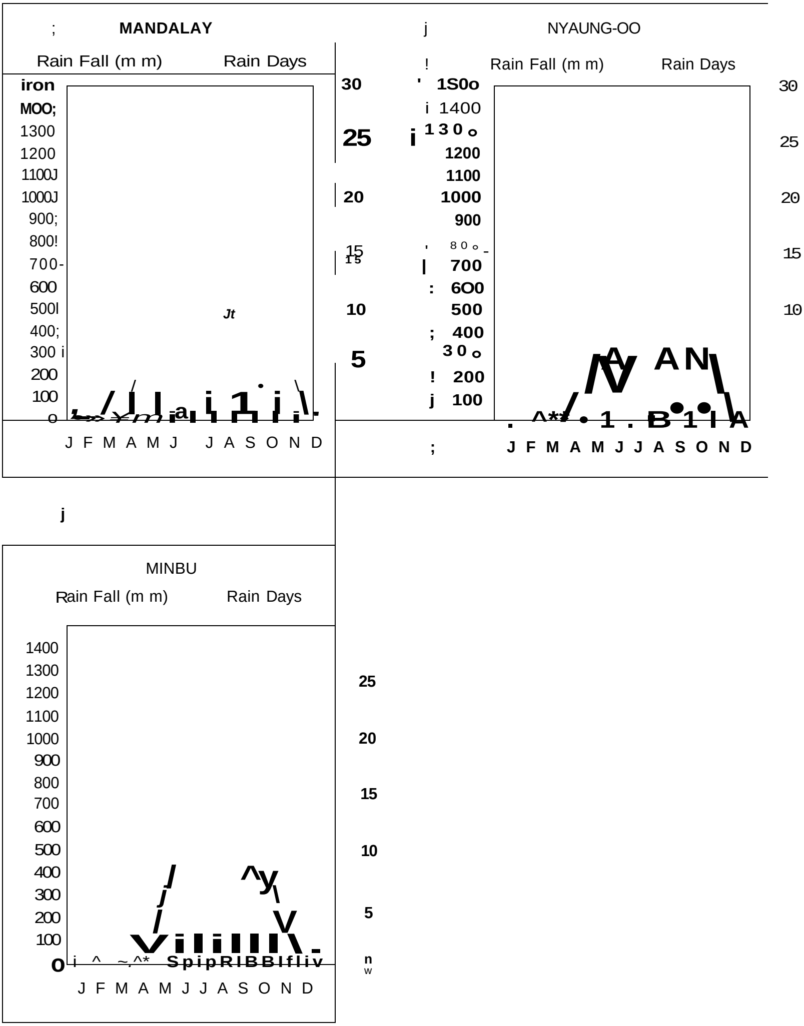
gure(3.15.a) Monthly distribution of rainfall and rain day for Kalaywa, Mawlaik, Mindat & Falam



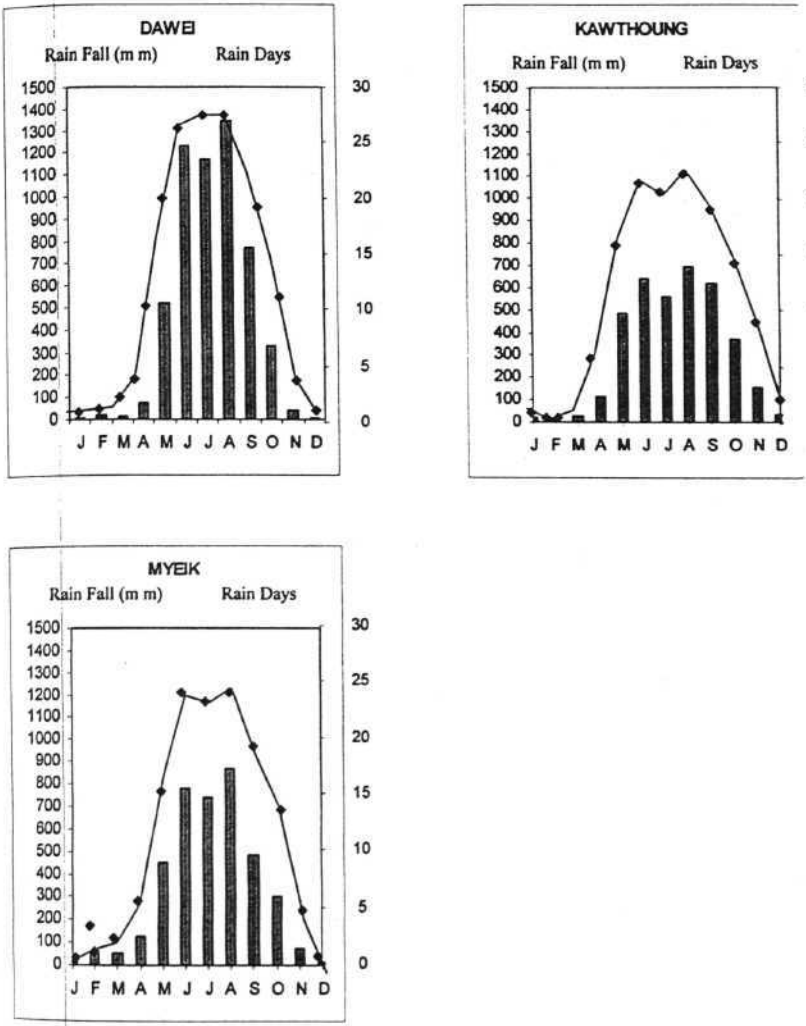
ıre(3.15.b) Monthly distribution of rainfall and rain day for Katha, Gangaw, Pyay & Loikaw



gure(3.15.c) Monthly distribution of rainfall and rain day for Meiktila, Shwebo, Yamethin & Monywa



(3.1$.d) Monthly distribution of rainfall and rain day for Mandalay, Minbu & Nyaung-Oo



Figure(3.15.e) Monthly distribution of rainfall and rain day for Dawei, Myeik & Kawthoung be much more in June; the second factor is related with the Northward shifting of the ITCZ (monsoon trough) during monsoon months. Therefore, mean monthly rainfall in July is slightly less than that of in June. The higher rainfall in August may be due to the Easterly waves in August. Fig (3.15.e) shows that the rainfall amount received in July is only 50 mm less than that of June; and about 100 mm less than that of August.

3.5 Trends of Rainfall by Cumulative Deviation

Trends of rainfall are analyzed over time with the help of trend analysis. It indicates the rise and fall in rainfall in a particular time period. The increasing trend of rainfall can be considered to be a positive sign for agricultural development in particular, and the sectors of economy, in general. Adequate knowledge of rainfall behavior and the generated water resources in the region are prerequisites for an effective planning of cropping pattern.

In this study, the method of cumulative deviation is used to show the condition for annual total rainfall. The departure of the rainfall of each year from the average of the entire series is first obtained and then, beginning with the first year, then, year by year accumulated algebraic sums of these are calculated and entered. In a series of wet years there is an accumulating excess of rainfall and the line moves upward, in the dry years it moves downward. The line slopes up when the year is wet, and down when it is dry, without reference to its position relative to the zero line. (Blair. 1948). Fig (3.16.a) to 3.25.b) show the alternate increase and decrease of accumulative deviation of total rainfall from the mean for all stations.

From Fig (3.16.a) it can be seen that in 1953 there was an increase of cumulative deviation and from 1953 to 1959 decline of rainfall occurred. This was followed by a rise for about 17 years with a setback in 1972, then a rapid decrease from the years 1977 to 1989 at Thayawady, Maubin, Yangon, Mawlaik and Kalaywa (see Fig. 3.16.a to b). After 1980 the curve is irregular, with brief periods of excess and deficiency. But there is an exception, at Thayawady, for there is the rapid increase of rainfall after 1980 to 1983.

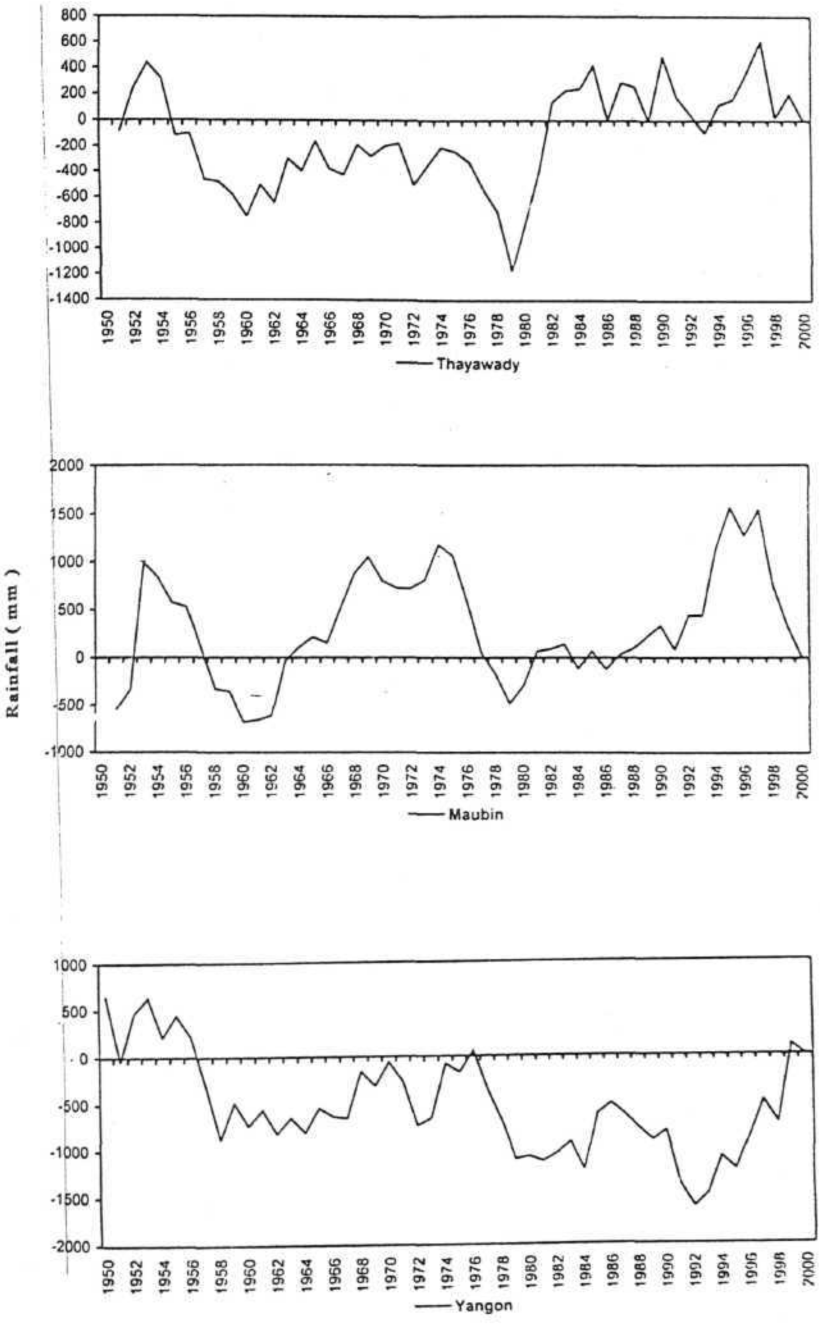
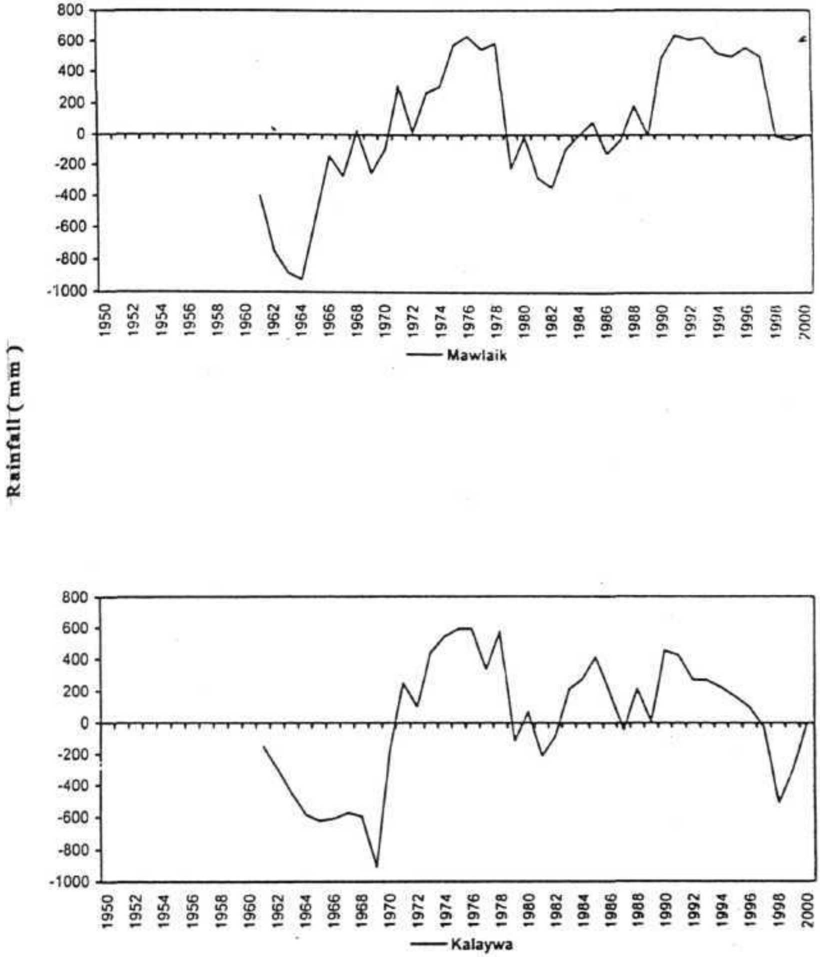


Figure (3.16.a) Cumulative deviation of annual total rainfall from the mean for Thayawady, Maubin and Yangon .



Figure(3.16.b) Cumulative deviation of annual total rainfall fron the mean for Mawlaik & Kalaywa.

At Thibaw, Lashio, Taunggyi, Nyaung-Oo, Shwebo and Yamethin, the trend is irregular with brief period of increase and decrease, (see Fig.3.17a & b).At Kyaington, Mandalay, Loilem, Minbu, Monywa, Gangaw, Toungoo, Pyay, Pyinmana, Meiktila, Hmawby (see Fig. 3.18 a to d) the cumulative deviation of rainfall increased in the period (1972 to 1978) and is followed by the decreases of rainfall after 1978. The year of the highest cumulative deviation of total rainfall is 1978.

From Fig (3.19a and b), it can be seen that the highest rainfall occurred in 1976, at Pinlaung, Loikaw, Falam, Mindat and Putao. There is an increase of rainfall before 1976 and the cumulative deviation of total rainfall from the mean is marked wetter than average. But some exceptions are 1987 and 1990 which show dry years at Pinlaung and Putao respectively.

At Pathein, Bago, Mawlamyaine, Myeik and Dawei the dominance of dry years prior to 1959-60 is clearly seen, while the greater frequency of occurrence of wetter years after this date till 1983 is also clear (see fig. 20a and b). However, a difference in trend is significant during 1970 to 1977 at the station Mawlamyaine. Further, the drought of the decade 1983-1992 is shown predominantly on both graphs.

In Fig (3.21) the abnormal wet period is shown conspicuously on the graph for Ye, Hpa-an and Thaton. It can be seen that there is the highest cumulative deviation from the mean of annual rainfall in 1982 at Hpa-an, 1971 at Thaton and 1972 and 1982 at Ye.

At Shwegyin and Thandwe, it can be seen that there was an increasing accumulation of rainfall above normal for 4 years from 1961 to 1965, and there was a small alternate increase and decrease of cumulative deviation of total rainfall from the year 1965 to about 1975-76. A decline in rainfall occurs with some interruptions, for 18 years, from 1977 to 1994 at Shwegyin and for 13 years from 1977 to 1989 at Thandwe (see fig. 3.22). Fig 3.23 shows the alternative increase and decrease of cumulative deviation at Kyaukpyu and Sittway, the highest cumulative deviation of total rainfall can be found in 1971 and followed by the drier than average years after 1971 to 1989. After 1989, the curve rises again. At Hkamti and Hinthada, the

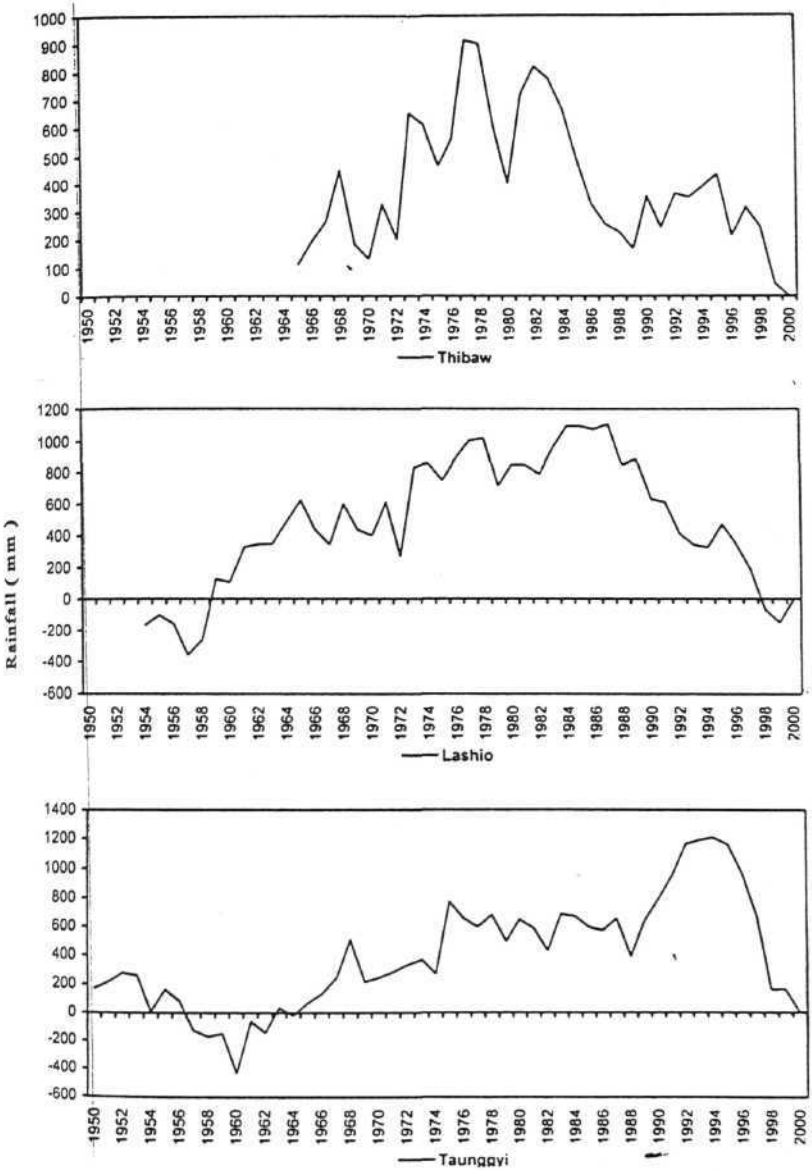


Figure (3.17.a) Cumulative deviation of annual total rainfall from the mean for Thibaw, Lashio & Taunggyi.

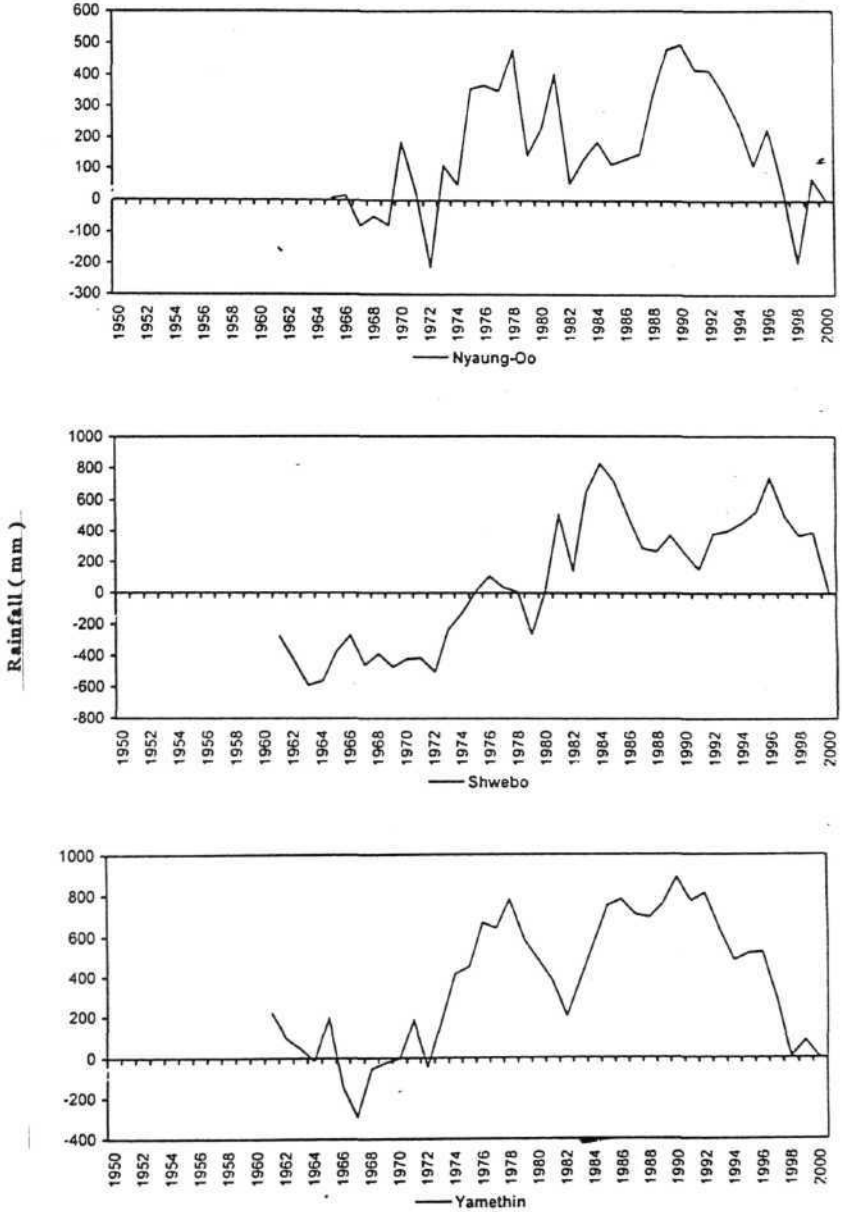


Figure (3.17.b) Cumulative deviation of annual total rainfall from the mean for Nyaung-Oo , Shwebo & Yamethin .

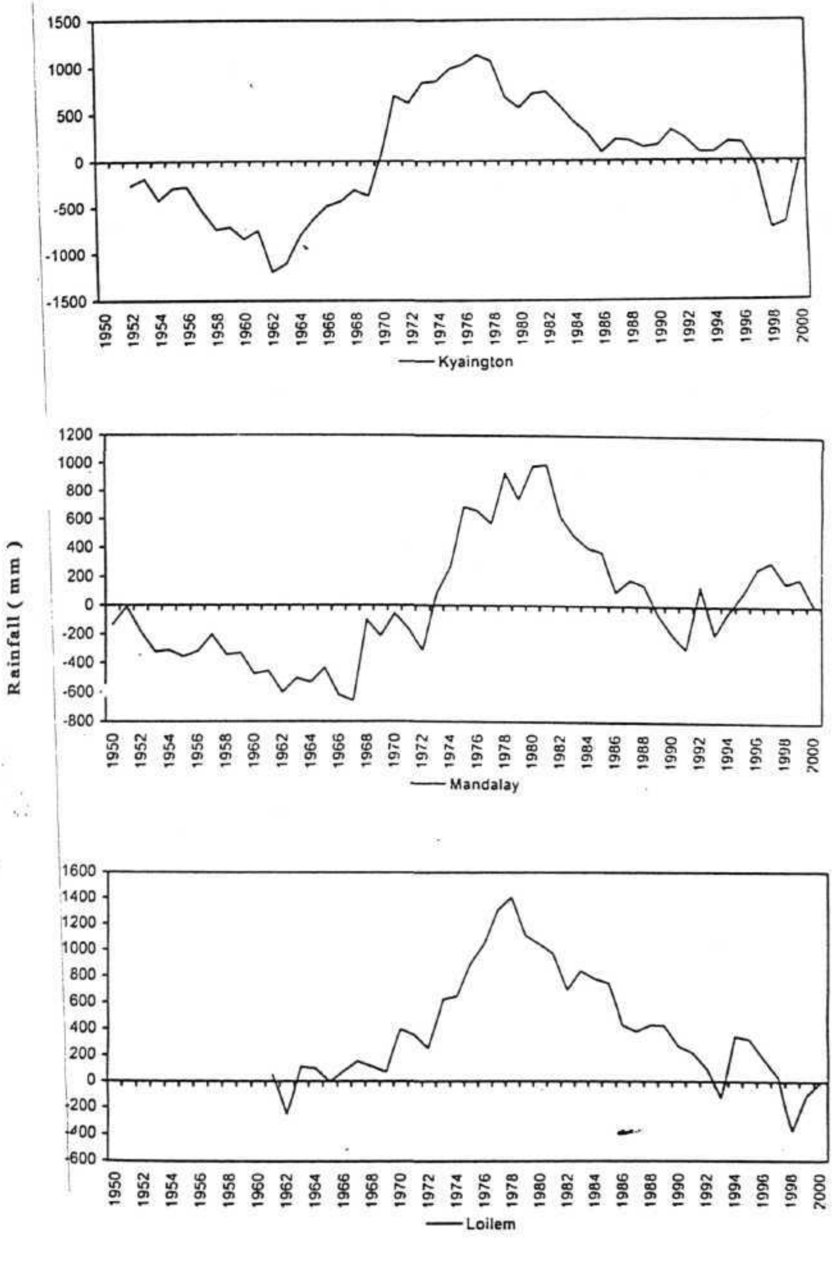


Figure (3.18.a) Cumulative deviation of annual total rainfall from the Mean for Kyaington , Mandalay & Loilem .

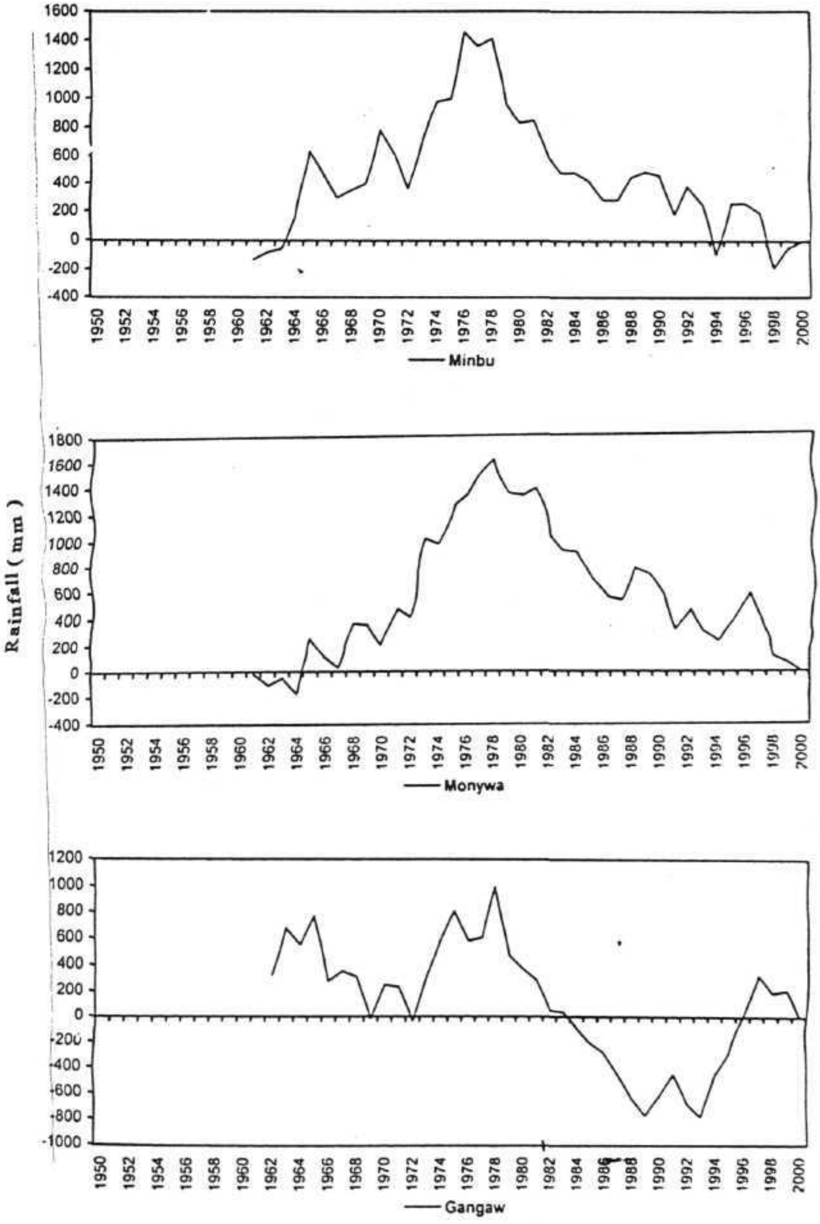


Figure (3.18.b) Cumulative deviation of annual total rainfall from the mean for Minbu , Monywa & Gangaw .

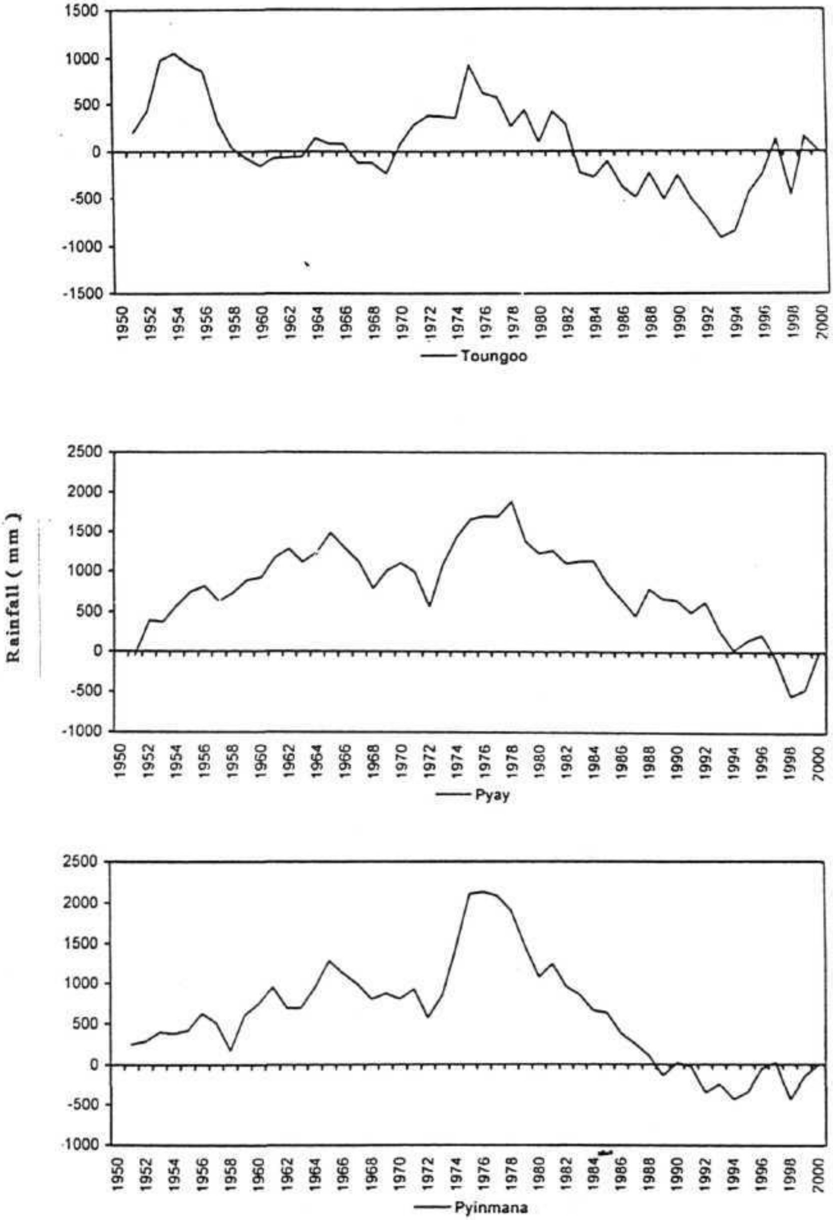


Figure (3.18.c) Cumulative deviation of annual total rainfall from the mean for Toungoo , Pyay & Pyinmana .

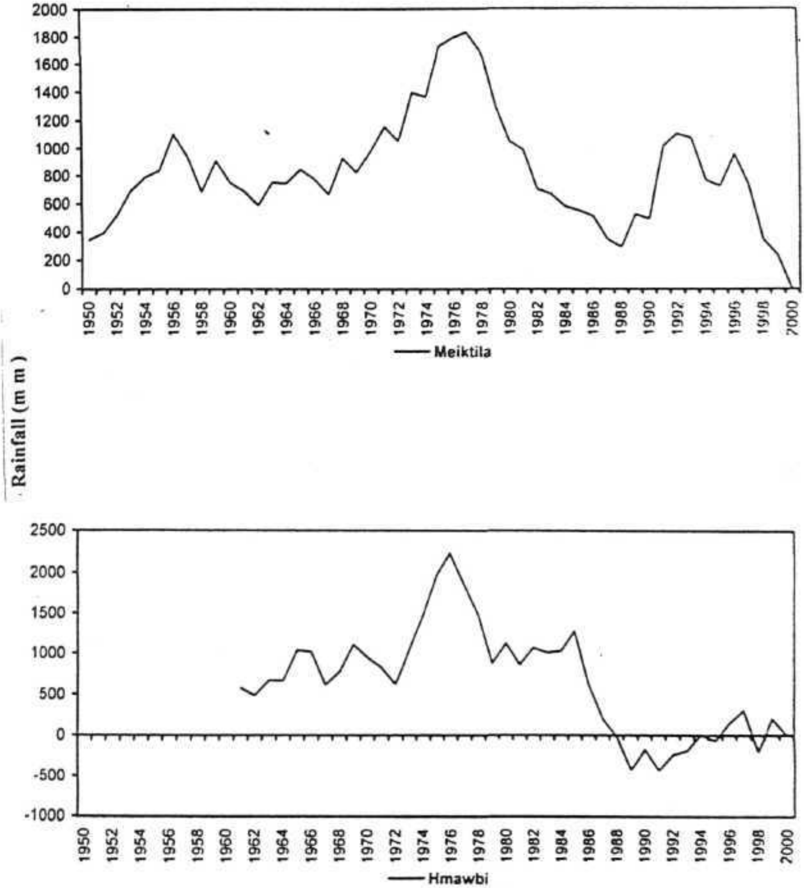


Figure (3.18 .d) Cumulative deviation of annual total rainfall from the mean for Meiktila & Hmawby.

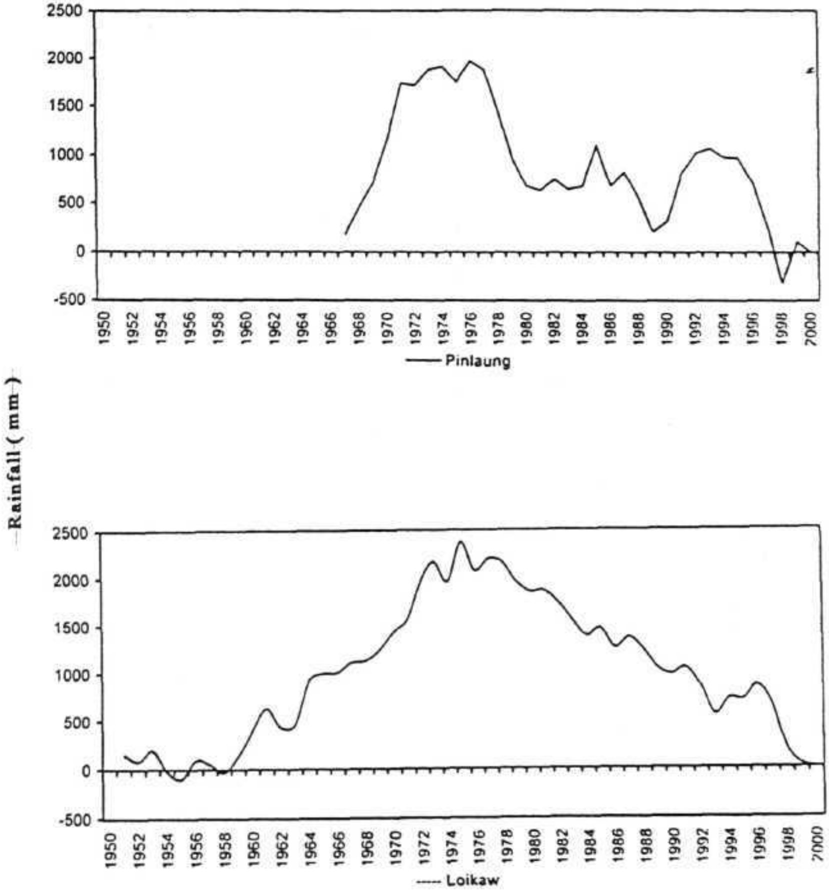


Figure (3 .19.a) Cumulative deviation of annual total rainfall from the mean for Pinlaung & Loikaw .

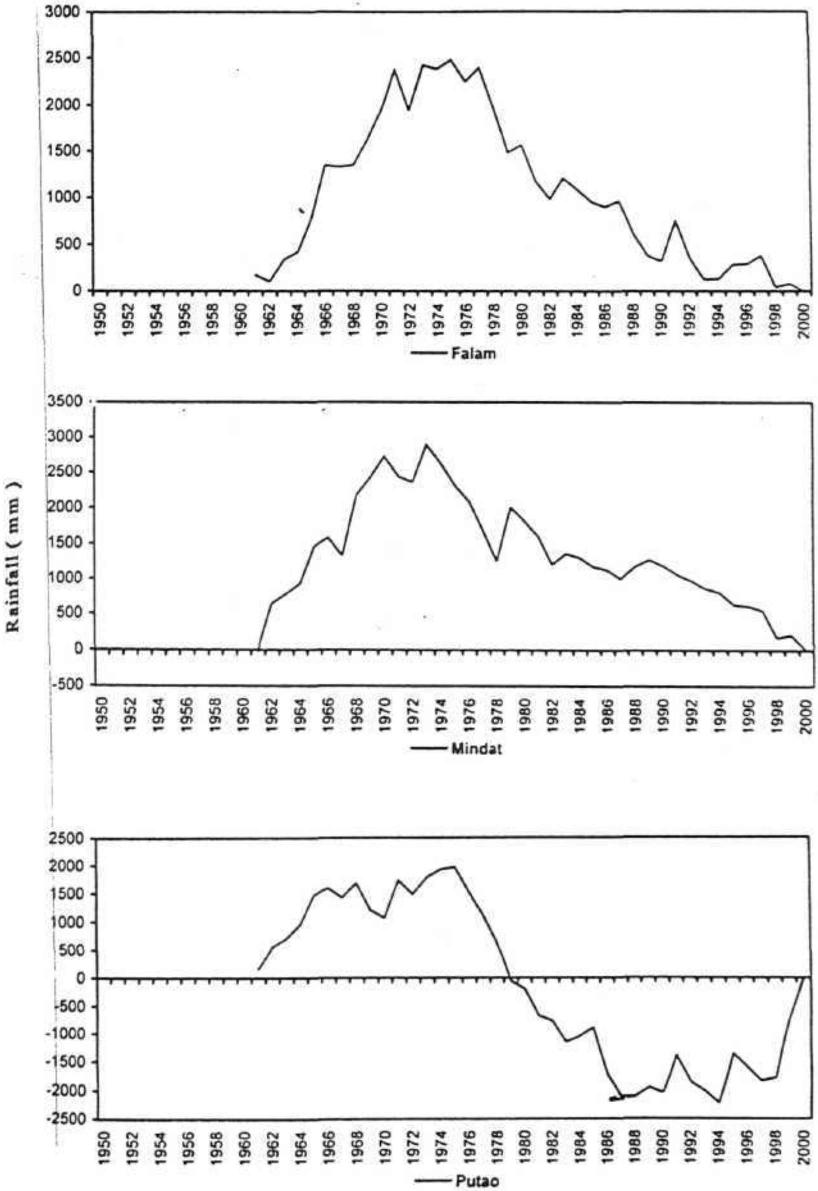


Figure (3.19.b) Cumulative deviation of annual total rainfall from the mean for Falam , Mindat & Putao .

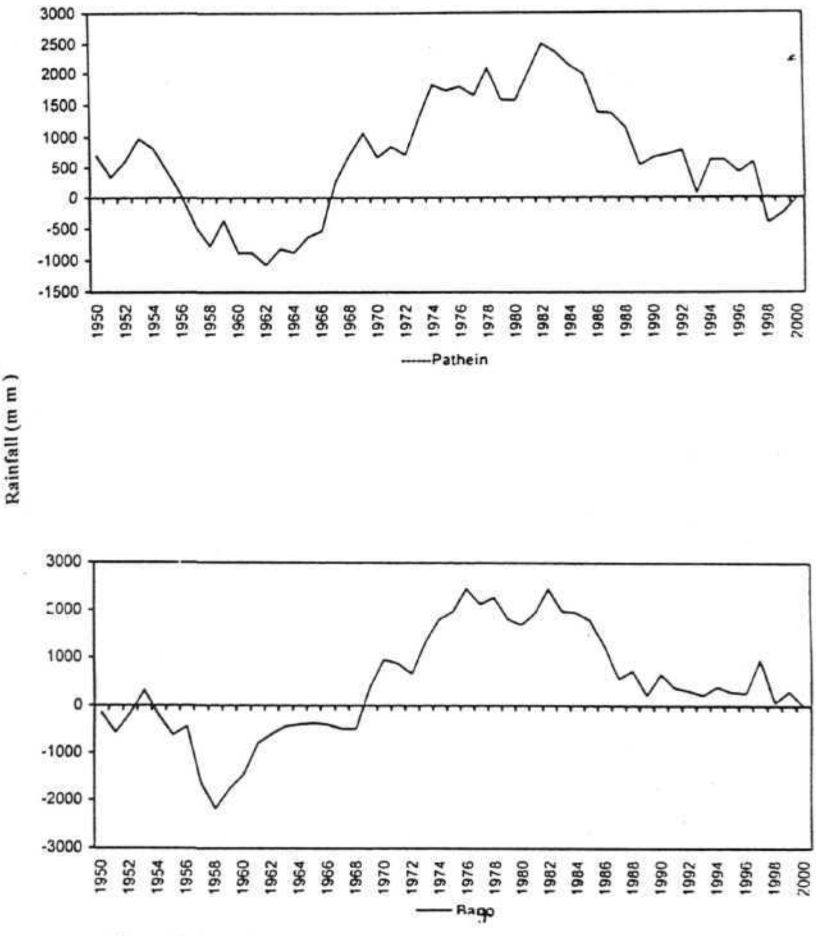


Figure (3.20.a) Cumulative deviation of annual total rainfall from the mean for Pathein & Bago .

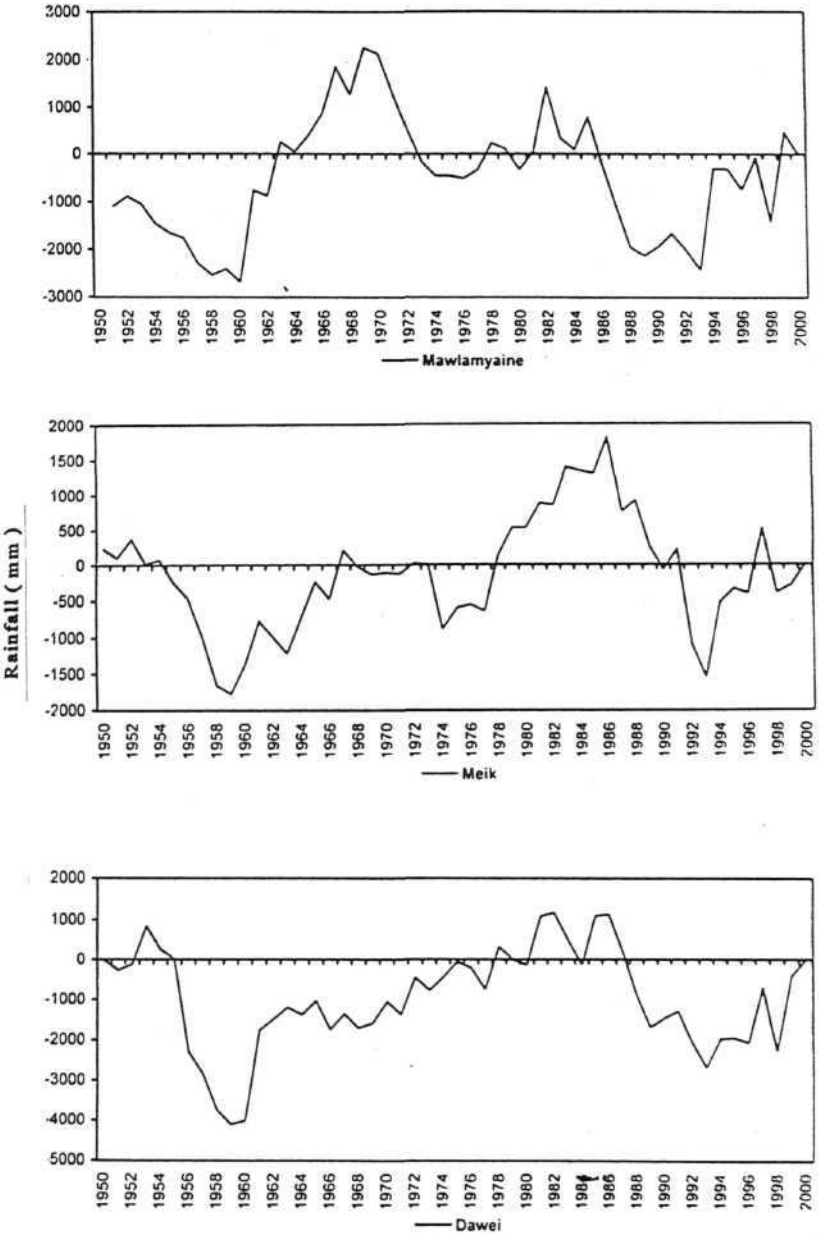


Figure (3.20.b) Cumulative deviation of annual total rainfall from the mean for Mawlamyaine , Myeik & Dawei .

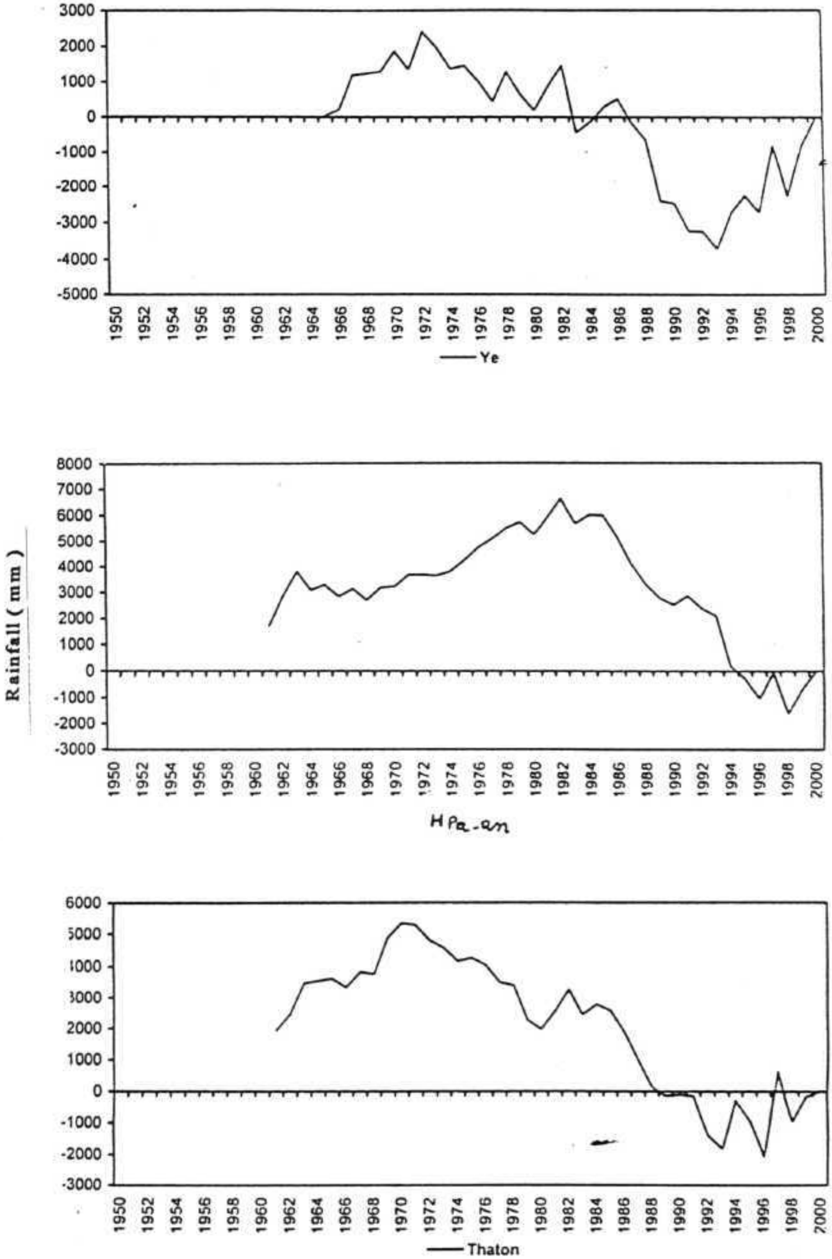


Figure (3.21) Cumulative deviation of annual total rainfall from the mean for Ye , Hpa- an & Thaton .

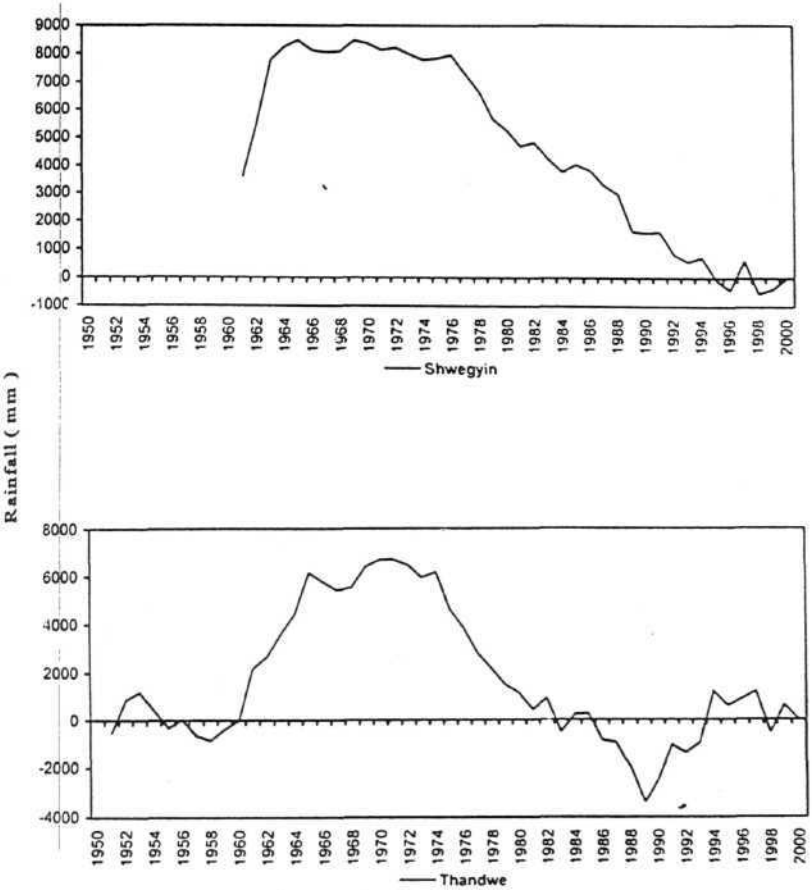
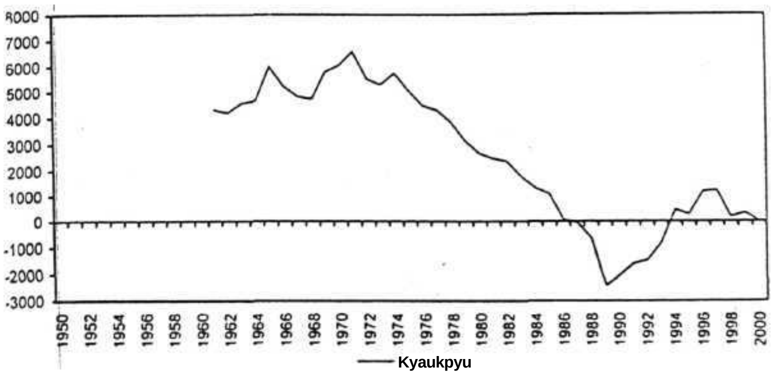


Figure (3.22) Cumulalivc dcviaiion of annual loia! rainfall from ihc mean for S'nwegyin & Thandwe .



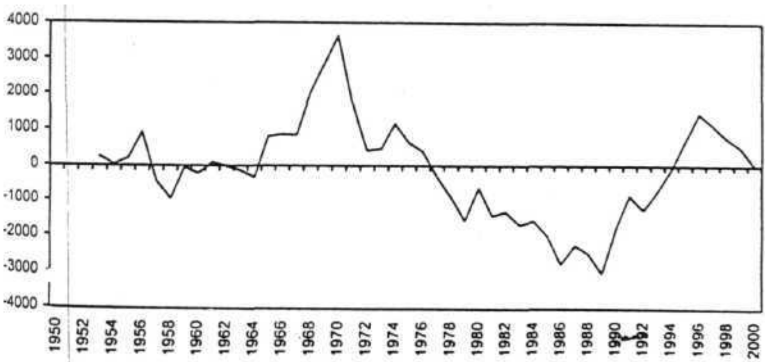


Figure (3.23) Cumulative deviation of annual total rainfall from the mean Kyaukpyu & Sittway .

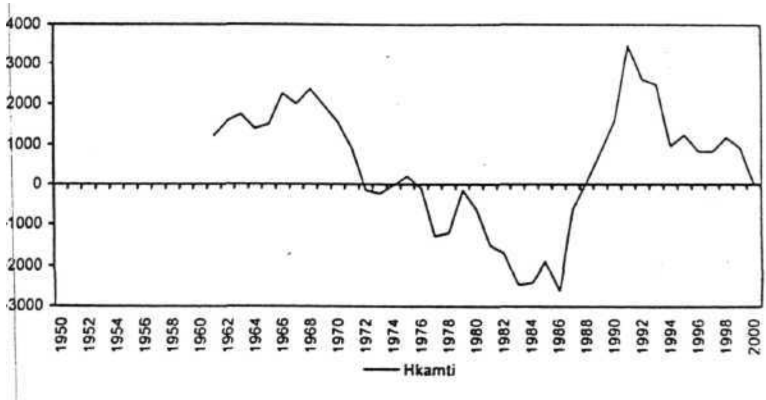
dominance of drier than average years prior to 1980 and 1983 are clearly seen. This was followed by a rapid rise in rainfall in 1987 and 1990 respectively (see fig. 4.24). These two stations show a peculiar feature of increasing accumulation of rainfall after 1980.

The rest of the stations (Katha, Myitkyina Bhamo and Kawthoung) are out of the above mentioned categories (see fig. 3.25a and b). At Katha, the highest rainfall occurred in 1959. There was an increase in rainfall before 1956 and decrease in rainfall during this year. At Myitkyina, the lowest rainfall occurred in 1958. The decrease of rainfall occurred before 1958 and increase of rainfall after the year 1959. (Fig. 3.25 a and b) shows the alternate increase and decrease of cumulative deviation of total rainfall from the mean at Bhamo and Kawthoung.

3.6 Onset and withdrawal of the Southwest monsoon in Myanmar

The Southwest monsoon of Myanmar is one of the important natural meteorological phenomena for the agricultural sector of the country as it is for the entire Indian sub continent. Agricultural activities each year are regulated according to its behaviors. The time of onset and withdrawal, its strength and duration decide the time where, when and which type of crops are to be cultivated. Instances of poor crop production due to the vagaries of monsoon are well known to farmers. In the absence of reliable monsoon forecast farmers resort to folklore and traditional rain forecasts each year in the performance of their yearly agricultural affairs.

With the advance in agriculture and agro-meteorology, authorities have now undertaken proper methods and precise planning in agricultural activities. For example if an early monsoon rain is anticipated for a particular region, double cropping method may be taken into consideration, where as if the monsoon rain is expected to be less than its normal amount, higher proportion of crops with shorter life span may be given higher priority to those having longer life span . There are many other possible steps that the agricultural planners have in mind in the event of unfavorable monsoon rain forecasts. As such, it is of great importance that advance knowledge of the arrival and the time of withdrawal of the monsoon rain are given to



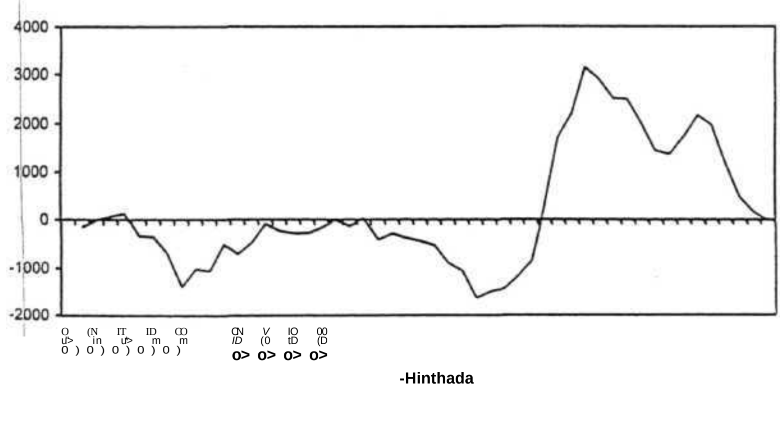


Figure (3.24) Cumulative deviation of annual total rainfall from the mean for Ilkamti & Himhada .

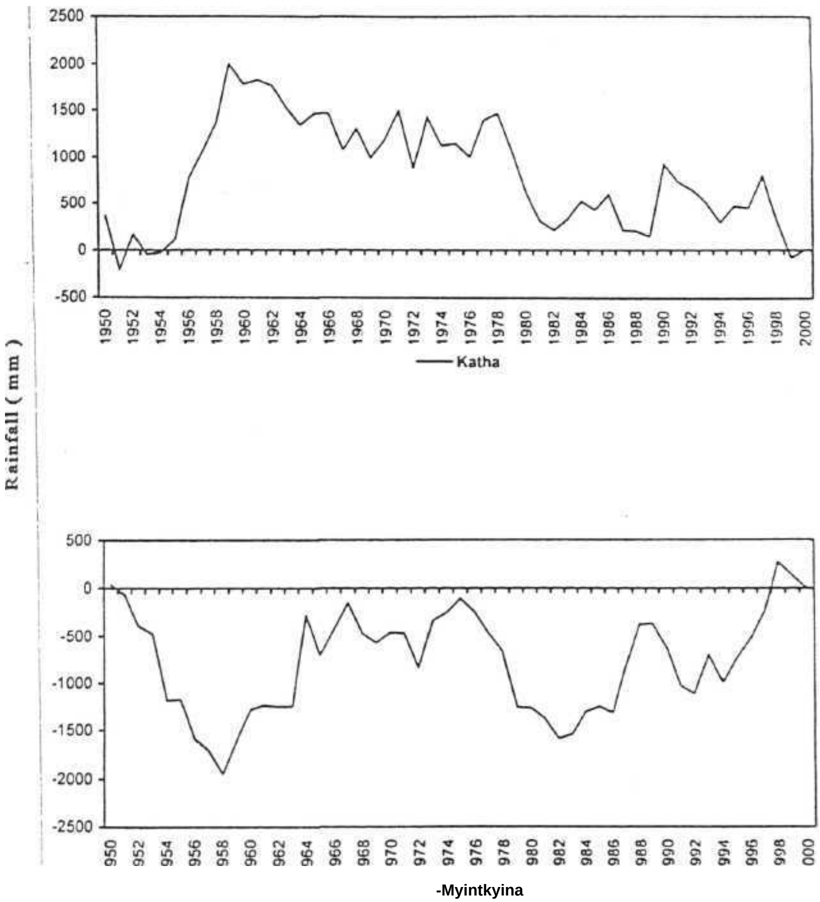
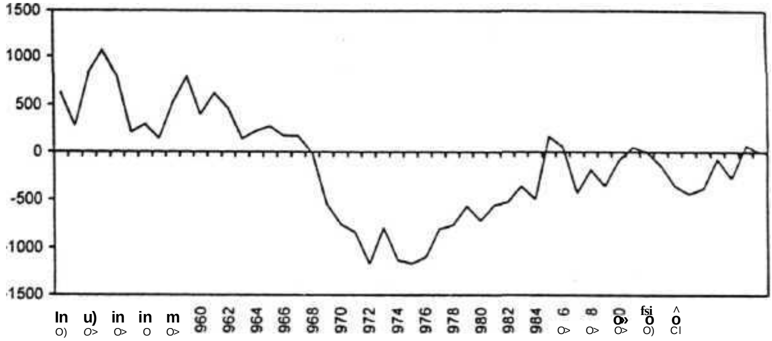
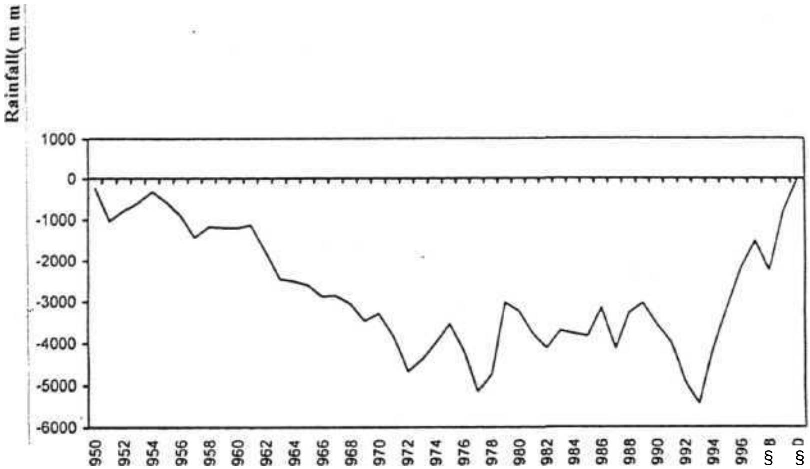


Figure (3.25.a J Cumulative deviation of annual loial rainfall lrom the mean for Kalha &. M\imkyina .



-Bhamo



- Kawthoung

Figure (3.25.b) Cumulaiivc deviation of annual total rainfall from the mean for Bhamo & Kawihoung . —

the authorities' concerned .This being the case, the responsibility of the time of onset and withdrawal of the monsoon rests on the department of meteorology and Hydrology.

The general out look of the conditions of the monsoon rain for the early, peak, and late monsoon periods together with the time of onset of the monsoon have to be given as early as March each year. By the last week of April, forecasts of the early monsoon (May and June) rain condition together with the approximate date of onset is issued. By the last week of June forecasts for the peak monsoon (July and August), is issued. In the last week of August, rains for the late monsoon (September and October), together with the time of withdrawal of the monsoon have to be forecast.

In order to determine the arrival of the Southwest monsoon in various parts of Myanmar, daily rainfall charts are plotted for the month of May. For example, years 1972 and 1974 are chosen. The year 1972 is considered as a year of normal onset of the monsoon. While doing this kind of analysis, care must be taken, not to be confused with the rainfall induced by Bay of Bengal depressions or cyclones or by pre- monsoon thunderstorms with rainfall which is brought in by the advancing monsoon. In the year 1972, no depression was found in the Bay Bengal. It will be seen that continuous rain began on the 9th of May at Myeik, the arrival of the monsoon being on the 17th of May in Mawlamyaine while it moved into Yangon on the 19th of May. It reached Rakhine coast around the 25th of May. From the rainfall of the stations in Central and Upper Myanmar, it is obvious that the monsoonal rainfall was critically retarded.

3.6.1 General and normal dates of onset / withdrawal of monsoon in Myanmar

The Northern Summer Monsoon Season is defined as "'the period between the onset of Southwest monsoon over the South Asia region and the withdrawal from it". The date of onset of the monsoon at various places in Myanmar is defined as the date of the first day of three consecutive rainy days with daily rainfall of 2.54 mm or more (Aung and Thaung, 1985). The normal dates of onset and retreat of monsoon in %anmar are June 1 and October 15. The dates are fixed by the Department of

Meteorology & Hydrology Department, Yangon. Monsoon in Myanmar generally onsets during the end of May or first week of June and withdrawal or retreat is during mid- October. The dates of onset are earliest over Southern Myanmar and subsequently move northwest to Southern India and Bangladesh by the start of June. Monsoon usually extends northward and is generally established over the whole country by about the first week of June. The monsoon begins to retreat in the middle of September and usually retreats from the whole country about the middle of October.

The advance of monsoon, as well as its withdrawal is not a single event but a series of events taking place during the fairly long period of time. The dates of onset and withdrawal / retreat of the monsoon over Myanmar can differ by a week / or even from its normal date of occurrence. The onset and withdrawal are subsequently supposed to have taken place over an area where the areal or temporal distribution of rain condition appear as the rain conditions of the average monsoon season , and at the same time ,the sea level pressure pattern and the upper air circulation patterns approach the normal condition. The extreme date of onset and withdrawal in a particular year can be estimated with the help of a limit of 1 standard deviation on either side of the mean. In most of the cases, those years falling outside the limits, have drought condition.

The onset and withdrawal dates of Myanmar (1951-2000) are shown in Table 3.3. In examining the normal dates of onset and withdrawal over Myanmar, we find there were 3 days of late onset in 50 years, starting from 1951 to 2000. The first late date in onset was June 16 in 1992, the second late date was June 14 in 1977 and the third late date was June 14-in 199$. These may be due to tropospheric flow pattern and its associated pressure of field in the low level circulation, which must have affected on the acceleration of the advancement of monsoon over Myanmar. But, these years of late monsoon arrival had no adverse effect on agriculture activities because the supply of rain water was adequately met by pre-monsoon showers, and irrigation water from the dams which were recently constructed.

There were years when onset of the monsoon was abnormally early such as the years 1956 (May 5), 1964 (May 5), 1968 (May 8), 1974 (May 11) and 1975 (May 19). The early onset of monsoon in the Dry Zone of Myanmar often promotes the increased cultivation of edible oil crops such as groundnuts, sesames, and local short staple cotton. However, occasionally heavy rains in the pre monsoon periods may decrease of the yield of the early monsoon crops. The early monsoon in Delta region is helpful for growing early jute before paddy.

The monsoon begins to withdraw from the Northern part of Myanmar in the middle of October (October 15). The circulation pattern in the upper troposphere changes from summer to winter regime. The Westerly winds begin to appear at 700 millibar level (300,000) feet. The weakening of the Easterlies and Southward shift of the sub tropical cyclone and the monsoon troughs are the events which are the characteristic of the retreating monsoon.

According to Table 3.3 there were 3 extremely early dates of withdrawal, September 24 in 1998(21 days earlier than the normal date of withdrawal), September 9 in 1997, (36 days earlier) and September 21 in 2000, (24 days earlier). These three abnormal early dates of withdrawal had been due to the effect of global circulation patterns of the atmosphere and are recent occurrences suggesting probable climate changes. There are four extremely late dates of withdrawal of monsoon: October 29 in 1952, October 27 in 1961, October 30 in 1970 and October 26 in 1975. Late withdrawal of Monsoon is important for "Kaing crops" (post monsoon crops) for those late rains constitute "Aung ya" or successful watering to the post monsoon crops.

Table 3.3 Deviation of onset and withdrawal dates of monsoon over Myanmar (1951-2000)

Date of onset of Monsoon	Deviation of -/+ days from mean date June 1	Date of withdrawal of Monsoon fromOct 15	Deviation of-/+ days from mean date Oct 15	No. of raining days in Monsoon
4-Jun-51	-3	17-Oct-51	-2	136
19-May-52	+13	29-Oct-52	-14	164
27-May-53	+5	12-Oct-53	+3	139
24-May-54	+8	14-Oct-54	+1	144
23-May-55	+9	15-Oct-55	0	146
5;May-56	+27	ll-Oct-56	+4	160
29-May-57	+3	13-Oct-57	+2	138
H-May-58	+18	14-Oct-58	+1	154
29-_May-59	+3	19-Oct-59	-4	144
2j9viay-60	+4	14-Oct-60	+ 1	140

30-May-61	+2	27-Oct-61	-12	151
24-May-62	+8	15-Oct-62	0	145
27-May-63	+5	20-Oct-63	-5	147
5-May-64	+27	20-Oct-64	-5	169
21-May-65	+11	14-Oct-65	+1	147
20-May-66	+12	14-Oct-66	+1	148
19-May-67	+13	18-Oct-67	-9	153
8-May-68	+24	17-Oct-68	-2	163
25-May-69	+7	7-Oct-69	+8	136
25-May-70	+7	30-Oct-70	-15	159
25-May-71	+7	10-Oct-71	+5	139
25-May-72	+7	19-Oct-72	-4	148
17-May-73	+15	15-Oct-73	0	152
ll-May-74	+21	23-Oct-74	-8	166
19-May-75	+13	26-Oct-75	-11	161
24-May-76	+8	5-Oct-76	+10	135
14-Jun-77	-13	4-Oct-77	+11	113
5-Jun-78	-4	17-Oct-78	-2	135
ll-Jun-79	-10	18-Oct-79	-3	130
6-Jun-80	-5	8-Oct-80	+7	125
4-Jun-81	-3	17-Oct-81	-2	136
9-Jun-82	-8	6-Oct-82	+9	120
l-Jun-83	0	16-Oct-83	-1	138
29-May-84	+3	7-Oct-84	-8	132
29-May-85	+3	20-Oct-85	-5	145
7-Jun-86	-6	8-Oct-86	+7	124
8-Jun-87	-7	14-Oct-87	+1	129
30-May-88	+2	20-Oct-88	-5	144
12-Jun-89	-11	8-Oct-89	+7	119
4-Jun-90	-3	7-Oct-90	+8	126
6-Jun-91	-5	26-Sep-91	-11	113
16-Jun-92	-15	l-Oct-92	+14	108
13-Jun-93	-12	ll-Oct-93	+4	121
7-Jun-94	-6	2-Oct-94	+13	118
6-Jun-95	-5	2-Oct-95	+13	119
2-Jun-96	-1	2-Oct-96	+13	123
9-Jun-97	-8	9-Sep-97	+36	123
14-jun-98	-13	24-Sep-98	+21	103
26-May-99	+5	30-Sep-99	+15	128
24-May-2000	+7	21-Sep-2000	+24	121
Mean of Deviation	-3.4043		-1.4043	138.8298
Std Deviation	10.3811		7.2251	15.4685

.Source: Meteorology & Hydrology Dept, Yangon, Myanmar, 2000.

Prolonged periods of unusually heavy late rains in Central Myanmar may also have an adverse effect on harvesting of long staple cotton and diminishing effect on the yield of important oil crops. Heavy early rains often results in the destruction of young cotton plants, e.g., and the destruction of young cotton plants in 1974 was the best example. Both dates of onset and withdrawal of monsoon give the length or duration of monsoon period for each year. The year with long duration of monsoon period is considered to be a good rainfall year. The correlation between total amounts of rainfall with that of their duration supports the nature of good or bad rainfall year. Climatologically, the Southwest monsoon is generally considered as part of summer monsoon system of South and South East Asia. The onset and withdrawal of monsoon rain is regular in Myanmar. Myanmar receives extensive raining season from middle of May to middle of October.

Economically, the monsoon of Myanmar tends to promote the cultivation of various crops because: severe storms and floods are not very common; the period of monsoonal rain is extensive and covers almost the whole period of rice cultivation; the adverse weather conditions which are common in neibouring countries do not usually extend into Myanmar; the weather situation and topography do not support the migration of dangerous insects like locust, etc; and the withdrawal of monsoon is gradual; the monthly distribution of rainfall is reliable. But one finds that years with abnormally excessive monthly rainfall or years with abnormally less rainfall is quite common. Such being the case, the timely arrival and withdrawal of the summer monsoon and the effective seasonal distribution and total amount of rainfall are of great importance to the economy of various regions of the country.

3.6.2 Summary

When the spatial distribution of rainfall is evaluated, it is found that the amount of rainfall gradually decreases towards the Dry Zone from the neighbouring higher topography regions. However, it is discovered that the cause of least rainfall over central Myanmar is not because of less or late onset of monsoon, but because central Myanmar lies within the rain shadow area. It is also identified that topography plays an important role in the variability of rainfall. The trends in spatial distribution of rain days are similar to that of the rainfall. The lowest value area of mean rainfall intensity occurred in the Dry Zone in June, July and August, and out of Dry Zone, in May, September and October.

When the seasonal distribution of rainfall for Myanmar is examined, two modal rainfall patterns such as Uni-modal pattern (single maximum) and Bi-modal pattern (double maximum) can be identified. In the uni-modal pattern the average monthly rainfall values are highest either in July or August. The first group of July maximum rain can be found along the coastal areas of Rakhine state, the Ayeyawady valley between the area under Pyay and the area of upper deltaic region, the Northern •hills region (upper part of Sagaing Division and Chin state), Mogok, Thandaung and Pinlaung area. The region of the uni-modal pattern with August maxima extends in nearly all of the Shan plateau, Bhamo area, lower parts of Ayeyawady, the Bago Division, the Sittoung valley, and the Kayin and Mon states.

In bi-modal pattern, it can be found that rainfall values are high in two months (May or June and August or September), and this is due to the low frequency of Easterly waves during July and more frequency during August. The first maximum occurs in the very early rainy season in the months of May or June. The second maximum occurs in the month of August or September. The second type is subdivided again into two groups based on the total rainfall. In the first group, stations in Sagaing Division, Kaehin state, Chin state, the Dry Zone and the upper part of Bago Division are included. Each station has monthly peak values of less than 500 mm. The second group is characterized by the monthly peak values of more than 500 mm. In the second group, stations in Taninthayi Division: Dawei, Myeik and Kawthoung are included.

According to the coefficient of variation, the lowest variability is observed at Putao, the Eastern Highlands, and coastal area of deltaic region and coastal strip of Taninthayi with a value of 10 percent to 15 percent. The regions which received the rainfall variability of 15 percent to 20 percent are coastal areas of Rakhine state except Kyaukpyu; Chin state, Western part of Sagaing Division, lower part of Kaehin state, Eastern part of Shan highlands, upper part of Ayeyawady and Bago Divisions and Kayah state.

In the middle part of Sagaing Division, Western part of Magway Division, and upper two third of Mandalay Division experience the values of the coefficient of variation from 20 percent to 25 percent. The highest variability is observed with core area of the Dry Zone with a value of more than 25 percent. However there is an exception that is the high value of coefficient variation of Shwegyin (25.66%) which is located in Bago Division, outside the Dry Zone. The high actual rainfalls for 1961, 1962, 1963, and 1997 of Shwegyin influence the percentage of variation occurred at Shwegyin.

Generally, it is observed that there is an inverse relationship between rainfall amount and rainfall variability. It shows that the lower the rainfall the higher the variability and the rainfall variability is greatest in the central areas (Dry Zone) of Myanmar and variability decreases away from it towards all directions.

As Myanmar is predominantly a monsoon region it is important to know the time of onset and withdrawal of monsoon, its strength and duration that decides when, where and which types of crops are to be cultivated. The onset date of Monsoon in Myanmar is June 1 and the withdrawal date is October 15. From 1951 to 2000, there were some years when onset of the monsoon is abnormally early such as the years 195fc, 1968, 1974 and 1975''. The years 1977, 1992and 199gare years in which the arrival of the Southwest monsoon is considered late in Myanmar.

The task of forecasting the dates of onset and withdrawal of the South West monsoon over Myanmar, especially when handicapped by lack of real time data, proper facilities although difficult, will have to be undertaken by all possible means. As much as it is rewarded by success through correct forecast, there were also times when the forecasts were wrong. Therefore, it seems that novel techniques of forecasting the monsoon with insufficient data need to be developed especially for the developing countries.

In addition, it must be admitted that the knowledge of summer monsoon in Myanmar is still imperfect. Further investigation based on more complete knowledge of global atmospheric phenomena is bound to reveal details about the vagaries of the monsoon. There is a need for research with reference to the changes in the atmospheric circulation pattern of the summer monsoon; the Sea- Air interaction in the Bay of Bengal and its effect on the activity of summer monsoon; the atmospheric circulation of the Pacific and its affects on monsoon circulation of the Bay of Bengal; and lastly the various changes that take place from year to year is as part of the climatic cycle of the whole Asian region or part of the global cycle.

CHAPTER IV

LAND USE ECOSYSTEMS AND ENVIRONMENTAL ISSUES IN MYANMAR: AN OVERVIEW

The present chapter is an attempt to discuss the environmental situation of Myanmar. It also focuses on the current environmental problems in the country. The chapter is divided into two sections. Section one focuses on the land cover and various ecosystems of Myanmar, while section two looks at the major environmental problems from a regional perspective with a focus on low and high production regions of Myanmar.

Section (I)

Land use And Resources in Myanmar

4.1(a) Nature in Myanmar Literature and Arts

In Myanmar literature and arts, one finds appreciation of natural surroundings. Nature is the major theme in the composition of poems and songs, and pastoral life is the favourite of Myanmar play rights, Myanmar theatrical arts display the same vain.

Myanmar dramatists choose natural environments for lovers, rendezvous because its enchanting audience is unsurprisingly romantic. When the Buddhism became the dominant faith professed by a great majority in Myanmar it permeated every aspect of Myanmar life. Due to Buddhist teaching, love and respect for natural environment was ingrained in Myanmar culture. Planting of trees and developing natural forests with arboreta as an act of religious merit are found recorded in some stone inscriptions at old Bagan.

In the month of Kason (June) the festival of ceremonially pouring fresh water on the sacred Bodh tree is held and as a life saving act of charity. Fishes and turtles from nearby dry ponds and lakes are taken to places where there is abundant water. The ecological practice of festival in Kason is a sort of public activity in the preservation of natural environment. Different months of the year have special flowers associated with them suggesting a close link between nature and daily life (see Ta'ble 4.1).

Table 4.1 Calendar months of Myanmar associated with the names of seasonal flowers

Sr No	Name of Month	Astrological Name of the Month	Name of Seasonal Flower
01	Tagu (April)	Mesha (Aries)	Gantgaw (Mesuaferrea)
02	Kason (May)	Vrishabha (Taurus)	Sagar (Champee Michelis)
03	Nayon (June)	Mithuna (Gemini)	Sabai (Jasmine)
04	Waso (July)	Kataka (Cancer)	Myatlay (Spanish Jasmine)
05	Wakhaung (August)	Simha (Leo)	Khatta-Land Lily (Ginum Nimaruam)
06	Tawthalin (September)	Kanya (Virgo)	Yinmar (Chukrasia Jabularis)
07	Thadinkyut (October)	Tula (Libra)	Kya (Water Lilies) Lotus (Nelumbo nucifere)
08	Tarzaungmone (Nov)	Vrischika (Scorpio)	Khawei (ridged guard)
09	Nattaw (December)	Dhanu (Sagarittus)	Thazin (Orchid)
10	Pyatho (January)	Mahara (Capricorn)	Khwanyo (Clematis Gabiane)
11	Tabodwe (February)	Kumbha (Aquarious)	Pauk (Butea minospernic)
12	Tabaung (March)	Mire (Pieces)	Tharaphi&ponnyet(Ochiocapres Siamensis and (Calaphylhem Inophyllum)

Source: Myanmar Agenda 21. 1992.

4.1 (b) Ecosystems and Natural Resources endowment of Myanmar

Myanmar has a wide variety of natural ecosystems ranging from land and forest ecosystems to marine, coastal and mountain ecosystems. These various ecosystems provide the country with rich natural resources. Land ecosystems include croplands, grasslands; grazing lands, woodlands and forestlands. According to an assessment made in 1989, of the total land area of 676553 km^2, the total area under cultivation is 79940 km^2 or about 12 percent of the total land area and forests cover 344237 km^2, which is 51 percent of the total land area. This is due to the fact that Myanmar forests have been prudently managed over the decades and sustainable exploitation of timber carried under the Myanmar selection system. In **Myanmar selected system,** the forest area is divided into 30 blocks of equal yield capacity. Each year, selection fellings are carried out in one of these blocks and the whole forest is therefore worked over felling cycle of thirty years.

Under this system when felling becomes due, all marketable trees, which have attained a fixed exploitable girth size, are selected for cutting. The fixed exploitable girth size varies with the type of forest. In good (moist) teak forest the girth limits at breast height 3m (4'6) 75 cm dbh (7'6"gbh) and in poor (dry) forest 65 cm dbh (6'6"gbh). Unhealthy trees that have not attained these sizes, but are marketable, are also selected for cutting if they are unlikely to survive through the subsequent felling cycle, if seed bearers are scarce a few high quality stem should be retained as seed trees. The same system of management is applied for hardwoods, with the exception that the girth limit fixed depends upon tree species. For the local supply working circle, coppice with standard or clear felling system is applied. Myanmar forests provide valuable products such as teak and hardwood and harbour a large variety of biological species, infact Myanmar teak is well known for its quality.

The wide variety of forest types including mangroves provide for a rich diversity of flora and fauna. As a result of its unusual ecological diversity, Myanmar is home to over 1000 species of birds, more than 300 known mammal species, and 700 hundreds of reptiles and amphibians, 1347 species of big trees, 741 species of small trees, 1696 species of shrubs, 96 species of bamboo, 36 species of rattan and 841 species of orchids so far recorded (Anon, 1993).

Inland water bodies' likes natural lakes, reservoirs, river systems, and ponds cover a total area of about 13327 km^2. Inland water systems together with the annual rainfalls provide vast amount of water resources for the country. Wetlands are found in many parts of the country. The principal wetlands are mangroves, swamp forests, lakes, and marshes. Mangrove forests in Myanmar are an important source of wood fuel and charcoal and provide habitat and shelter for estuarine fish, shrimps, prawns, birds, reptiles and many other kinds of wildlife.

According to Peter Gutter (2001), Myanmar is one of Asia's naturally richest countries. Its diverse ecosystem ranges from the Himalayas to the tropical reefs along the Bay of Bengal. Fertile agricultural lowlands once made Myanmar a leading rice exporter.

Its fishing ground was among the world's most bountiful. Its immense native rain forests, some of the last remaining in all of Asia, are home to numerous endangered plants and animals. It is however, noticeable that the biological resources have deteriorated over the decades due to disturbances caused by humans and fragmentation of habitats. In 1974, forests covered about 4, 98,676 sq.fcm or 74% of the whole country, out of which 51% were closed and degraded forests. During the fourteen year period from 1975 to 1989 the total forest cover had been reduced at the rate of 15,000 ha per year. Deforestation in Myanmar, unlike in some other developing countries is not only the result of commercial extraction of timber but also due to shifting cultivation, fuel-wood problem and to a certain extent, population growth. Shifting cultivation is practiced by about 2.6 million people mostly living in the Kachin, Kayah, Kayin, Chin and Shan states covering an area of about 1,42,000 hectares.

In Myanmar, more than 90 per cent of renewable energy consumption depends upon forests resources. Few rural homes in Myanmar have supply of gas of electricity. Thus, there is heavy reliance on fuel wood resulting in depletion of forest cover in marginal forests outside the reserved forest areas. Though Myanmar selection system has enabled the country to use its forest resources on a sustainable basis, it has been estimated that in the year 2000, as the population reached 50 million, the demand for wood fuel also increased accordingly.

4.2 Land Cover Distribution and Assessment

Myanmar is forest-clad with over 50% of forest cover. The coverage included closed forests and degraded forest either affected by shifting cultivation or otherwise. Degraded forests affected by shifting cultivation are not included under the forest cover of fifty percent. In general, rain forests occur on the west facing slopes of the mountains that run south to north along the western and eastern frontiers. Some tropical evergreen forests occur in the extreme south, but most of the rain forests are semi-evergreen (Collins, et al, 1991). Stands in the drier areas are deciduous and also fire resistant to some extent. Table (4.2.a& b) and Fig (4.1) show the land cover type distribution and their extent. Combining the figure of the evergreen, deciduous and mangrove forests, they accounted for 44% forest cover of the country. However, upon comparing the scrubland formation appeared in (Fig 4.1) with the 1991 National Forest Management and Inventory results, such land cover type not only falls under the degraded forest but also includes portion of the closed forest affected by shifting cultivation.

Majority of the evergreen forests are being accommodated by Kachin State in the north and Taninthayi Division in the south. In addition, these lush evergreen forests where the annual rainfall normally exceeds 70 inches also cover significant areas along the slopes of Rakhine, Shan States, and Sagaing Division.

Table 4.2.a Land cover type and extent in Myanmar, 1985-1986

Land Cover Category	Area (sq.km.)	%
Evergreen Forest	232211.8	35.1
Deciduous Forest	95930.6	14.5
Mangrove Forest	1826.7	0.3
Scrubland	193816.3	29.3
Agriculture	114051.6	17.3
Water Bodies	1676.0	0.3
No data available (cloud covered)	21407.9	3.2

Source: NOAA A VHRR Satellite Data, 1992.

Table 4.2.b Land cover type and extent in Myanmar, 1992-1993

Land Cover Category	Area (sq.km.)	%
Evergreen Forest	203245.9	30.8
Deciduous Forest	84955.2	12.9
Mangrove Forest	1823.8	0.3
Scrubland	220676.3	33.4
Agriculture	138252.2	20.9
Water Bodies	1036.4	0.2
No data available (cloud covered)	10908.1	1.7

Source: NOAA A VHRR Satellite Data,(1993).

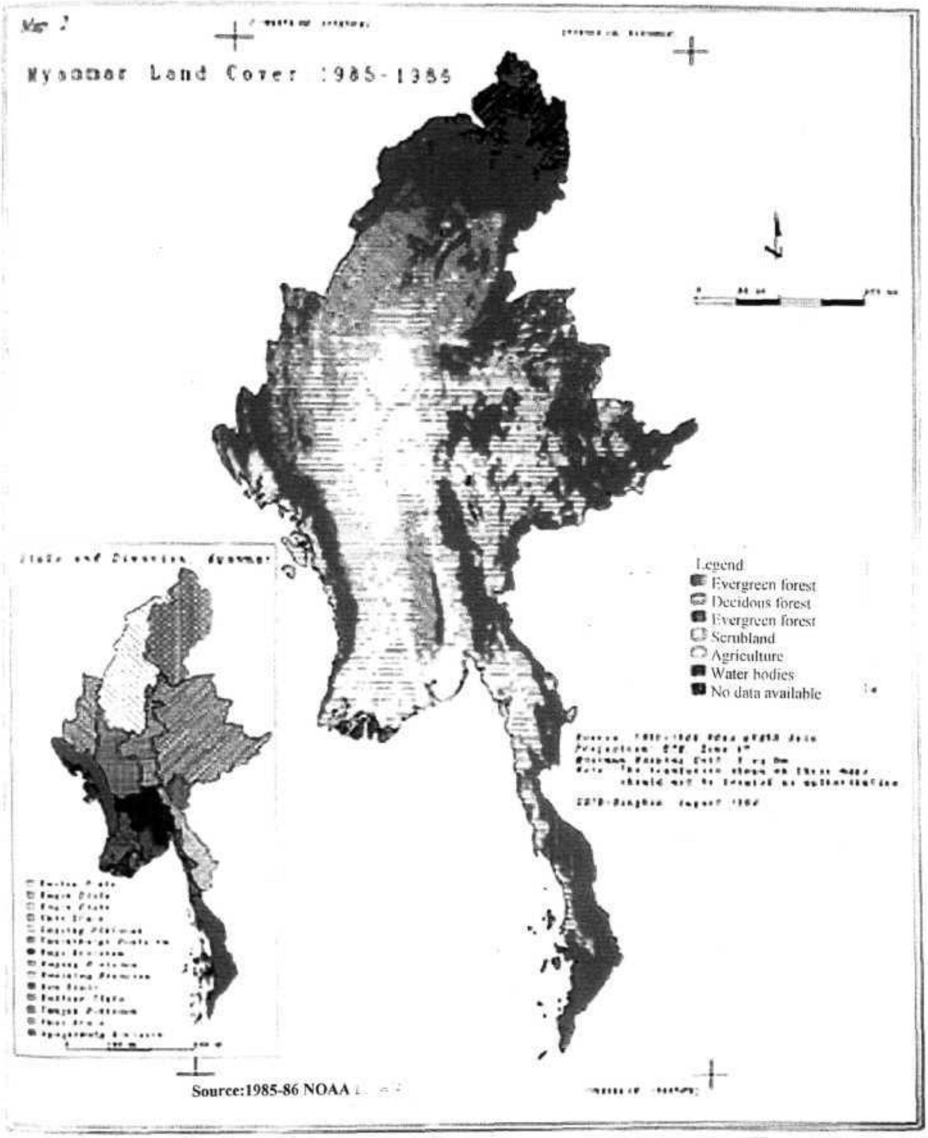


Figure 4.1 Myanmar Land Cover 1985-1986 by NOAA AVHRR

The three northern administrative groups of Kachin, Chin, and Sagaing hold the higher hectarage of the deciduous formations that are fairly distributed along the plateau of the Shan State where the altitude rarely overshoots an approximate 1000 m (Table 4.3). The dry deciduous forest along the vast stretch of the Ayeyawady plain typically covers the Bago and eastern side of Rakhine Yomas. It was believed that bamboos of several species are abundant especially in the Rakhine Yoma. Despite their conspicuous green feature, gregarious nature or often associated with other tree species their certainty to be distinguished with the use of AVHRR was found complicated. Nevertheless, local reports specified that generally, bamboos and canes are common associates occurring as under storey of the deciduous and evergreen forests. However, lower mixed deciduous forest does not have bamboos (Fig 4.2).

The heavily populated Ayeyawady plains, now almost entirely cleared for agriculture, lie in the rain shadow of the western ranges and especially in the central area have a very dry and seasonal climate. This area also supports the dry deciduous woodland and tropical thorn forest. Large areas under cultivation were dominant in the Ayeyawady plain that also extends as far as Sagaing division in the north. Because of the course spatial resolution of the AVHRR data, it was noted that small patches of cultivated fields along the slopes were categorized as part of the scrubland. Moreover, four considerable patches of cultivated land can be noticed in the coastal areas of Rakhine, hilly sections of Shan, Kayin, and Mon States. It can also be observed that the increasing proportion of agricultural areas tends to be parallel with the increasing share of the scrubland. This hold true especially in the States of Kayah, Mon, Kayin, and Shan (see Table 4.3) lists the land cover type distribution for different States/Divisions in Myanmar.

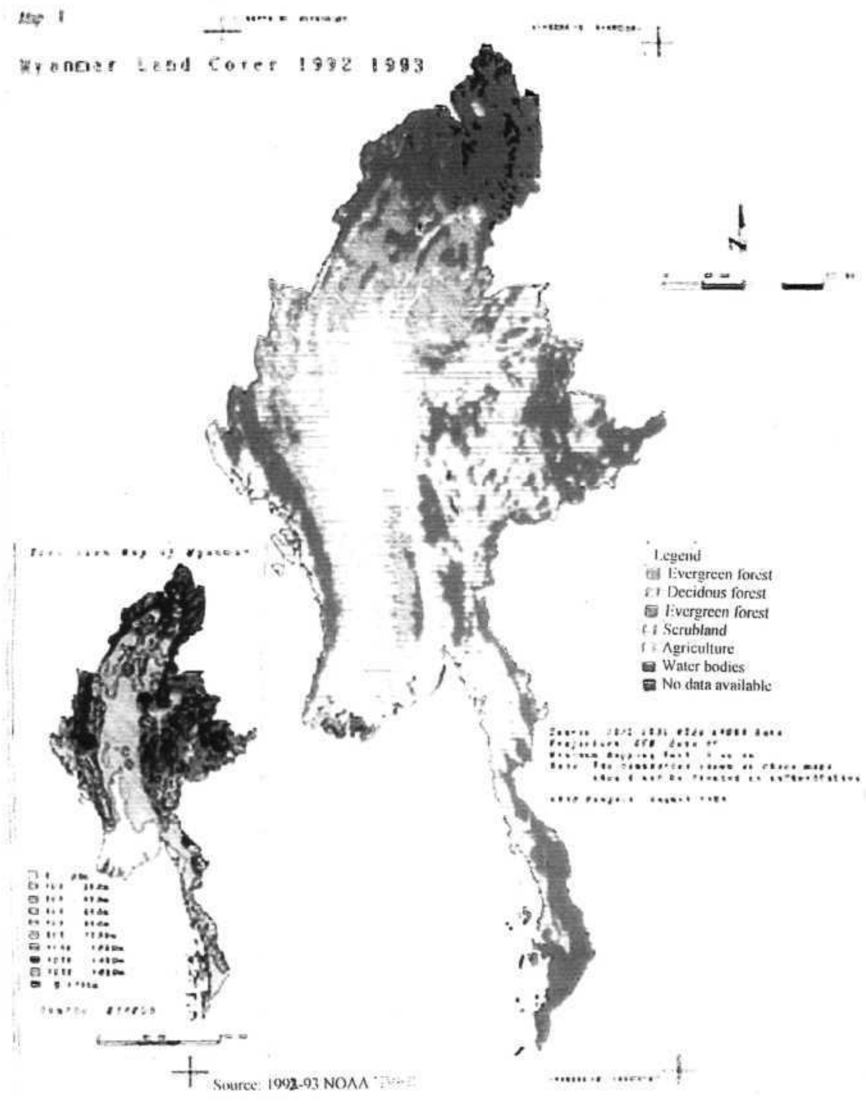


Figure 4.2 Myanmar Land Cover 1992-1993 by NOAA AVHRR

Table.4.3 Myanmar States and Divisions: Population and Non-forest area (1992-1993)

States & Divisions	Population (000)*		Population/ sq.km. (1990)	Agriculture (sq.km.)	%	Scrubland (sq.km.)	%
	1986	1990					
Ayeyawady Division	5322	5703	179.0	16511.6	51.8	11046.1	34.7
Bago Division	4032	4310	114.7	14195.7	37.8	11916.6	31.7
Chin State	388	411	11.3	204.1	0.6	13914.9	38.2
Kachin State	972	1052	11.7	1424.1	1.6	4354.6	4.8
Kayah State	186	206	17.8	1860.8	16.1	6090.1	52.6
Kayin State	1132	1225	39.5	4548.2	14.7	13466.5	43.5
Mag way Division	3483	3771	85.0	22414.3	50.5	19548.3	44.1
Mandalay Division	4936	5370	144.5	19130.3	51.5	11162.2	30.0
Mon State	1822	1996	184.6	3321.1	30.7	5761.9	53.3
Rakhine State	2176	2328	71.6	6364.2	19.6	6077.8	18.7
Sagaing Division	4155	4514	47.7	24728.7	26.2	22567.8	23 9
j Shan State	3923	4162	26.6	10872.6	6.9	79014.3	50.4
Tanintharyi Division	995	1089	25.5	867.0	2.0	8932.2	20.9
Yangon Division	4278	4649	486.1	6408.7	67.0	1956.0	20.5

Source: NOAA VHRR Satellite Data (1992-1993)

In the uplands of Myanmar, shifting cultivation is still the major agent of forest destruction. All forest types are affected by rising populations of itinerant farmers is steadily eating into the forest. Moreover, the increasing population pressure has led to a reduction in the number of years of the felling cycle and has forced farmers to penetrate further and further into the forest. The impact is more acute in the remote hill areas. Very large areas of forest have been cleared in eastern Shan State, Kayah State, Sagaing Division, and Chin State (Collins, 1991).

Table (4.3) indicates that population of Myanmar is highly distributed among the six states/divisions located in the Ayeyawady Plain such as divisions of Yangon, Ayeyawady, Bago, Mandalay and Magway with the inclusion of Sagaing Division. The distribution of large tract of cultivated area also follows the state or division where concentration of population is denser. An average of 176.2 individual /sq.km is exhibited by the six states/divisions along the plain of Ayeyawady. In addition, the Shan State, a predominant hilly area which is one of the biggest state in the country holds a high number of populace. It's combined agricultural area and scrubland comprises a considerable 57% of its total area. At least half of the landscape of adjoining states of Shan Plateau.such as the Kayah, Kayin, and Mon are considered as non-forest, wherein the proliferations of sparse woody vegetation in association with cultivated areas are abundant.

In a span of seven years, froml985-1986 to 1992-1993, land cover change exhibited a typical vegetation transformation similar with other Asian countries. As shifting cultivation continue to play a major role in land degradation, converting evergreen forest to mixed deciduous, dry deciduous forest becomes dominant (Table 4.2.b and Fig 4. 2). Moreover, in highly populated areas, repeated cuttings for domestic uses have transformed many of these magnificent stands into stunted scrub forest. The advancement of scrubland formation into the belt of either deciduous or evergreen group is the more apparent kind of land cover conversion. Besides, the encroachment of agricultural areas in adjacent forest accelerates the conversion into non-forest type.

Scrubland typically fragmented and found in remote hill country occupies a considerable proportion in Mon State (53.3%), Kayah State (52.6%), Shan State (50.4%), and also in Magway Division and Kayin State. The increasing proportion of agricultural land as it moves deeper within the extent of scrubland formations became more apparent not only on the plains but also in steep slopes. Most of the disturbed forests have given their way for the expanding agricultural area where environmental condition permits. A very quick, generalization can be observed from the (1992-1993) and (1985-1986) Land Cover Maps of Myanmar from AVHRR, that both agricultural area and scrubland exhibit conspicuous increase in terms of their extent. The Ayeyawady plain especially in the northern region, the coastal area of Rakhine State, and the Shan plateau are the common places of agricultural expansion (see Table 4.3).

It has been known that the management of the evergreen forest in Myanmar is a recent phenomenon largely in response to worldwide demand for wood and non-wood products due to the depletion of tropical hardwood resources in neighboring countries. The goal in management, however, is the development and maintenance of a commercially productive forest, which may be, or more likely, may not be identical in composition to the climax forest There is also an urgent need to strengthen the knowledge base on the silvicultural and management characteristics of the extremely rich and diverse species that comprise the evergreen forest, (Than, 1992).

In the case of Myanmar, the predominant shifting cultivation practices signify a gradual but chronic degradation of the landscape in line with the nature of land transformation. As shifting cultivation continues to play a dominant role in forest type conversion, the typical transformation from one type of vegetation to another is apparent, especially for the increasing proportion of open woodlands and dry deciduous group from the original evergreen or semi-evergreen type. Yet, the expansion of originally recognized scrubland that denotes mostly the presence of crop cultivation is the main feature of land degradation. Such landscape modifications as discerned in the time series analysis of AVHRR data subsequently lead to increased attention for a deeper investigation of the area. The use of high-resolution satellite data supplemented by field information is of vital importance. This will serve as an early warning system towards preventive measures in areas exhibiting major land transformation or active deforestation.

4.3 Forest Resources

The analysis of 1989 Landsat tone image had indicated that Myanmar is still endowed with one of the most extensive natural forest cover in the world with 43% of its area under closed forest and another 30% under woodlands. The status of forest cover in 1989 is given in (Table 4.4).

Table 4.4 Forest cover of Myanmar (1989)

No	Land category	Area (sq.km)	Percent
1	Closed forests	293269	43.34
2	Degraded forest	50968	7.53
3	Forest affected by shifting cultivation	154389	22.82
4	Water bodies	13327	2.01
5	Non- forest	164600	24.30
6	Total	676,553	100

Source: Forest Fact sheet, Mvanmar,1993.

Close and degraded forest, which can be considered as actual forest cover constituted 344237 Km^2 or approximately 51% of the total area of the country. The assessment of the change in forest cover conducted in 1990 revealed that the actual forest cover had decreased at an annual rate of 220,000ha or 0.64% of the actual forested area during a period of 14 years from 1975 to 1989. This was mainly due to shifting cultivation, illicit cutting, and encroachment for agriculture purposes.

In 1995, of the total land area, 3 88,500 sq.km (57 per cent) is forest; of that area, 103,600 sq.km constitute reserved forests and 284,900 sq.km comprise public forests (unclassified forests).

4.3.1 Timber resources

The forests comprise numerous timber species, including the most valuable timber, teak. Associated with teak are other important hardwoods such as Pyinkado and Padauk. The Dipterocarp and sub-alpine forests, mangroves and estuarine and bamboo forests all contribute to providing some 1,200 timber species and 780 varieties of small trees. Currently, however, only about 45 species are being exploited.

The forestry sector registered significant increase in 1989-90 as a result of grants on the tender system to cooperatives and private sector for extracting hardwood and other forest products other than teak. Granting logging concessions was terminated in December 1993. The sale of logs in foreign currency, however, is done occasionally through systematic tender systems by the Myanmar Timber Enterprise.

Out of the 2088 trees species, 85 have been re-formed and accepted as producing multiple use of premium quality timber. Studies on the properties and utilization of the lesser-used timber species are being done, and their utility extensively promoted. The attempt is to increase commercial production and reduce the pressure on the premium quality timber. Forest area of the country has been estimated by forest types and is shown in (Table 4.5) Forest area by types of Forest. The forest area may also be divided by type of vegetation and productivity as shown in (Table 4.6). The volume of growing stock of timber is shown in (Table 4.7). The table shows that the forests in Myanmar contain some 2.2 billion cubic meter of standing growing stock of timber. The total annual growth would mount to 31 million cubic meters of the commercially exploitable production forests. 103090 sq.km (15.2% of the country) are reserved forests while 270,677 sq.km (35.6%) are other forests. Apart from the production forests there are some 7731 sq.km of protected forests covering 1.14% of the country.

Table 4.5 Forest area by types of forest

Types of vegetation	Productive forest (Mill in ha)	Unproductive forest	Grand total (Mill In ha)
Closed broad leaf	1859	357	2216
Mangrove	12	4	16
Conifer	16	-	16
Total	1887	381	2248

Source: Kyaw Tint, 1995

Table 4.6 Forest area by types of vegetation in hectares

No	Types of vegetation	Productive forest	Unproductive forest	Total (000) ha In ha.
1	Closed broad leafed	20655	11908	32563
2	Mangrove	382	403	785
3	Bamboo	963	-	963
4	Conifer	113	-	113
5	Total	22113	12311	34427

Source: Kyaw Tint, 1995.

Table 4.7 Volume of growing stock of timber(Million in ha)

Sr.No	Types of forest	Area in ha.	%
1	Tidal beach &swamp forest	1376900	4
2	Tropical evergreen forest	5507800	16
3	Mixed deciduous forest	13425300	39
4	Dry forest	3442400	10
5	Deciduous dipterocarp forest	1721200	6
6	Hill &temperate evergreen fore	8950100	26
7	Total	34423700	100.00

Source: Kyaw Tint, 1995.

4.3.2 Plantation Resources

An attempt on raising teak plantation using Taungya (shifting cultivation) (agro forestry) method was first made in 1856. The success with this method led to a wide spread planting of teak, Acacia catechu, and xylia Kerri, and by 1930, a total of cover 19,000 ha had been planted. In 1932-33, changes in plantation policy resulted from findings that the danger from bee hole borer was three times as serious in plantation as in natural forests and that it was not profitable to grow timber in plantations for export. The government thus ordered to plant teak and xylia Kerri only for domestic use and not for export.

However, in 1937-38 the government again revised the policy to increase the establishment of plantations to 600 ha per annum. That was again checked during World War II and gathered momentum again only in 1963. Up to that period, only a few thousand hectares of manageable plantations were established annually. These plantations were formed more on a compensatory nature in scattered small plots of approximately to (20) ha. They were treated as natural forest after attaining the age of 40 years.

Extensive forest plantations in large blocks were formed commencing from 1972, and further large-scale plantation programme was launched starting from 1980. It started with a target of 16,190 ha annually. It reached a peak of 36,340 ha in 1985. However, this was considered to be 100 ambitious and unmanageable and currently is limited to 32,380 per annum. A total of 543288 has had been planted up to 1995.

4.3.3 Bamboo Resources

Bamboo grows abundantly through out the country either mixed with tree species or in the pure stands. Pure stands of Kanyin-wa (mellocanna bambusoides) stretch over and area of about 8,000 sq.km on the Rakhine mountain range with an estimated growing stock of 21 million metric tons. Taninthayi division also contains pure stands of WA-ya (oystermanthera nigrocilliata) over an area of some 1800 sq.km with estimated growing stock of 6 million tons. The bamboos in the Bago Division are of mixed -forest type and consists of a number of different species of which Kyathaung-wa (Bambusa polymorphia), Thait-wa (caphalostchynper grauel) and Myin-wa (dendrocalamus stratus) are commercially important of the 96 known species of bamboo only about 13 species are considered commercially important so far.

4.3.4 Mangrove Forests Resource

Myanmar has more than 2000 km of coast line along the Bay of Bengal that comprise the Rakhine, Ayeyawady delta and Taninthayi regions, the pattern of land use in the coastal areas consists of mangroves, coral reefs, see grass beds, evergreen forests and water lands, settlement and various types of agricultural land .The areas contribute to maintaining biological resources which are significant for the country's economy, and for the conservation of biological diversity.

Mangroves are found in all three regions. The delta formation is the most extensive one, which is situated at the Southern most portions in the Ayeyawady Delta. Another two formations are found along the sheltered coasts in Rakhine and Taninthayi regions. The mangroves of the Ayeyawady comprise about 29 species and represent the most complex and variable vegetation found among the mangroves of the Asian region. Wildlife in the Delta currently consists of a unique mixture of marine and land fauna and they owe their existence to the plant communities and ecosystems that give them shelter. There are 65 species of fishes, 13 species of prawn, 4 species of crabs, 9 species of shell fishes, mussel, and oyster inhabiting in delta. In addition, there are 6 species of mammals, and over 30 species of birds.

Mangroves in Myanmar are of interest to conservationists because of the unique life forms that live among them and the adaptation of mangroves themselves. However, most of the extensive mangroves in the Ayeyawady delta are much degraded because of exploitation for fuel wood and charcoal production.

4.3.5 Biodiversity status

Myanmar is often cited as the last frontier of species recorded for plant life and 1071 are endemic. It also has a rich wildlife resource, which includes over 1000 species of birds, more than 300 species of mammals and 700 species of reptiles and amphibians. Out of these, species such as the Asian elephant, tiger, thamin deer, Ayeyawady dolphin, gaur and four species of marine turtles are included in the list of globally endangered species.

Four hundred birds' species, mammals, hooded tree pie, white-browed nuthatch, white-throated babbler, and Myanmar yuhina are endemic. Myanmar also has the most diverse snake fauna in the old world tropics. The country has 68 swallowtail butterflies so far recorded and ranks fifth in the in this respect. However, 45 species of mammals, 39-species of birds, and 36 species of reptiles in Myanmar have been listed as endangered.

4.4 Fishery sector and Marine resources

The fisheries sector is considerably important in Myanmar's economy, as fish constitutes a major source for animal protein in the diet of the people. Myanmar has an abundance of rivers and streams, a long coastline and a large mangrove area in the delta region. An area of about 486,000 sq.km in the coastal regions has been demarcated as an economic zone for fisheries. The country also has an ocean area of about 163,000 sq.km, which is suitable for trawling.

Types of fishery in Myanmar are determined by nature of catch. Fresh Water Fisheries consist of (a) fish culture, (b) leasable fisheries, and (c) open fisheries. Marine Fisheries include (a) in-shore fishery and (b) offshore fishery. Freshwater fisheries are mainly of the nature of flood fisheries made possible through vast river systems and heavy rainfall. There are also leasable fisheries, which cover a vast area. Fish culture operations are at the same time undertaken extensively in ponds, lakes, and reservoirs.

Fresh-water fishing is made up of pond and river (leasehold) fisheries, both conducted by the private and State sectors, and open and flood fisheries conducted by the private sector. The total catch appears to have expanded since 1988, although seasonal fluctuations make it difficult to assess trends.

Myanmar is so rich in fresh water fish, marine fish and prawn that maximum catch, without deteriorating fishery resources, amounts to 1.5 million metric tons per annum. Area for fresh water culture in natural lakes, ponds, streams, canals, tanks and dams is estimated to be about 8.2 million hectares. Production on fish and prawn from 3474 lakes in Myanmar has been 68,000 tons annually. Water body of 41 dams, with a total area of 80,000 hectares serves as rich resources for fishery. Tidal forest of 6 million hectares at the mouth of three main rivers plays as breeding ground for fresh fish and prawn for a period of half a year. The country is endowed with rich and varied marine and inland fishery resources, with a production potential (sustainable yield) of 1.05 million metric tons per annum from marine source alone. Inland water bodies such as natural lakes, reservoirs, river systems ponds etc. cover an area of about 8.2 million hectares.

To overview the Marine fisheries, the Union of Myanmar enacted the "Territorial Sea And Maritime Zone Law" on 9 April 1977 and the law clearly defined the Baselines (straight lines drawn between fixed points on the mainland, on islands or rocks officially recognized by Myanmar as its territory. Schedules of such points are indicated in the Law). The Territorial Sea extends twelve nautical miles from the baselines. The Continental Shelf (extending two hundred nautical miles from the baselines) and the Exclusive Economic Zone in which the zone area covers a distance of two hundred nautical miles from the baselines.

Myanmar has a long coastline of 2832 kilometers. The total area of swamps along the coast is about 0.5 million hectares which provides a very good basis for the development of shrimps and prawn culture. The continental shelf (shallow coastal area) covers 228,781 sq kilometers and Myanmar's Exclusive Economic Zone (E.E.Z) is 486,000 sq. kilometers wide. According to surveys and research undertaken in marine fisheries, the Maximum Sustainable Yield (MSY) of the Union of Myanmar is estimated at about 1.05 million metric tons per year. It is promulgated that Myanmar Special Economic Zone for Marine Fishing is demarcated from base line to 2000 nautical mile Private Sector, Cooperatives and joint ventures actively participate in fishery business while State supervises only model Fish and Prawn Farms and hatcheries. With an aim to develop the private sector, State owned fishing vessels, ice plants and cold storage facilities are hired or sold out to the private entrepreneurs.

Along with coasts, local fishermen still practice the "drift net" and "trammel net" methods for harvesting near-shore fish. Even so, in accordance with government regulations and guidelines, only officially prescribed nets are permitted for catching a particular kind offish. Regarding fishing vessels, vessels of a maximum 30-foot in length with 6 horsepower engines are allowed to operate close to the coast while larger vessels must operate at 5-10 miles from the shore, thus preventing over harvesting of near-shore reef fish resources.

In 1988-89 Fiscal years, the export of fish and prawns earned US$ 10 million. However, in 1998-99 fiscal years, it earned US$ 201.33 million and the amount of US$60.78 million was earned from the period between 1 April 1999 and 28 September 1999. In the year 1999-2000 fiscal years from all the states and divisions, the production of Prawn by nature of catch is shown in the (Table 4.8).

Aquaculture played a minor role in Myanmar's fisheries industry till 1989. Only three thousand hectares of fishponds were established at the time. However, due to the encouragement and support by the government through the law relating to aquaculture, the aquaculture industry has now expanded to over ninety thousand acres of fishponds. The Government of Myanmar has thus encouraged the expansion of aquaculture through proper management so as not to cause environmental degradation. Intensive breeding, improper use of chemicals, destruction of mangroves and other fish habitats, discharge of untreated wastes etc. are considered grave offences, and are dealt with accordingly.

Table 4.8 Production of Fish and Prawn by nature of catch in Myanmar

(Thousands in Viss)

No	Particular	1995-96	1996-97	1997-98	1998-99	1999-2000
1	Fresh water fisheries	13350	141959	141613	153626	176750
	Fish culture	41791	50670	50195	55798	60573
	Leasable fisheries	37359	38310	38347	41539	49058
	Open fisheries	52353	5297	53071	56289	67119
2	Marine fisheries	278882	386560	53071	465215	67119
	In shore fishing	103186	143027	154269	172130	538919
	Offshore fishing	175696	243533	262676	293085	339819
	Total	412385	528519	558555	618841	713669

Source: Facts and Figures, Myanmar, 2002.p-108.

At present, only fourteen percent of the total production could be exported due to insufficient number of processing facilities, ice plants, cold stores etc. Although the government still manages some demonstration farms and hatcheries for extension service, the main infrastructures in the fishery industries are managed and operated by private entrepreneurs. In other words, there is no State owned institution competing with the private sector in fishery and fishery related operations. There are about (646) species of fish in Myanmar's Marine Fishery Waters and most of the exported products come from this source.

Section 2

4. 5 Environmental problems of Myanmar

The following section reviews the major environmental problems in Myanmar.

4.5.1 Environmental issues relating to land and water resources

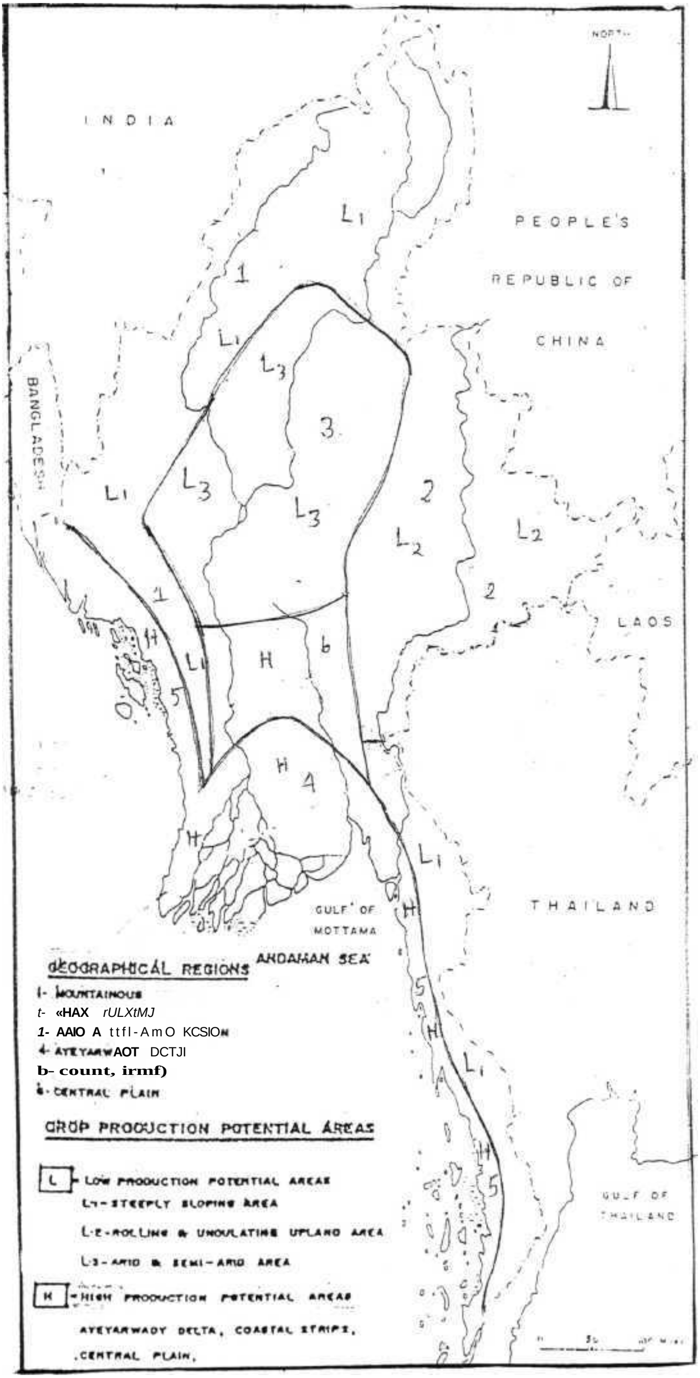
Environmental issues of Myanmar can be studied under two broad categories, land, and water. The land related environmental issues could further be bifurcated into problems of low and high agricultural production potential areas.

4.5.1.1 Low Production Potential Areas and Environmental Issues

Low Production Potential Area (LPPA) is the mountainous region of Shan plateau and arid and semi-arid regions. The LPPA occupy about 97 % of the land area, whereas only 51% (21.1) million people of the total population live there and only about 51% of the present cultivable area is located in this area. The LPPA accounts for only 32% of the total rice area of the country and produces about 27% of the total rice production. Among the LPPA, the arid and semi-arid region is the most favourable area for crop production development. The Shan plateau has medium favourability and the mountainous region is the least favourable. Therefore, the LPPA are subdivided into LI, L2, L3 depending upon their topography, climate and soils (Tha Tun, Oo, 1999),(see Fig 4.3).

(a) The Steeply Sloping Area (LI) and environmental problems

The Chin Hills, Northern Ranges, bordering China, and India, leeward side of the western mountain ranges and eastern Dawna mountain ranges, bordering Thailand are included in the LI area. The elevation ranges from 700m to 2000-3000m above sea level and the mountains are steep and highly dissected with gradients of 45% to 70%. The atmospheric temperature is usually chilly and the annual rainfall is 2000-2500mm. The Mountainous Red Brown and Yellow Brown forest soils (Cambisols) are the dominant soils of this area. They are acidic and low in fertility the high gradient and the shallowness of soils make the area very unfavourable for intensive annual crop



I'igurc *A3* Land classificasion due to soil capacity of Myanmar cultivation. Soil erosion and landslides are common hazards of this area.

The LI occupies about 40% (27.28 million ha) of the country but it is sparsely populated. Kachin, Kayin, and Chin are the major races of the area totaling about 2.74 million people or 6.6% of the total population. The people are simple and not very ambitious. They cultivate only 5.31% of the whole rice area and produce very low rice yields per acre. Therefore the area is not self-sufficient in rice for local consumption.

In this area, **shifting cultivation** is the major hazard detrimental to the environmental sustainability. There are about 71.69% ha of shifting cultivation land planted with rice and other domestic crops annually. This is equal to 22% of the total shifting cultivation area of the country. The shifting cultivation area and the upland area are 17% and 5% respectively of the totally sown LI (Low Production Potential Area). These areas are cultivated with upland rice; other cereals and food crops in the rainy season and left bare the rest of the year. There are also more than 100,000 ha of annual fallow land. All these lands are prone to yearly water erosion. The increasing population pressure will make the shifting cultivation area increase and the fallow land areas bigger, causing more **deforestation and soil erosion.**

Deforestation in this area was mainly caused,by slash and burning for shifting cultivation. Appraisal by the forest department in 1989 stated that total forest areas affected by shifting cultivation by the Kachin, Kayin and Chin states, were 16.66%, 61.30%, 69.15% respectively. The data indicates the serious state of deforestation, and the accompanying land degradation and ecological destruction.

(b) Rolling and Undulating Upland Area (L2) and environmental problems

The Shan plateau region *is* designated as L2 (Rolling and Undulating Upland Areas) area, which is border China, Laos and Thailand in the eastern part of the country. This area totals 19.14 million ha and occupies 28.2% of the total land area of the country. L2 has distinct physical features of tableland like topography. The tableland rises abruptly from near sea level in central Myanmar from 650 to 1200m above sea level in the Shan and Kayah States in the east. This region is well known as the Shan plateau and is famous for its pleasant climate and scenic beauties. The average altitude is about 1000 m above sea level but is varied due to the rolling and undulating topography. The eastern most borderline mountain range can be as high as 2000 meters and above.

The most dominant and agriculturally important soils are the red earths (oxisols/ ferralsols), which are also known as Terra-Rosa, red lateritic soils or simply red soil. The soils are acidic and low in fertility due to the removal of topsoil and bases by surface water erosion and leaching. But the texture is loamy and easy to work. The profile development is deep and water absorption is good. The soil is almost devoid of organic matter. It is very responsive to liming fertilization.

The Shan and Kayah groups are the major occupants of this area, though there are many different minorities. The total population of L2 is 4.43 million, which is about 11% of the total population of Myanmar. The population density is much less than that of Myanmar as a whole. The people are very simple and unambitious. These factors are taken into consideration in the planning of area development.

Shifting Cultivation is also the major cause of environmental deterioration in this area. More than 100,000 ha or over 32% of the total annual shifting cultivation area of the country is found in this region. More than 16% of the total sum area in L2 is annually under shifting cultivation. More shifting cultivation is practiced in L2 than other parts of the country because many different minor races are scattered over the mountains which are not very steep like those of LI and hence it is easier to slash and burn.

Upland cultivation plays an important role in the development of agriculture of L2. Over 35% of the annual agriculture upland crops such as upland rice, maize, soybeans, vegetables and cash crops occupy the area. There are more than 360,000 of annual fallow land. Almost all of these areas are covered with crops or weeds only in the rainy season and left bare to the sun and wind in the rest of the year. Not only the topographical nature of L2 is favourable for water erosion, but also the light texture soils, which are devoid of cementing agents like organic matter, are favourable for wind erosion too.

In this area the main cause of **land degradation** is shifting cultivation, which is causing accelerated erosion. The slash and burning exposes the soils to sheet and gully erosion and the wrong agronomic practices such as cultivation against the slopes cause rill erosion. Therefore, slight to severe soil erosion is found in almost all the upland and has resulted in the gradual decline of crop yields which in term leads to more deforestation and slash and burning by the local farmers to produce enough food for their mere survival. In this way a chain reaction on the environmental destruction continues.

It has been universally accepted that deforestation and slash and burning cause serious losses not only of timber species, but also other rare flora and fauna. Myanmar is no exception. But no firm data can be cited here about the ecological and genetic deterioration due to deforestation and slash and burning in Myanmar. Moreover, it can be said for sure that the ecological losses will be great because L2 is topographically and climatically unique in Myanmar and is the home for rare flora and fauna.

(c) Arid and Semi-Arid Area or L3 area and environmental problems

The lower part of the Sagaing division and the whole of Mandalay and Magway divisions are included in L3 (Arid and Semi-arid Areas). This region is known as the dry zone of Myanmar. The L3 occupies about 19 million ha or 28% of the country. This region is included in the low production potential areas due to its arid climate and unreliable rainfall, but agriculturally L3 is the second most important area of Myanmar except for paddy.

The L3 occupies the upper part of Ayeyawady alluvial plain and the elevation ranges generally from 0-250 m above sea level. The peripheral areas are foothills of pre-mountain ranges of LI and L2, and the central part is usually level or slightly undulating. The area has the highest maximum temperature from 105' F to HOT and lowest annual rainfall from 750 mm to 1000 mm. Therefore more than 75% of the total irrigated area of Myanmar is found in this region.

There are two main soil types namely, red brown Savannah soils (luvisols) and dark compact soils (vertisols) which are agriculturally important soils of Myanmar after the paddy soil (gleysols). The low and level areas re-occupied by the vertisols and the higher periphery, gently sloping and undulating areas are occupied by the luvisols. The soils have neutral to alkaline reactions. The vertisols are dark in colour and characteristically high in clay content whereas the luvisols are reddish brown in colour and have more than 65% of sand. The two contrasting characteristics of the soils give the region the agricultural capability of growing different low land and dry land crops such as rice, wheat, groundnut, sesame, sunflower, cotton, pulses, and beans.

The total population of the region is estimated to be 14 million or 33% of the population of Myanmar. Majority of the population are Burmese with a few minorities. The people are industrious, ambitious, and intelligent. A majority of the population are well-established farmers since the region has a history of ancient Myanmar Kings. Impressive irrigation systems initiated by these kings are still functioning in these areas.

Only 14% of the total shifting cultivation area, i.e., about 46,000 ha is under shifting cultivation in L3 and is practiced only on the higher periphery of L3 which are foot hills and pre-mountains of the LI and L2 areas. This shifting cultivation area makes up only 1.5% of the total cultivated land area of L3, whereas the upland crops area occupies 64%. About 22% of the total low land rice area and about 87% of the total upland and dry land cropping areas of Myanmar are found in L3. More than 75% of the total irrigated area is concentrated in this region. Therefore, area-wise shifting cultivation does not seem to be harmful, but since many irrigation dams and canals are situated in this area, there is a costly danger of siltation of the irrigation systems due to the soil erosion from upper shifting cultivation areas. Moreover, a high average of upland and dry land cropping within the area is also subjected to wind and water erosion because, although the uplands of this area are not highly sloppy like in L2, they are still susceptible to both types of erosion, having 3-10% slopes, rolling and undulating topography and light sandy texture. Since this area has a high potential for future agriculture development, minor consideration must be given to the environmental sustainability of this region.

The main cause of deforestation in this area is woodcutting and charcoal making. There is a common belief that the central dry zone was once a thickly forested area; but due to the heavy woodcutting for brick making to construct numerous Pagodas during the time of ancient Myanmar kings, the area was gradually turned into semi-desert like conditions. The forest department (1989) appraised that the L3 area has 68,444 km2 of closed forest, 18,344 km2 of degraded forest and the forest affected with 25-75% shifting cultivation was 27,207 km2 or about 24% of the total forest area of L3.

Myanmar as a whole has 24.3% of non-forested land whereas this L3 area has more than 37% of non-forested land. This figure indicates the extent of deforestation for dwellings and cultivation purposes. Other statistics shows that the quality of the forest is also degrading due to human influences, and aridity of climate. From 1975-89, the closed forest areas have decreased in Mandalay and Magway divisions, except in the Sagaing division. Even the degraded forest areas have declined to give way to upland crops and shifting cultivation. The population pressure on this area can cause further destruction of forests and its quality.

Land degradation is the most serious problem of this area. As mentioned earlier, there are two agriculturally important soil types in L3, namely Iuvisols, vertisols. Both soils are subjected to land degradation of one form or another. The Iuvisols, which occupy the upper periphery and rolling and undulating topography, with light texture and loose structure, suffer from both wind and water erosion. The luvisols are completely devoid of organic matter for cementing soil particles, which are easily blown away during summer windstorms. Water erosion damages soil with gentle slopes on rolling and undulating topography during the rainy season. Therefore, coarse layers are exposed in most of the luvisols of this region, negatively affecting the crop production.

On the other hand, the heavy clay low land vertisols are affected by salinity and acidicity due to saline and sodic irrigation water on one hand and bad drainage and salt accumulation by the water flow down from the upper periphery, on the other hand. In this way the soils of L3 are degrading due to the reduction in soil depth, fertility, moisture holding capacity and productivity. Genetic erosion in this area is occurred but no statistics are available to present the facts and figures. However, circumstantial evidence indicates that there were woodlands in this area, which were a sanctuary for endemic flora and fauna.

Thus, it is clear that the most affected environmental problems of LI, L2, and L3 areas are **deforestation** and **land degradation** by shifting cultivation and woodcutting for fuel.

4.5.1.2 High Production Potential Areas (HPPA) and Environmental issues

The high Production Potential area (HPPA) consists of Ayeyawady delta region, the coastal strips, and the central plain regions. The HPPA occupy only about 3% (2.14 million ha) of the total land area of the country.' However, over 49% of the total population of Myanmar inhabit in these areas. The HPPA has more than 49% (4.05% million ha) of the total arable and permanent cropped land areas of Myanmar. These areas account for more than 68% of the total rice land and about 74% of the total rice harvest of Myanmar. Industrial raw materials like jute and rubber are exclusively grown in this area. Therefore, the HPPA is extremely important agriculturally and economically.

The central alluvial plain and the Ayeyawady Delta regions are generally level plains with a few high altitude spots such as Bago mountain range. The coastal strips have level topography extending towards the sea, whereas the western parts are hilly due to the descending foothills of the western and Dawna Mountain Ranges.

The coastal strips receive the heaviest rainfall (3750-5000 mm) in Myanmar. The Delta and the central plain region also receive a high quantity of annual rainfall ranging from 2000-2500 mm. Supported by the flat terrain and heavy clay soils, the HPPA has become the most important rainfed lowland rice growing area known as the "Rice bowl of Myanmar".

The soils are predominantly Meadow Gley (Gleyic Cambisols) and alluvial soils (fluvisols). Small areas of yellow brown lateritic soils (Latosols/Cambisols) are found on the foothills and pre-mountain areas of the central strips. Meadow gley soils are well developed and have heavy clay textures with a high water retention capacity and low infiltration rate. These soils are slightly acidic and low to moderately fertile. The alluvial soils are better drained, more fertile and possess silty clay loam textures. Both soils are good paddy soils with a high potential for increasing cropping intensities if supplemented irrigation is provided. The soils are also responsive to heavy fertilization.

The yellow brown lateritic soils are found in the small area with hilly and undulating topography. They are acidic in reaction, heavy in texture, low infertility and suitable for orchards, garden and plantation crops. More than 65% of the garden and plantation crops of the country are located in this region. Since 49% of the total population, i.e., over 20 million people live in this HPPA area which covers only 2.14 million ha , the population density is 10 people/ha , which is much higher than that of LPPA. About 80% of the population is ethnic Bamar and the rest are Rakhine and Mon. All those occupants are intelligent, ambitious, and competitive people. Agriculture in this area is well developed and the farmers are very responsive to modern technologies and land and water development. Erosion hazards are very low because shifting cultivation is negligible except in some areas at the foot of the western and Dawna mountain ranges, but this region has a different set of environmental problems.

(a) Water logging and Salinity

Water logging and flooding are two harmful phenomena affecting the sustainable agricultural development of this area .The HPPA is often hit by the annual tropical storms, especially in the coastal and delta region. Inadequate draining systems and silted waterways due to the soil erosion of the upper LPPA makes this low land area waterlogged and inundated. Delay in sowing of crops due to water logging, in undulation and annual flooding reduces due to the water logging, in undulation and annual flooding reduces the crop yields considerably. In some areas, no crops can be grown at all during the rainy season due to the stagnation of water. Water logging and flooding not only reduces agricultural activities, but also cause the spread of water borne diseases among the population of the surrounding areas. The average of surface water irrigation in this area is negligible and there is no ground water irrigation here. Therefore, there are no dangers of acidicity and ground water salinization in HPPA. But salinization due to flooding and seawater encroachment is a problem in this area. Many areas along the coastal regions and low-lying delta regions are subjected to annual tidal water encroachment - causing soil salinization. Though severity of the salinity is not very pronounced during the rainy season in which rather salt tolerant rice crops are grown. The salinity effects appear greater after the rain stops, and a second crop is almost impossible in this salt affected area.

(b) Hazards of Monoculture

The HPPA is essentially a mono-cropping rice cultivation area. Even after the introduction of High Yield Varieties (HYV) which gives more time for second cropping, the average cropping intensity of this area still remains at 11.3%, which is much lower than the national average cropping intensity of 12.5%. The main reasons for low cropping intensity in this area are heavy rains and lack of irrigation. During the rainy season only rice is favourable while in the dry season there is lack of moisture for the second crops. The present main second crop is jute, which is grown by pump irrigation. The benefit of rice mono cropping of this area is food sufficiency for the country and promotion of rice export to earn foreign currency. But there are environmental hazards as well in this monoculture. There are the dangers of spread of insects, pest and disease which can thrive year after year on the same crop plant, especially HYV, the deterioration of soil structure due to the prolonged submergence; reduction of iron and manganese which are toxic to plants; the rise of ground water table; and the depletion of the same type of nutrients from the soil nutrient reserves year after year, contributing to nutrient imbalances.

(c) Fertilizer Imbalances

All the arable and permanently cropped soils are generally deficient in available N and *?2* O5, while K2 0 was sufficient to maintain the modest yields of traditional crop varieties. However, with the introduction of modern high yielding varieties and increasing cropping intensities, the soil reserves of plant nutrients are rapidly depleted, especially in this area in which high yielding varieties replaced 40-60% of the traditional rice varieties. The fact is that the introduction of short duration HIV's made it possible to increase rice-based double cropping, which removes additional soil nutrient reserves.

The Union of Myanmar average rice yield from 1940-1970 was 1-67 metric tons per hectare. The fertilizer use was mainly farmyard manure (FYM). However, with the introduction of HIV's. better techniques and increased inputs of chemical fertilizers and insecticides, rice yields increase to 2-3 metric tons per hectare, during the year 1970-1985 . However, supplemental fertilizer nutrition is very low being only 20-34 kg/ha so as to be insufficient to replenish the nutrient removal by the crops. Micronutrients were never used commercially in Myanmar agriculture. Therefore, environmental pollution due to excess use of chemical fertilizers will not pose a problem in Myanmar in the near future. On the contrary, the environmental hazard is the excess removal of soil nutrients and inadequate replenishment of them.

Another problem is the imbalanced application of chemical fertilizers. In 1987-88 crop seasons, 202815 tons of chemical fertilizers were used to grow 11-53 million acres of rice. The ratios of the applied fertilizers were 80:14:6 for urea, TSP and MOP respectively. But the farmers are very willing to apply urea because the immediate response of urea application can be seen by the instant green colouring of plants. But the farmers are reluctant to use phosphorous and potash fertilizers whose effects are not immediately observable on the plants. Therefore, the long-term application of imbalanced chemical fertilizers can cause a serious nutrient imbalance in the soils, which can lead to soil deterioration and reduce crop production.

The soil micronutrient problems are not extensively investigated yet; but it can be said for sure that Myanmar soils are definitely deficient in microelement such as zinc and sulphur, as some experiments indicated crop response to Zn and Sulphur applications. The above facts indicate that nutrient imbalance exists and needs to be corrected immediately; otherwise it will lead to environment deterioration of the arable lands.

4.6.1.3 Strategies for Sustainability in the Low Production Potential Areas

It is evident from the above that shifting cultivation and land degradation are the two main causes of environmental deterioration and low crop production of the (LPPA) low production potential areas. Shifting cultivation is the main cause of deforestation, which in turn leads to accelerated soil erosion and land degradation in the LI and L2 areas. However, shifting cultivation is only partly responsible for the environmental degradation of the L3. The land degradation due to wind and water erosion, and salinization and alkaiinization are the main cause of environmental degradation of L3. Therefore, the strategies for the sustainability of environment and agriculture of the LPPA must be based upon the different local conditions. The following measures are being taken at the macro and micro levels to promote sustainable and environmentally sound land and water development in the LPPA.

(i). Firstly, the shifting cultivation areas and the deforested areas were surveyed and recorded by the forest department and land records department, while the saline and alkaline areas were surveyed and identified by the land Use Division of Myanmar agriculture service.

(ii) Once those areas were identified and extents of damage were known, then the departments concerned undertook the approximate measures. Research and experiments were conducted as required.

(iii) The Forest Department is preventing further deforestation by educating the villagers concerned about the laws and liabilities of indiscriminate woodcutting and forest burning, and has introduced reforestation with the participation of the surrounding villagers and Taung-ya {shifting cultivation} system, which can benefit both the farmers and the department.

(iv) The land records department is responsible for recording the success or failure of various cropping areas including shifting cultivation.

(v) Myanmar Agriculture Service is educating the villagers through extension agents about the demerits of shifting cultivation and also demonstrates the construction of bench terraces, contour bands and advises an appropriate hillside farming methods such as valley cropping, strip cropping, etc.

(vi) The Land Use Division has conducted experiments to find out suitable methods of land reclamation and soil amendment for the saline and acidic soils and demonstrated and advised the farmers on the use of appropriate technologies.

Many departmental activities have been going on for a long time on the preservation of the environment at micro levels in agricultural, industrial and health sectors; but the following initiatives will be pursued more energetically to stimulate environmental awareness at grass root levels:

(i) Education of hill and upland farmers about the detrimental effects on the environment of slash and burning and deforestation;

(ii) Practical demonstration of the causes and effect of accelerated soil erosion to the fanners.

(iii) Preventive measure of soil erosion and land degradation and appropriate hillside and upland farming technologies will be transferred to the farmers through training and group discussions.

4.5.1.4 Strategies for Sustainability in High Production Potential Area

It is evident that HPPA is endowed with vast extents of leveling land, which is not susceptible to wind and water erosion. The area is gifted with better soils and abundant rainfall, which makes this area the rice bowl of Myanmar. This area possesses about 50% of the current arable and permanently cropped land of Myanmar and has potential for future agriculture expansion.

However, the environmental hazards such as water logging, nutrient imbalances, monoculture, and misuses of pesticides need to be controlled for environmental and agricultural sustainability. The following measures are being taken at macro and micro levels to promote sustainable and environmentally sound land and water development,

(i) The irrigation department increased the flood protection area from 1.8 million metric acres in 1961-62 to 2.652million metric acres in 1989-90. Drainage facilities were increased from 1.8 million acres in 1961-62 to 4.79 million acres in 1989-90.

(ii) The Myanmar Agricultural Services is investigating the salinity problems of the area, researching soil ameliorative methods and introducing salt tolerant HYV rice varieties,

(iii) The Myanmar Agriculture Service is undertaking soil testing and soil-crop-fertilizer research on the farmers' fields to determine the soil nutrient status and balanced fertilizer norms for rice.

(iv) The Myanmar Agriculture Service built a new pesticide plant in upper Myanmar in 1988 and is producing neem pesticides at an increasing annual rate. The farmers are welcoming these products. Therefore, there is a great potential for the increased production of neem extracts, which can replace a large portion of toxic chemicals in plant protection.

(v) The Myanmar Agriculture Service is importing less harmful and toxic pesticides and encouraging their use only at the economic threshold levels, which can be determined by scouting methods.

(vi) The Government of Myanmar has recently enacted a pesticide law and agriculture agents are training and educating the farmers as well as the pesticide retailers on the correct handling and usage of pesticides.

(vii) The Myanmar Agriculture Service demonstrated and encouraged rice farmers to grow rice-based and second crops such as jute, groundnut, sunflower and sesame, either with the residual moisture or by pump irrigation from numerous fresh water rivers and streams in the delta. Thereby, the farmers can earn more money and the adverse effects of rice monoculture are reduced.

To stimulate environmental awareness and existing and potential means for monitoring social and environmental consequences for high production potential areas are largely the same as described for low production potential areas in the previous section .At the macro level, however, the Myanmar Agriculture Service, Irrigation Department, and Fisheries Department will increase their efforts to educate both farmers and fishermen about environmental destruction caused by logging, soil salinization, nutrient imbalance, monocropping and misuse of pesticides.

4.5.2 Other Major Environmental Problems in Myanmar

4.5.2.1 Soil Resources and their Problems

There are about 24 soil types in Myanmar, which are dictated by soil-forming factors such as rainfall, parent rocks, and topography and landforms. However, only three main soil groups are recognized as agriculturally important; alluvial, black and red laterite soils. The alluvial soil makes up some 50 per cent of the total sown area and is located in river basins and the delta. Black soil occurs in about 30 per cent of the area and is generally found in the dry zone region, while red laterite soil accounts for 20 per cent of the area and is found in lower Myanmar associated with undulating topography.

Problem soils are characterized by soil and agro-climatic constraints to sustainable agricultural production, limiting the range of crops that can be grown successfully. In Myanmar, problem soils occupy an area of nearly 1 million ha, representing about 7.8 per cent of the total cultivable land. Of the area of problem soils, about 68.75 per cent (660,000 ha) comprises saline and alkaline soils, although most of them are current under cultivation. The remaining problem soil area comprises acid sulphate, degraded, peat, and swampy soils. Therefore saline and alkaline soils are the predominant problem soils in Myanmar. In the hilly region and the central plains of Myanmar gradual degradation of soil fertility is occurring through erosion. However, the worst affected region is the dry zone, which covers Mandalay, Sagaing, and Magway Divisions. The depletion of natural resources is a matter of concern, as is the wasteful destruction of forests through shifting cultivation, with its wind and sheet erosion. In the hilly regions, wind and sheet erosion and gradual desertification in the semi-arid zones are cases in point.

Steps needed to be taken to introduce and enforce terraced cropping or stripped cropping with appropriate forest belts in between, in lieu of shifting cultivation, in the hilly regions. In some parts of the hilly regions of the Chin and Shan States traditional shifting land use practices have resulted in continuous soil degradation, making the land less suitable for economic crop production. In order to avoid the recurrence of such problems, steps are being taken to promote terrace cultivation and conservation farming methods in those areas. The Inlay Lake has become shallower because of the soil erosion in watershed area, loss of vegetation cover, and unfavourable agricultural practices such as slash and burn cultivation and shifting cultivation. Similar phenomenon is found in the dry zone area of central Myanmar. Similarly, extensive wind belts, associated with suitable cropping pattern in the dry zone, need to be established to minimize soil losses and halt desertification. For the development of soil-depleted areas, measure will be taken to prevent further deterioration of hitherto eroded and fertility depleted fallow sloping

4.5.2.2 Impact of fertilizers and pesticides on environment

Concern over environmental damage has assumed global dimensions and Myanmar cannot remain divorced from stark realities. However, because of budgetary and foreign exchange constraints, the sum total of pesticide and fertilizer use does not meet the actual requirement, which may be a blessing in disguise. As yet, pollution and contamination are not grave problems in Myanmar. The utilization of pesticides and fertilizers is very low compared to neighbouring countries. In fact, of the 23 in the Asia-Pacific region, Myanmar is among the 10 countries, which have the lowest fertilizer consumption in terms of nutrients (1990-91 figures).

Being a developing agricultural country, at least for the foreseeable future, Myanmar will inevitably use pesticides in agricultural food production, although other parallel efforts of non-chemical nature are being investigated in plant protection strategies. The most practical way to handle the pest problem is the use of chemicals with intelligent concern and proper control. However, recent data indicates the need for cautious control through coordination and cooperation between government agencies and with the people themselves .In addition, agricultural pesticide use in the country is expected to increase with the abrupt change of cropping pattern aimed at increase in rice production and the expansion of various crop-growing areas.

The quantity of pesticides imported by semi-government organizations and NGOs has been growing in recent years. In the near future the proportion of imports by private organizations may dominate as a result of government policy to encourage the private sector while the government concentrates on technical and legislative measures.

The Ministry of Agriculture has a pilot pesticides formulation plant for which technical grade materials are imported and pesticides produced. The plant extract insecticide is produced by the ministry's pilot neem pesticide plan. Insecticide from the neem tree is effective against many leaf-eating caterpillars but has little or no toxic affect on humans or the environment.

For the purpose of scrutinizing the efficacy of pesticides to be approved for use, minimizing hazards to human health and environment promoting safe and effective use of pesticides and assurance of registration, the government formed the Pesticide Registration Board in 1992. The Board is entrusted to implement the Pesticide Law with the following objectives:

(a) The registration of all pesticides before marketing;

(b) The control of pesticide use on food and environment;

(c) The control of pesticide production distribution and disposal etc;

(d) Monitoring the quality of pesticides in use; and

(e) The control of residues in food and the environment.

So far, no national standards for pesticide residues have been established. Since Myanmar has encountered some pesticide residues in food from international trade, it is essential to set maximum residue limits and legally control them. The ratio of samples violating the Codex Maximum Residue Limits (Codex MRL) and National MRL (export requirement), based on the number of samples analyzed by the Pesticide Analytical Laboratory in recent years is quite significant.

The commodities analyzed were mainly means for export and the residues exceeding the limits were mostly the result of post-harvest application of improper pesticides such as Aldrin and DDT. The national export requirements are generally lower than the codex MRL. The current use of persistent pesticides will affect the residual levels in food through plant uptake for many years. Some organo-phosphorous insecticides were also detected. In addition, residues from the incorrect use of post-harvest pesticides, e.g., aluminum phosphate, still remain to be examined.

The use of pesticides had started in Myanmar only in the 60's and the amount of their use is relatively very low. Since then the import and distribution is solely done by the concerned agency of the Government. Although Myanmar has a total crop sown area of about 9 million hectares, the annual import of pesticides remained low at about 800 metric tons, but in some years, it rose up to 1000 metric tons to 1900 metric tons, as pests and diseases outbreaks have been low. However, it is expected that pesticides utilization *will* definitely increase in the future, as Myanmar gets more and more into producing high quality agriculture produce and crop intensification.

Though the pesticide usage quantity of Myanmar is still being under the danger level, the mode of utilization is important. Some farmers have very little knowledge of pesticides and are using them indiscriminately, not only killing the targeted pests and insects, but also *the beneficial insects, soil micro organisms and natural predators.*

Incorrect method of spraying, timing and washing of the spray equipments has contaminated the rural lakes, ponds, and rivers causing direct affects to the onsite fish and farmers. Offsite effects also can be found in the downstream areas. Indirect effects are also found upon wildlife and surrounding people who consume the contaminated water, fish, and vegetables. Another defect caused by the incorrect usage of pesticides is the development of more resistant insects and pests. They become more tolerant to the frequently used pesticides. The pesticides become totally ineffective or stronger and higher dosages are needed which are more harmful to the environment and the people. To solve this problem, the Government of Myanmar has recently enacted a pesticide law and the agriculture agents are training and educating the farmers as well as the pesticide retailers on the correct handling and usage of pesticides.

The use of organic chlorine pesticides has already been banned, but they are still used for vector control because alternative measures cost high. A thousand tons of pesticides are used for agriculture and sanitation control for these 10 years. The problems are contamination of natural resources and food with the persistent pesticides and illegal traffic of pesticides from border regions.

4.5.2.3 Marine Resources degradation and coastal degradation

The coastline of Myanmar, from the Naff estuary of Rakhine State to Kaw Thoung of Taninthayi Division is about 1,800 kilometers. When the coastlines of gulfs and islands are included the coastline totals nearly 3,000 kilometers, of which about 230,000 sq.km in area is suitable for marine fishing.

The sea area of Myanmar is estimated to contain a standing stock of 1.7 million tons of pelagic and demersal fish, of which about 1 million tons comprise the maximum sustainable yield (i.e. can be caught without diminishing the original stock). Since the total fish and prawn catch in 1994-95 was only 600,000 tons, it is obvious that as far as marine fishing is concerned there is no over exploitation; thus there is no danger of depleting the marine resources at the present rate of production. One support piece of evidence that the current marine catch per hour of 200 kg is unchanged from that recorded over the past 15-20 years. Foreign fishing and joint venture company vessels are allowed to fish only outside the continental shelf and fees are imposed in accordance with GRT. Those measures also help to prevent overexploitation of marine resources.

(a) Coastal Erosion and Sedimentation

Myanmar has 410,000 ha of mangrove areas along its coastline, which are being systematically preserved. The marine forests furnish protection from natural disasters such as storms, tidal waves, and floods while catching the silt from rivers and streams thus minimizing erosion. Since there are very few factories, mineral mines or wharves along the coast of Myanmar there is no natural sedimentation yet, and since the coastal aquaculture industry is still using the tradition "trap and hold" method, sedimentation is not a threat.

(b) Reef Degradation and Eutrophication

Along the coasts, mangrove forests as well as reefs are important habitats for marine fauna. The existence of coral reefs also prevents erosion, as do the mangrove forests; old and traditional methods are still largely practiced in catching fish and prawn along the reef. Since methods such as dredging and the utilization of specific poisons and bombs are not commonly practiced yet, reef degradation and eutrophication are not a danger at present (Thein.M, 2000).

4.5.2.4 Mangrove Forest Degradation

The original area of mangrove forests in Myanmarwas 953.641 acres (385933 ha) in early 1990. Due to over exploitation for firewood and charcoal and the excessive expansion of agriculture land, half of the mangroves area has been depleted during the last decades. Bio-fuel is the major source of energy in Myanmar. Approximately, 27 million air-dries ton (ADT) of biofuel, 61% of total energy consumption of the country is consumed annually. The trend of wood fuel consumption and the net surplus, deficiency in Ayeyawady Delta for 1990, 2000, and 2005 (in million ADT) are shown in (Table 4.9) below:

Table 4.9 The trend of wood fuel consumption and the net surplus /deficiency in Ayeyawady Division for 1990, 2000 and 2005 (in million ADT)

year	Sustained yield woodfuels	Local Consumption	Export	Import	Surplus/ Deficiency
1990	0.59	3.99	1.22	0.10	-3.83*
2000	0.86	4.51	1.00	0.30	-4.35**
2005	0.59	4.71	1.00	0.30	-4.82**

**Source: Myanmar Energy Sector Investment and Policy Reviewed by World Bank Team, 1991.*

*** Project figure*

Myanmar forests in Bogalay, Laputla, and Maulamyaing kyun of Ayeyawady Forest Division have been managed systematically since the early twentieth century. These mangrove ecosystems are fragile but essential to support the sustained production of fisheries and inland rice cultivation. They provide the coastal dwellers with shelter, protection from the ravages of severe winds and with timber for domestic uses, fuel wood, charcoal, and many other forest products.

To meet the needs for fuel wood, charcoal and other forest product, these mangrove forests have been exploited beyond their capacity. Large parts of reserved forests in Ayeyawady delta, except Meinmahlatkyum wildlife sanctuary, have been degraded, deforested, and mostly depleted due to excessive fuel wood /charcoal production and paddy field encroachment.

These tidal forests (mangroves), according to 1942 estimates, covered 671492 acres as shown in the (Table 4.10). Due to the ever increasing demand for firewood and charcoal by Yangon city and for various forms of forest product, produced by the local population, the 1990 estimate, indicate that mangrove forest have been reduced to

438,000 acres. Mangrove forests in the delta had been excessively exploited and eventually turned into agricultural lands. According to 1950 assessments the mangrove forests have been undergoing depletion at a rate 2.4 times higher than that of the depletion of forests in the country, which highlights the need to urgently implement management strategies for the mangrove ecosystems. Table (4.10) shows the assessment of Ayeyawady mangrove forest area from Aerial photo Interpretation and Landsat Imagery. Though appropriate measures have been taken to protect the mangroves in the delta, at present, due to increases in population as in table (4.11) and excessive needs for fuel, most of the mangroves, which were out of reach of the forest department staff, have been heavily encroached.

Table.4.10 Ayeyawady mangrove forest cover assessment from API & Landsat Imagery (Area in Acres)

N 0	Township	Mangrove Area(Acres)							
		1942		1954		1984		1995	
1	Bo gal ay	373,685	100%	316,632	84.73%	271,106	72.55%	60211	16.11%
2	Laputta	251,102	100%	217,858	86.76%	164,142	65.37%	16589	6.6%
3	Maulamyein kyun	46705	100%	44,997	96.34%	11,824	25.31%	146	0.31%
		671492	100%	579,487	86.30%	447,072	66.58%	76946	11.46%

Source:(I) Forest Department NFMI Project,MYA/8S/008 Da'afor 1924 tc 1984

(2) Japan Forest Technical Associalion(JFATA),1995, Forest Register for 1995.

Table 4.11 Townships population in Ayeyawady mangrove areas from 1931-1993

Sr.No	Township	1931	1953	1983	1993
1	Bogalay	8074	23211	294225	353419
2	Laputta	-	12843	238516	262393
3	Maulameingyun	7747	16464	-	271008

Source: Manpower and Immigration Dept, Ayeyawady Division, Pathein, 1995.

The government, in 1993, stopped extraction of all forests of produce from mangrove forests and extensive replanting and protective measures have been taken. As a result regeneration is apparent in some areas. Due to excessive pressure on delta forests for the supply fuel wood and charcoal and the extension paddy cultivation, the forest area in Laputta, Bogalay and Maulamyaing Kyun has reduced substantially as shown in(Table 4.1 (^respectively. The forest cover in Laputta is 6.6%, 16.11% in Bogalay and almost nil in Maulamyaing kyun, against 62.5% in 1925 in these townships. Ayeyawady mangrove forests have been seriously degraded and it could affect the mangrove ecosystem. If the mangrove ecosystem is unbalanced, a scarcity of forest produce, Salinization of paddy fields, erosion of riverbanks, decreasing number offish and prawns will follow and the consequences will bring a severely damaged natural environment and food scarcity.

The following facts can be considered as the main cause of degradation of Ayeyawady mangrove forest:

(a) Although the mangroves had been managed systematically prior to the Second World War, some of them became a refuge of the insurgents after the war, and effective management was not possible.

(b) As the resettlement of villages was legally permitted in the mangrove-reserved forests around 1960, management of forest resources was weakened.

(c) There was over exploitation of firewood and charcoal to meet the demands of Yangon city and the local community. Until 1993, about 400,000 tons of firewood and charcoal was produced annually to meet this demand.

(d) With the assistance of the World Bank, a large area of mangroves was converted to paddy fields in the 1970's.

(e) Inability of working plan renewal resulted in the inability of applying the plan after the 1970's.

(f) Township - level management occurred after the district - level management ceased in the 1980's.

(g) The migrants encroached in the demarcated forest reserves for firewood and they gradually grew rice there.

(h) The illegally reclaimed paddy fields of the migrants were later occupied by wealthy persons from other areas and small villages were formed. Along with rise in agricultural and fishery business, 18879 acres were depleted and transformed into paddy fields.

(i) Land, food, poles, and firewood were abundant and easily accessible in the reserved mangroves areas at all times.

(j) Mangroves were assumed to be common property resources and illegally settled on a first come first served basis.

(k) After the prohibition of the commercial production of firewood and charcoal commencing from 1993, meeting the local requirement became an important issue. For the consumption of the urban and rural communities of Ayeyawady delta area, 300,000 tons of firewood is needed annually. Inevitably, the illegal exploitation of mangroves increased (Tun Paw Oo.U, 1993)

4.5.2.5 Water Related Problems

Myanmar is rich in water resources. Estimated run-off is 180.5 billion m3 per year in normal year, only 5% or 55 billion m3 is utilized for irrigation and drinking water. Potential for water resource development is high. As population grows, water demand increases and it leads to extraction of groundwater. At present ground water is extracted from shallow aquifer without any bacterial inspection. This might cause sanitary problems. Groundwater sanitation should be managed. Besides unrestricted extraction of groundwater might lead ground subsidence and salinization which should be prevented by proper management. There is no specific agency, which has the budgetary mandate of authority to have initiatives of water resource management.

The Inlay Lake has become shallower because of the soil erosion in watershed area, loss of vegetation cover, and unfavourable agricultural practices such as slash and burn cultivation and shifting cultivation. Similar phenomenon is found in the Dry Zone area of .central Myanmar. Traditional water management system can no longer meet the requirements of the market economy. Reform of the water resource management system and strengthening of the relevant authorities' capabilities are required. Insufficient information and data on water resources are also of the obstacles.

According to the 1995 survey, drinking water supply coverage was 60% nationally and 50% in rural areas. The low access, particularly in the rural areas, requires water collectors who are mostly women and girls to walk long distance to safe water sources. Use of even safe drinking water in bad sanitary situation contributes high incidence of infectious diarrhea, especially among children under 5 years old.

Rainfall in Dry Zone of central Myanmar is less than 1000 m, where water is extracted from the deep well with hand or motor pumps. Provision of drinking water from mini-irrigation system has also been attempted in some areas. In south Myanmar, shallow dug wells as well as tube-wells are used. In the coastal area where the groundwater is salinized, rainwater collection system is used. In hilly areas, natural spring are tapped and piped down to communities. Water supply system in Yangon can not guarantee the water quality good for drinking, as existing water treatment facility is incapable. The second reason is that there is a military industry using lead beside the water reservoirs in Gyobyu or Phugyi.

There are more than 300 towns in the country, most of which still lack of sanitary water supply system. Schools offer sanitary education, which contributes dissemination of idea on safe water and sanitation. It is expected that 100% coverage of safe water supply will be achieved by 2005. However, insufficient budget and inadequate priority of the sector may be constraints. Further, though many authorities share the responsibility of water supply, National Water and Sanitation Committee takes the initiative (JICA, 1999).

4.5.2.6 Pollution Problems

There's some air pollution in Yangon city by vehicle emission gas, but the extent of the pollution is not yet described although Japan International Cooperation Agency (JICA) technical operation was initiated in 1999-2000 in order to introduce air pollution monitoring technique to Myanmar. Neither laws nor standards are established for air quality control. The organization in charge of air pollution prevention is not defined.

(a) Waste Management

In Myanmar, a large number of industries and factories are located in the vicinity of cities likes Yangon and Mandalay. But some large-scale light and heavy industries have been established in different parts of the country. Most processing plants are located in close proximity to the sources of raw materials. Rice mills are found along the riverbanks in the rice-growing delta. A large number of factories and plants have also been built along the Ayeyawady River. However, the level of industrialization is relatively low and as a result, the extent of industrial pollution is minimal and no major pollution hazards due to industrial wastes have been experienced in the country. The Myanmar Investment Commission has issued guidelines whereby all projects established with the permission of the Commission shall be responsible for the preservation of the environment at and around the project site. The enterprises are duly responsible to control the pollution of air, water and land and other environmental production matters. Moreover according to the Factories Act, effective arrangements are required to be made in every factory for the disposal of its waste and wastewater effluents. In Myanmar, most of the large industrial plants have their own on-site treatment systems for controlling pollution due to the disposal of industrial wastes.

The Development Committee undertakes wastewater and Solid waste management in most of the towns and cities in Myanmar. The villages in the rural areas with respect to their waste disposal system are mostly supervised by the Health Department. The wastewater and solid waste management in Yangon consists mainly of the collection and disposal system, which comes under the responsibility of the Yangon City Development Committee (YCDC). Plans are underway to upgrade these systems in the immediate future.

Myanmar has several legal frameworks and legislations dealing with environmental protection of which water pollution, solid and air pollution are some of its key components. But they are difficult to enforce unless a certain degree of penalty is meted out to the offenders. Moreover since the environmental standards are still lacking effective control to protect the environmental cannot be undertaken yet. Presently, authorities responsible for environmental affairs are formulating measures to establish National Environmental Standards, which are crucial component in the environmental management programme. The plan for improvement of solid waste management drawn in 1980 presented the development of 13 sites of landfill and employment of waste collection by containers. A pilot study was conducted under the plan, but the whole plan is still not implemented.

Collection coverage of household waste is estimated to be 25% compared to the generation quantity. A collection vehicle rings the bell to draw attention and the inhabitants throw their waste into the vehicle. The collected waste is disposed in the dumpsites located in sub-urban area. Stabilized waste from these sites are offered free of charge to the public for use as compost in home garden and in the creation parks and gardens in the city. Municipal workers and scavengers salvage useful material at communal street dumps or dumpsites and sell it to allied cottage industries.

Paper mills, leather tanning factories and textile factories discharge toxic and hazardous industrial waste. It is necessary to watch it because the waste amount will increase as the economy grows (JICA, 1999).

(b) Industrial Waste Water

The government has taken water treatment measures for the state factories such as paper mills, textile mills with bleaching and dyeing process, tapioca starch factories, and breweries. Examples of water pollutions are Sittoung paper mill, which destroyed the aquatic life in Sittoung river and Kyunchaung fertilizer plant, which discharged arsenic, used in its process to the Ayeyawady river. Myanmar's investment Commission has issued s notification in June 1994, requiring all permitted enterprises to install wastewater treatment plants and other pollution control facilities to be able to comply with the sanitary and hygienic regulations.

Neither institutions for water pollution control nor the effluent standards have been established. Ministry of Labor is responsible for inspection and reporting on wastewater under the factories Act. Yangon City Development Committee and Mandalay City Development Committee is responsible for water pollution control in their city areas.

The degree of air or water pollution caused by industry or agriculture has been minimal due to the still low level of industrialization and relatively small amount of chemicals used in agriculture. However industrial expansion is expected in the near future owing to the recent change in the country's economic policy that will increase involvement of the private sector and foreign investments in its economic and industrial activities. Growing use of chemicals is however to be expected in agriculture.

4.6 Environmental Conservation and Management in Myanmar

Environmental considerations are not yet fully incorporated into the national development plans. This is partly due to the fact that the over all environmental condition is still satisfactory and do not necessitate immediate environmental protection measures. However, Myanmar's consciousness over nature conservation dates back many years ago. Historical records show that environmental conservation and protection works were initiated since the last dynasties of Burmese kings during which teak (Tectona grandis) trees were declared as royal property and royalties were levied for extraction (Brandis, 1896). Forests were reserved as sanctuaries where catching, hunting, killing, or harming of birds and animals were strictly prohibited. However, the concept behind the conservation of wildlife then, was basically religious and was not the conservation of biodiversity in modern sense. The Myanmar kings also undertook protection of teak forests. The systematic management of forests started only inl856, when Dr.Dietrich Brandis was given charge of the Bago forest (Blandford 1956; Forest Department of Myanmar, 1989; Stebbing, 1947). Following the early in 1857, new rules were published, bringing the Bago forests under regular conservancy and controlling the removal of teak trees. Soon after this, Brandis drew up the first working plans for Bago teak forests. The plans were drawn based on ring counting and observation of trees of known age. He calculated that it took 24 years for trees between 45cm dbh (4'6"gbh) to 60 cm dbh (6'6" gbh) to become yield trees of 60 cm dbh (girth 6' 0") and over. Accordingly he described that 1124th of the number of yield trees should be cut annually. Brandis estimated the number of yield trees for Bago forests from linear valuation survey. This silvicultural system, which forms the basis for the present management method, was known as the Brandis Sected System and was maintained for many years. The original Brandis Selected System was modified into the Myanmar Selected System in 1920, is still in use up to the present time. This system is merely a selection-cum- improvement system with the main features being to carefully protect the immature stock and assist it to attain maturity (Blanford, 1956). This improvement felling consists of thinning in immature teak, removal of certain proportion of silviculturally undesirable mature trees, opening up of patches of established and advance growth, climber cuttings, removal of inferior growth suppressing teak and its valuable associates, and cutting of dead and moribund trees (Kermode, 1957). Instead of 24 years of felling cycle, Myanmar increased 6 years, thus, making felling cycle into 30 years and the management system was also renamed as "Myanmar Selected system".

At present, Myanmar's environmental management pattern is largely sectoral. For instance, the Ministry of Forestry is responsible for sustainable forest management including wildlife conservation, while the Ministry of Industry controls and regulates industrial activities and pollution. The Ministry of Health is responsible for environmental-related health issues. The Ministry of Livestock, Breeding, and Fisheries carry out conservation of marine and fresh water fishery resources. There has been a growing awareness of the environment among the public authorities in Myanmar especially in the past decade. The National Commission for Environmental Affairs (NCEA) was established in 1990. It serves as the national focal point and coordinating agency on environmental matters.

The (NCEA) as the focal point and coordinating agency is responsible for coordinating environmental programs, plans and projects of both publish and private sectors. However due to financial, technical and manpower constraints, the (NCEA) can not fully carry out its mandates and responsibilities. Moreover to ensure sound and effective environmental planning and management information on existing environmental situations is required. The establishment of the environmental Databases Unit in NCEA only began in April 1994 and at present the collection of environmental data and information on a nation wide scale has not yet been undertaken.

With the rise in environmental awareness, presently, more and more government ministries and departments are incorporating environmental considerations in their plans and projects and are involved in environmental related activities in some ways. The general public is also becoming more involved in environmental protection and conservation measures.

The Union of Myanmar presently has 46 legal instruments relating to environmental protection. Various government ministries and departments administer these laws. The important environmental related laws include the Pesticide Law (1990) which monitors and controls the selection, storage, transportation and use of pesticides to protect people, crops, other biological entities and the environment; The Myanmar Marine Fisheries Law (1990) which lays down regulations to protect the marine fisheries; The Myanmar Tourism Law (1993) which aims to preserve and develop historical sites, monuments, natural scenic beauty, natural environmental heritage and traditional art and customs of national races ; The Forest Law (1992) which aims to implement the forest policy and environmental conservation policy of the Government and the Protection of Wild Life and Wild Plants and Conservation of Natural Areas Law (1994) which aims to protect wild life and wild plants and to conserve the national areas of the Government. The Factories Act has provision whereby effective arrangements are required to be made in every factory for the disposal of wastes and waste water effluents. In Myanmar, most of the large industrial plants usually have their own methods of treating wastewater and controlling air pollution.

4.6.1 National Environment Policy

The National Environment Policy of Myanmar believes in "the wealth of a nation is its people, its cultural heritage, its environment and natural resources. The objective of Myanmar's environment policy is aimed at achieving the integration of environmental considerations into the development processes to enhance the quantity of the life of all its citizens, every nation has the sovereign right to utilize its natural resources in accordance with the environmental policies, but great care must be taken not to exceed its jurisdiction of infringing upon the interests of other nations. It is the responsibility of the state and every citizen to preserve its natural resources in the interest or present and future generations. Environmental protection should always be the primary objective in seeking development". In the draft of the state constitution, "environment" means "natural environment". It states, "The state shall protect the natural environment".

Myanmar Agenda 21 was prepared as an environmental action plan as well as the following environmental policy. The NCEA Commission has competency over all environmental matters and will be responsible directly to the Cabinet Internationally the NCEA will act as a focal point with government bodies and international organizations. In the following section the national forest and marine policies are discussed, each of them has impact on environment.

4.6.2 Myanmar Forest Policy

Since Myanmar had been a province of India under the British Rule, the 1894 Indian Forest policy had guided the forest management in Myanmar for many years. In the face of a dynamic population and a rapidly changing socio- economic and political environment there was a need for an explicit forest policy to address the change. It had also been recognized that the new policy interventions were needed for calibrating a fit between forest plans and programmes, the forest resource base and the people. The need for ensuring ecological balance, environmental stability and enhancing the contribution of the forestry sector towards socio-economic development of Myanmar in a sustainable manner was also eminent.

In view of the importance of the Myanmar forestry sector in enhancing national socio-economic development and ensuring ecological balance and environmental stability the Myanmar Forest Policy (1995) has been formulated in a holistic and balanced manner within the overall context of the environment and sustainable development taking full cognizance of the forestry principles adopted at UNCED. It formalized the commitment and intent of the Government to ensure sustainable development of forest resources while conserving wildlife, plants and ecosystems.

The forest through increased productivity while controlling the socio-economically the policy has identified **six imperatives** that the Government must give the highest priority in order to achieve broader national goals and objectives. These are:

(a) Protection of soil, water, wildlife, biodiversity and environment;

(b) Sustainability of forest resources to ensure perpetual supply of both tangible and intangible benefits accrued from the forests for the present and future generations;

(c) Basic needs of people for fuel, food and recreation;

(d) Efficiency to harness, in the socio-environmentally friendly manner and the full economic potential of the forest resources;

(e) Participation of the people in the conservation and utilization of the forests; and the socio-economic development of the nation.

(f) Public awareness about the vital role of the forests in the will being and socio economic development of the nation.

According to the imperatives, the policy has focused on **the protection** of soils, water catchments, ecosystems, biodiversity, genetic resources, scenic reserves and national heritage sites, on the **sustainable** forest management to ensure in perpetuity the level of benefits both tangible and intangible for the present and future generations, on **providing the basic needs** such as fuel, water, fodder, shelter, food and recreation, on the **efficiency** in harnessing the full economic potential of and environmentally unacceptable side effects, on the people's **participation** in forestry, wildlife and nature conservation activities and in establishing plantations and increasing non farm incomes by applying community and agro forestry systems, and on raising **awareness** of the decision-maker and politicians in national socio-economic development, bio-diversity, soil and water conservation and environmental stability essential for sustained life on earth.

The forest policy aims at a balanced and complimentary land use, gazeting 30% of the total land area as reserved forest and 5% as protected area systems, encouraging participatory forestry, making EIA of development projects obligatory, intensification of silviculture and management, promotion of non-wood forest products and private investment in wood-based industry, encouraging down stream wood processing and use of under-utilized species, phasing out gradually of round log export, and strengthening forestry research, training and institution in both quantitative and qualitative terms.

The Burma Forest Act 1902, with amendment made from time to time, had been in use up till the new forest legislation, Forest law 1992, was promulgated by the State Law and Order Restoration Council in November 1992. The new forest law, in line with the Myanmar Forest Policy, focuses on the balanced approach towards conservation and development issues implicit in the concept of sustainable forestry. It decentralizes the management and opens up opportunities for increased private sector involvement in timber trade. Highlighting environmental and biodiversity conservation, the law encourages community forestry and people's participation in forest management to meet the basic needs of the rural people, but prescribes severe punishments for forest offences. In addition, the Ministry of Forest (MOF) has promulgated the Forest Rules in 1995.

In conformity with the new Forest Policy and Legislation, and for the purposes of gaining environmental stability and addressing basic needs of local communities, active participation by the rural population is urgently needed to plant trees in barren lands and to reforest degraded areas. To achieve these goals "Community Forestry Instructions" are issued by the Forest Departments prior to the formal enactment of the Community Forestry Rules.

The Community Forestry Instruction, 1995 is a comprehensive and liberal legal framework to promote community participation in forestry. It defines Community Forestry as the "reforestation of areas insufficient in wood fuel and other forest products for community use" and for the "planting of trees and extraction and utilization of forest products to obtain food supplies, consumer products and income" by local community participation. The features of the instructions are that existing reserved forest and government plantations can also be alienated as community forests; that procedures to apply for community forests are simple; that it is mandatory to prepare a management plan before handing over the forest to community: that certificates are issued by the Forest Department (FD) to the user groups; that substantial inputs are provided by FD; that responsibilities and duties of user groups are transparent; and that provision made for prohibitions, harvesting of forest products, pricing selling, taxation, and transportation are reasonable.

In order to promote and facilitate community participation in managing the forests, the Director-General of the FD had issued a significant statement of "Community Forestry Instructions" in late 1995, focusing on management of forests by rural communities through protection of natural vegetation, establishment of forest nurseries and *forest plantations so as to enable them to fulfill their own basic needs for firewood,* farm implements and small timbers. The Community Forestry Instruction *clearly* demonstrates the sharing of forest management responsibilities towards the rural communities through user groups' activities and efforts with in-kind and technical assistance from the FD. It also focuses on the flow of benefits to the communities, participating in forest management activities. The duration of lease of land for the establishment of Community Forest is set initially for 30 years and it is extendible depending on the performance and desire of the user's group.

As clarified by the major activities mentioned, forest resources of Myanmar are being managed towards sustainable development within the context of security of resource base, production, conservation of biodiversity, replenishment of renewable resources, and social and cultural dimension. Under-utilized or Less-used timber species are to be evaluated and introduced to both domestic and world markets. With regard to the promotion of less-used species utilization and markets, efforts are being undertaken in many ways, i.e. through research and development, activity programme and internationally funded projects.

So far, only teak and few hardwood species are harvested at commercial level and many of the non-teak hardwoods are virtually untapped from the point of commercialization. Even large tracts of bamboo resources are still poorly tapped for commercialization. Forestry sector is now providing enough room for the expansion of private sector and international entrepreneurship to fully utilize these under-tapped forest resources.

The deltaic and coastal mangroves are the important breeding grounds for aquatic species. They engaged fishing industries and provide the local people with food, shelter, small timber, fuel wood and other forest products. Myanmar has more than 2000 km coastal line and mangroves are found in three regions, namely Rakhine, Ayeyawady Delta and Taninthayi with coverage if some 785,00 ha of which 320,106 ha are reserved forest. These mangroves are primary source of biofuel, sawn timber, ports, and poles for local people. They also serve as essential breeding and feeding grounds for diverse species. However, due to over explorations of mangrove forests for firewood and subsistence forming, deforestation and degradation of mangroves have been taking place, particular like Ayeyawady delta and Rakhine.

As of 1999-2000, some 100,000 ha of mangrove forest have been given effective protection, about 10,203 ha of forest plantation were established, and more than 4454 ha of community owned multi-purpose plantations have been formed. In addition, 13,715 improved cooking stoves were distributed to save wood fuel consumption.

4.6.3 Suggested **Policies for the Promotion of Sustainable Development** in **the Forestry Sector**

The following suggested policies are proposed by the State:

(a)Forest Inventory

In order to ensure availability of up-to-date information on national forest cover, a forest inventory should be taken regularly; using satellite imagery, the geographical information system and aerial photography followed by statistically and biologically sound ground checks. The inventory must include, the location, topography, type of forests, tree species and, if possible, some parameters for estimating the age of trees so that the value of forest products can be appraised at the time of the inventory. Such data are valuable in checking whether or not illegal timber extraction is taking place.

(b) Forest Protection

Existing forests need to be guarded and protected from various forms of destruction, be it ecological or mechanical and especially from illegal loggers and poachers. Access routes by land or sea must be blocked and regularly checked.

(c) Securing high productivity from use of agricultural and forest land

Areas requiring urgent action to contain adverse impacts on forests include the adoption of improved technology to secure high productivity from agricultural and forest land, combined with a careful assessment of land potential to permit allocation for the most appropriate use. Investments in research, training and the dissemination of necessary technology are required to ensure optimum, together with adjustments in policy and planning in order to support implementation. A fundamental requirement is the awareness, commitment and full participation of the *de facto* decision-makers, i.e, the population and communities involved in forestry and agriculture.

(a) Social forestry

Apart from the long-term benefits of eco-restoration, including soil and water conservation, the immediate benefits of forestation are substantial in terms of generating employment and providing fuel and fodder. In addition to State and Division schemes for social forestry, the centrally sponsored schemes of social forestry such as the greening of nine districts in the central dry zone of Myanmar and village fuel wood plantations should be extended to cover all fuel wood deficit areas. Special attention should be given to the identification and propagation of indigenous, location-specific and thermal-efficient species that are acceptable to the people. Efforts must also be made to bring down the unit cost of afforestation and to secure wide participation by the population. Forest management should be made more sensitive the aspirations and needs of the public.

(b) Coordination and cooperation between the agricultural and forestry sectors

The agriculture and forestry sectors should coordinate and cooperate closely in various tasks including, proper land-use planning, construction of dams, watershed management and catchments area control, preventing siltation and sedimentation of reservoirs, coping with submerged trees in new irrigation projects and Sloping Agricultural Land Technology (SALT). SALT is an excellent example of where agriculture and forestry programmes combined symbiotically to form a replicable model. SALT is a well-known soil conservation-oriented farming system developed in the Philippines in the late 1970s. The agro forestry technology of SALT has gained Asian-wide popularity as a culturally appropriate, ecologically fit, economically sound and technically a cute development tool. SALT should be introduced as an effective substitute system in slash-and-burn areas. SALT technology will complement government policy on the development of border areas and ethnic groups as well as secure the border regions.

(c) Land-use Policy

Encroachment into tropical forest areas is the result of population pressure, which results in the need to expand agricultural land. The problem calls for a land use policy to oversee and coordinate overall land utilization in the country. It is necessary to prepare a land-use plan, which should ensure that land is used for the purpose for which it is best suited .The most important issue is to ensure that the total land area of Myanmar is used prudently and effectively as that will ultimately lead to socio-economic development in an environmentally friendly way.

(d) Shifting cultivation

The problem of shifting cultivation has long been a focus of attention among administrators, foresters, agronomists and diverse specialists. With the application of SALT, about 2 million roving farm families who cultivate an area of about 2,430,000 ha, which mainly comprises un-classed and degraded forestland, can settle down in locations of their choice. Through SALT they can enjoy farm produce as well as forest products. However, the rapidly growing population has resulted in a major increase in the frequency with which shifting cultivation blocks are being cultivated that has led to changes in the vegetation. Consequently, serious efforts should be made to establish a well-defined tenure system to serve as an incentive for shifting cultivators to improve the productivity of the land. All available means should be employed through education and training of fanners to promote the use of permanent and modern agricultural systems (Thein, M, 1998).

4.7 Two Sustainable Initiatives

4.7.1 Development of Ayeyawady Mangrove Project

Due to the serious and alarming effects of depletion of mangroves, which constituted about 46% of Myanmar mangrove resources, the Government of Myanmar requested international assistance to redress the growing wood fuel supply demand imbalance in the Ayeyawady delta and to develop the planting technology needed to rehabilitate degraded and denuded areas to conserve the mangrove environment and enhance its protective and productive functions. The Mangrove Reforestation Project

(MYA/90/003) was carried out from March 1991 to December 1993. The continuation of the project, the community Development of Ayeyawady Mangrove project (MYA1931 026) was from February 1994 to December 1995. Community Development of Ayeyawady Mangroves was continued for three years (1996 to 1998) as Project (MYA/99/008) adding a new Township Maulamyaing Kyun to the original Bogalay and Latputta Townships. All three Townships are considered most critical for rehabilitation of the Ayeyawady Mangroves.

The objective of the development project is to promote sustainable human development by improving the socio- economic welfare of disadvantaged communities in critical areas in the coastal Ayeyawady delta, through mangrove environmental regeneration, protection, improved fisheries, income generation and sufficiency in wood fuel and wood products. The **three immediate objectives** of the project are:(l) strengthening rural capacity in planning and implementing mangrove protection and conservation to improve sustainable fisheries and wood fuel supplies;(2) improving mangrove protection conservation, wood fuel supply demand balance and estuarine fisheries in selected villages to achieve sustainable supply- demand balance; and (3) improving rural capacity to undertake and manage income generating activities based on mangrove land and water resources.

Villages practicing mainly agriculture, forestry, fishery and a combination of these were selected as project villages. Community development works were emphasized in these villages. Sixteen villages from eight village tracts were selected in Latputta Township. Thirty -two villages from eight village tracts were selected for Bogalay Township, totaling forty- eight project villages altogether. In Bogalay Township, mainly agricultural villages were located as a cluster very close to town.

The immediate Project Activities are: (1) 2400 acres of mangrove plantations in the forest reserves, 1000 acres of mangrove forests to be naturally improved by RTF (Regeneration Improvement Felling) method, (3) Development of village owned woodlots(community), (4) Environmental protection plantings to be introduced, (5) At least 20,000 acres to be allotted for future RIF operations.

Forest Resource and Environmental Development Association (FREDA), with the financial assistance of Action for Mangrove Reforestation, Japan (ACTMANG), and Japan International Cooperation Agency (JICA) had launched a programme to reafforest 500 ha of Mangrove plantations within 5 years (1999-2003) in the southern portion of Pyindaye reserve forest, Bogalay Township. Concerned efforts of FREDA project staff in collaboration with the FD of Bogalay Township and the community participation enabled them to establish 346 ha of mangrove plantation up to July 2001. The project, thus, comes to 4 years instead of 5(1999-2002).

During the year 1999, FREDA has purchased several thousand seedlings (about 150.000) from the FD nursery at Byonhmwe for planting of 130 acres (52.5 ha). However, during the year 2000, adequate number of seedlings could be produced from Oakpo- kwinchaung for planting of 350 acres (141.5 ha). In 2001, both Oakpo-kwinchaung and Wagon nurseries have capacity to produce 720,000 seedlings to plant 375 acres (152ha). FREDA is now establishing 2 more nurseries one at Kanyingon and the other at Khakyin, so as to save time for transporting seedlings to the planting sites in the year 2000. Out of 350 acres in 2000 and 375 acres (year 2001) of plantations area the Regeneration Improvement Felling (RIF) areas of 75 acres and 100 areas is included (see Table 4.11.a). The RIF operations is carried out to improve the degraded natural mangroves were regenerated and promising seedling and sapling growth need to be released from the over head cover. Enrichment planting is carried out in the gaps in the RIF areas. Total plantation including enrichment planting and RIF areas for 3 years are presented in the Table 4.11.a and Plantation Establishment in 2002 is shown in table 4.1 l.b).

Table 4.11.a Plantation Establishment during 3 years

Sr.No	Year	Plantation area(acres)	RIF area (acres)	Total area(acres)	Remarks
1	1999	130	-	130	
2	2000	275	75	350	Included 50% enrichment
3	2001	275	100	375	Planting in the RIF areas
		680	175	855	

Source: Ohn.U, Mangrove Project, 2002.

Table 4.11.b Plantation Establishment in the year 2002

Sr. No	Name of village	User group members	Planting area in acres	Natural RIF area in acres	Total area in acres
1	Oakpo-kwin Chaung	35	25		25
2	Tebin Seik	18	25	-	25
3	Wagon	42	30	20	50
4	Kanyingon	71	120	30	150
5	Khakyin	22	40	10	50
6	Kywe Te	38	30	20	50
7	Ma HmweKwin	27	30	20	50
	Total	253	300	100	400

Source: Ohn, U, Mangrove Project,2002.

Not only the reforestation of mangroves, the study on marine life and their relationship with mangrove system is already started and local cottage industry level livestock farming, environmentally friendly fish and prawn culture, charcoal burning and wood vinegar collection, sewing and weaving for the women and handicraft making from various mangrove species are the future development programmes in the project area.

ACTMANG also distributed nitrogen fixing and soil improving plant species to improve the unproductive and abandoned fallow lands to become productive again.

Project personnel in collaboration with the ACTMANG team are conducting several research programmes such as soil and water quality analysis, relationship between mangrove and marine life, and the community development and participation in restoring mangrove ecosystem(Htein Lin, "Saving the Mangroves in the Ayeyawady Delta", **The Late Friday** News,98th edition, 2002).

4.7.2 Desertification and the Dry Zone Greening project

In Myanmar due to its better rainfall, desertification is a recent problem and is localized to the Central Dry Zone Area. This area is a region affected by droughts in the last few decades and combined with loss of vegetation cover; the conditions are ripe for the spread of desertification. To counter the threat of desertification the Dry Zone Greening project was initiated.

Even before Myanmar became a party to the United Nations Convention to Combat Desertification (UNCCD), greening of the arid zone has always occupied a place of priority in Myanmar environmental protection endeavours. After Myanmar became a party to the Convention, these efforts have been further enhanced with the establishment of the Dry Zone Greening Department in 1997. This department together with the Myanmar Agriculture Service, Irrigation Department and Water Resources Utilization Department of the Ministry of Agriculture and Irrigation act as the principal implementing agencies.

Among the measures taken by the Government to combat desertification, "Greening Project for the Dry Zone" is significant and most effective. The Greening Project is being implemented by the Dry Zone Greening Department. The Dry Zone Greening Department was entrusted with the following objectives:

(1) To green the Central Dry Zone of Myanmar;

(2) To protect and conserve the environment as a whole, and land and water resources in particular;

(3) To provide the basic needs for forest products of the rural people;

(4) To enhance the socio-economic development of rural people on a sustainable basis;

(5) To raise local people's awareness of the value and beneficial effects of forest and trees;

(6) To enhance knowledge and promote participation of the public on environmental conservation and sustainable development;

(7) To improve micro-climate conditions of the environment so as to support sustainable productivity of agriculture; and

(8) To prevent desertification.

There were major four main tasks to be implemented, which had been set up by the Dry Zone Greening Department: (a) Establishment of forest plantations; (b) Protection and rehabilitation of remaining natural forests; (c) Initiating development and utilization of wood fuel substitutes; and (d) Development of water resources.

(a) Establishment of Forest Plantations

Prior to DZGD, the Forest Department has been establishing forest plantations in deforested areas to restore forest cover and to rehabilitate environment. Up to 1997/98, a total of 72,210 acres (29,233 ha) had been planted under the Nine Districts Greening project. In 1998/99, DZGD planted a total of 35,287 acres (14,280 ha) comprising 18,280acres (7,398 ha) of village forests, 8,920 acres (3,610 ha) of watershed plantations, 2900 acres (1,174 ha) to green mountains, 137 acres (55 ha) for research purpose and 5050 acres (2,044 ha) of wood lots.

In 1999/2000, DZGD planted a total of 35040 acres comprising 13,257 acres of village forest, 14,700 acres of watershed plantations, 2,700 acres to green mountains, 133 acres for research purpose and 4,250 acres of wood lots. (Reports, DZGD, 2000).

(b) Protection of Natural Forests

About 1.82 million acres of degraded forests and about 2.8 million acres of forest affected by shifting cultivation have been identified as existing in the Dry Zone. Protection against human, cattle and fire has been found to be very effective in improving degraded forests. Degraded forests considered to be capable of improving naturally are, therefore, identified, demarcated and protected. Constant patrols are being made by forest guards permanently stationed along the borders. Silvicultural treatments such as weeding, cleaning, climber cutting, thinning and coppicing are provided where necessary, in order to accelerate natural growth while fire lines and inspection path are constructed for efficient fire prevention. Of these, priority areas are identified and a total of 100, 000 acres of natural forests had been specially protected each year since 1997/98. In addition, approximately 1.8 million acres (1.09 ha) of degraded forests have been earmarked for conversion to closed forests by natural means during the 30years of the Master plan.

(b)Initiating Development and Utilization of Wood Fuel Substitutes

Wood Fuel consumption is one of the main causes of deforestation, and excessive cutting of trees for firewood before they are fully grown, leads to the loss of growth potential of the forest stands. In most developing nations more than 80%of wood extracted are being used for fuel. In Myanmar too, illegal extraction of trees for firewood and charcoal has been a major cause of deforestation and forest degradation.

Therefore, Forest Department had launched fuel wood substitution programme to reduce pressure on the utilization of wood for fuel. The DZGD since its creation in 1997 had distributed some 100, 000 efficient cooking stoves and 9.2 million numbers of briquettes (7.4 million kg), and the use of 45, 000 metric tons of agricultural residues by villagers in the dry zone was also recorded over the same period. Distribution of efficient cooking stoves and briquettes and the use of agricultural residues in place of fuel wood were found to have surpassed the targets adopted by DZGD for the years 1997/98 and 1998/99. In support of forest protection and conservation, wood fuel substitution has been identified as a main task of the DZGD. Three activities have been carried out as follows:

(i) Distribution of fuel efficient stoves

Total numbers of 94628 A-l cooking stoves were distributed in 1998/99.About 40, 500numbers of A-l cooking stoves are to be distributed in 1999/2000and all the necessary arrangements have been undertaken.

(ii) Promotion of fuel briquette production and utilization

In 1998/99, 8.35 million fuel briquettes were distributed for wood fuel substitute activities. Fuel briquette mills would be set up in Sagaing township of Sagaing Division and Yezin of Mandalay Division for mass production of fuel briquettes. It is targeted to distribute about 7-million fuel wood substitute inl999/2000.

(iii) Utilization of agricultural residues

To promote wood fuel substitutions, utilization of residues of agricultural crops such as stalks of sesame, pea, cotton, peanut husks and etc, are to be encouraged. In 1998/99 nearly 34, 000 tons of agricultural residues were used as fuel. It is targeted to use 14,000 tons of agricultural residues as fuel in 1999/2000.

(d) Water resources development

Rains fall only in a few days annually and water is very scarce in the Dry Zone. This constitutes the biggest obstacle to green the Dry Zone. It is thus imperative to construct check dams and ponds to collect rainwater, and to tap underground and river waters by pumping in order to assist greening activities and the local needs.

In 1998/99, the DZGD has been able to construct 170 ponds and 12 tube wells. The biggest success in water resource development is the success in implementing Tant-Kyee Taung water distribution programme. Under this programme water from the Ayeyawady River is pumped to the top of the mountain, which is 1, 024feet above sea level and about 6980 feet away from the river. The main objective of this programme is to help reforest the very degraded and steep sacred mountain. In 1999/2000, it is targeted to construct 170 ponds, 5-tube wells andl71 check dams by the DZGD. (National Report of Myanmar on UNCCD)

4.8 Summary

In contrast to many other countries, Myanmar has experienced less environmental degradation and pollution problems. However, the country faces some local environmental issues arising mainly from underdevelopment and poverty.

Firstly, there is the problem of deforestation. In Myanmar, more than 90 percent of renewable energy consumption depends upon forest resources. Few rural homes in Myanmar have supply of gas or electricity, thus, there is a heavy reliance on wood fuel resulting in depletion of forest cover. During the 14 years period from 1975 to 1989, the total forest cover had been reduced at a rate of 115100 ha per year. Deforestation is also due to shifting cultivation, which is practiced by about 2.6 million people mostly, living in the hilly areas covering about 142,000 hectares. Most of the shifting cultivators are unaware of the damage caused to the environment by their traditional farming system. But, unavoidably, the hilly region people still have to rely on the shifting cultivation because it is the only way of cultivation, which can be done to grow the staple crops on the mountainous woodland. The problem of deforestation is very serious in two regions. The first one is Central dry Zone of Myanmar. Due to high population and very low rainfall, the area is very seriously affected and sustainable agriculture is faced with problems of land degradation and desertification. For this reason, government is supporting new initiatives for rehabilitation and reforestation in this area through the Dry Zone Greening project. The second region that needs attention is the Mangrove forest area of the Ayeyawady Delta. In this area the deforestation is high and entire mangrove forests were wiped out within two decades (Myint, 1995a). UNDP/FAO is operating in the area through community development programs to save the mangroves. (Myint, 1995b).

Secondly, there is a problem concerning loss of biological resources. Wildlife in Myanmar is presently being threatened and endangered as a result of habitat loss, hunting and poaching. It is estimated that there are 34 endangered species including 11 reptiles, 4 birds and 19 mammal species.

Thirdly, is the problem of pollution. However, currently the extent of industrial pollution and accompanying environmental degradation is rather localized. The degree of air and water pollution caused by industry or agriculture has been minimal due to the low level of industrialization and relatively small amount of chemicals used in agriculture. The data on sources of inland water pollution as well as data on air pollution and air quality are not available. There are no air pollution and air-quality monitoring stations and automobile exhaust monitoring stations in Myanmar. However, pollution from vehicles is also not significant and to at present Myanmar has not encountered serious problems concerning marine pollution. Indoor air pollution may exist but the danger has not been fully recognized. Surface waters to which people have access are sometimes found to be contaminated with fecal matters. Waste matter mainly due to unprotected wellheads and lack of drainage can also contaminate hand-dug wells. Ground water can also be affected by solid and liquid waste dumped onto ground.

Fourthly, land degradation through wind and water erosion is also found to have occurred in areas where deforestation has taken place. Soil erosion is especially found in the barren plains where the topsoils are blown away by wind. Water erosion also occurs along the slopes of denuded hills when heavy rains wash down the topsoils. The arid zone in central Myanmar is prone to wind erosion. The Central Dry Zone areas have relatively less trees and vegetation due to low rainfall. Indiscriminate felling of trees for wood fuel has aggravated the situation. With regard to national disasters, the occurrence of earthquakes, landslides, and famine due to droughts are negligible in Myanmar. Though there are cyclones and floods during the monsoon months, their occurrence is neither frequent nor devastating.

Finally, according to the assessment, the yield of teak, at current yield 4000 thousand m3 would have be supplemented in 2003(Myint, 1981, Tint & et al, 1993). In the case of other species, the yield from natural forests would be substantial and the plantation yield would be lesser than the yield of natural forests. Because the natural forests are inaccessible and the extraction is not possible and expensive. Plantations are very accessible and the final crop yields can be very economically important. Teak yield reduction in Myanmar is due to over exploitation especially in accessible areas. This can be recovered by providing rest period and proper silviculture operation. It is to be noted that plantation yields can be very high quantatively and economically. More emphasis should be given to the plantations with the higher investment. Sustainable forest management needs to account for the environmental services of the forests; only emphasizing the timber or non-timber forest at a sustained basis is not adequate. With the population growth and development, priority should be given to the conservation and sustainable management of the forest resources at both national and regional level.

CHAPTER-V

ENVIRONMENTAL DEGRADATION: THE ROLE OF WOOD FUEL USE IN TWO SELECTED RAINFALL REGIME REGIONS

5.1 Geographical Characteristics and rainfall variability in the Dry Zone and Ayeyawady Delta Region

The **Dry Zone** comprises Lower Sagaing, Mandalay and Magway Divisions. There are altogether 13 districts and 57 townships in the Dry Zone with a population of 14.2 million. The Dry Zone has an area of about 21,000 square miles (54,390 square kilo meters) or about 10 per cent of the country. The Dry Zone is thus a vast semi-arid low land between two higher regions, the Shan plateau on the East and the Rakhine Yoma and Chin hills on the West. These higher regions provide sharp geographical boundaries as well as climatic boundaries of the Dry Zone. Two major rivers, the Ayeyawady and the Chindwin flow through the Dry Zone from North to South connecting it to the Deltaic region in the South. The hills in the Dry Zone with the exception of Mount Popa are low (about 1000 feet high). They serve as local watersheds. Most of the local streams have water only immediately after the rain.

Except for the Dry Zone area, there is sufficient rainfall in Myanmar during the rainy season that extends from May to late October. The weather of Dry Zone is generally dry in the rest of the year. The coastal regions, the delta region and the northern part of the country receive an annual rainfall of about 5000 mm. The Rakhine mountain range in the west of the country obstructs the path of the southwest monsoon causing a rain shadow area in the central Dry Zone of Myanmar.

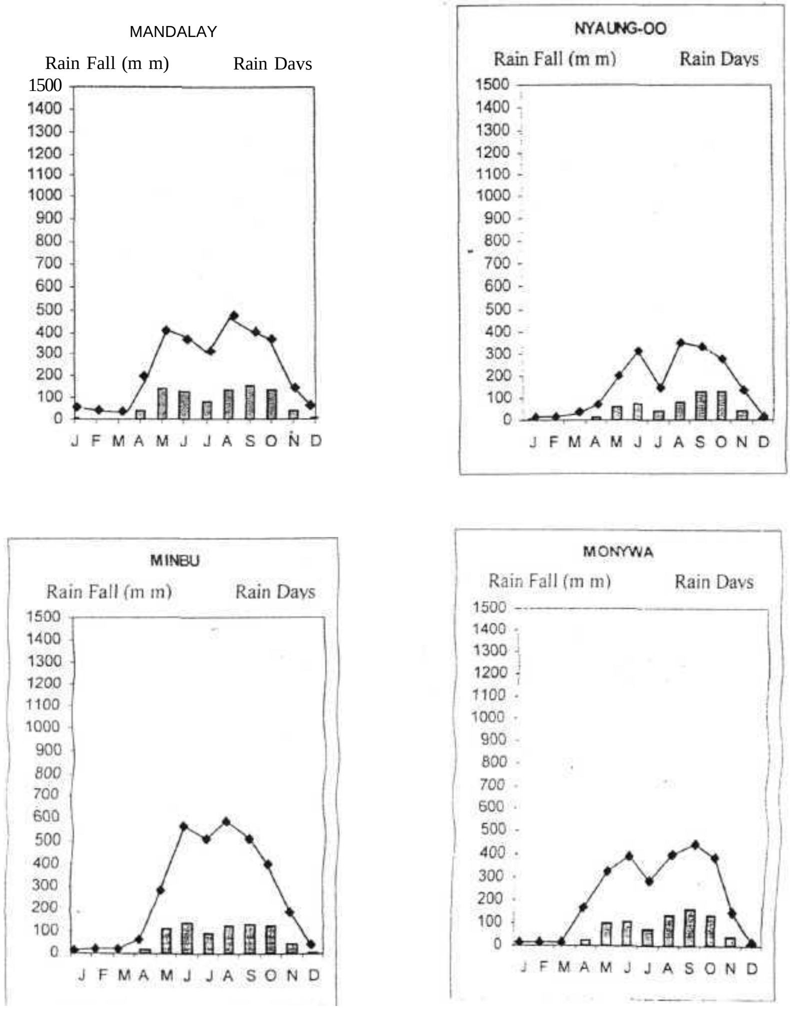
The Dry Zone area or the central part of Myanmar had been dry with low precipitation for many years. Its average annual rainfall is only 28.44 inches (722 mm), or about 31 per cent of 92.6 inches (2353 mm), which is the average annual rainfall of the whole country. The Dry Zone is characterized by less than 1000 mm of rainfall annually; less than in other parts of Myanmar and in the central part of

Myanmar it is less than 600 mm. The Dry Zone area is especially different from the other regions in the country in terms of dryness and hot weather conditions. Generally, the highest temperature is about 110" F (43' C) in March and April and the lowest temperature is only 46.1' F (8"C) in January. Humidity ranges from 42% in March and April to 80% in September with an average of about 63%. Although the average mean temperature is about 27' C, the temperature often rises to above 40' C in the hot season. As the Potential Evapo-Transpiration (PET) in the area is about twice of the annual rainfall, the ratio of annual rainfall or precipitation to potential evapo-transpiration falls within the range of 0.05 to 0.65 as specified in the United Nation Convention to Combat Desertification in Myanmar.

According to the distribution of rainfall pattern over central Myanmar, the isohyets prevail as concentric ellipse contouring around the confluence of the Ayeyawady and Chindwin. The Dry Zone of Myanmar is bounded by the 1000mm (39.37in) of annual rainfall. From the Dry Zone rainfall gradually increase towards all directions. The inner most core area experiences mean annual rainfall less than 600 mm (see fig 5.1), and is confined to Pakokku, Nyaung Oo and Myingyan districts, which are the hottest places in Myanmar. Regarding the seasonal rainfall pattern, Central Dry Zone falls into the double maximum or Bi-modal pattern, as the monthly rainfall values are high twice, or it can be found that rainfalls are high in two months, either (May or June) or August or September). In July mostly the monsoon break will occur (see fig 5.2).

Annual rainfall is most variable in dry areas. When annual rainfall is analyzed for the whole country, it can be seen that the variation of annual rainfall is highest in the core area of Dry Zone with the coefficient of variation more than 25%, for example, the coefficient of variation for Minbu, (Magway Division) is 28.10%, for Monywa (Sagaing Division) is 26.53%, and for Nyaung-Oo (Mandalay Division) is 27.64% and decreases towards all directions from this core.

The Dry Zone soils are generally poor and degraded due to very limited precipitation and a high evaporation rate. The soil textures are mostly sandy loam and loamy sand, which are unable to retain moisture and maintain the nutrients because of



g. 5.1 Some Bi-moda! pattern of rainfall stations in Dry Zone of Myanmar

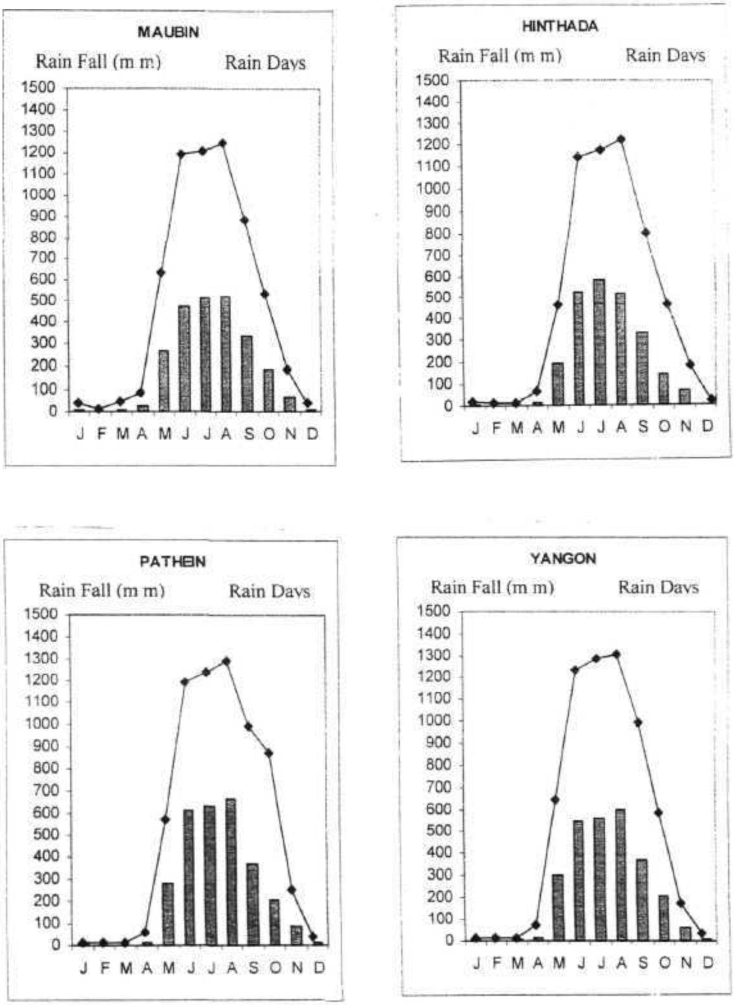
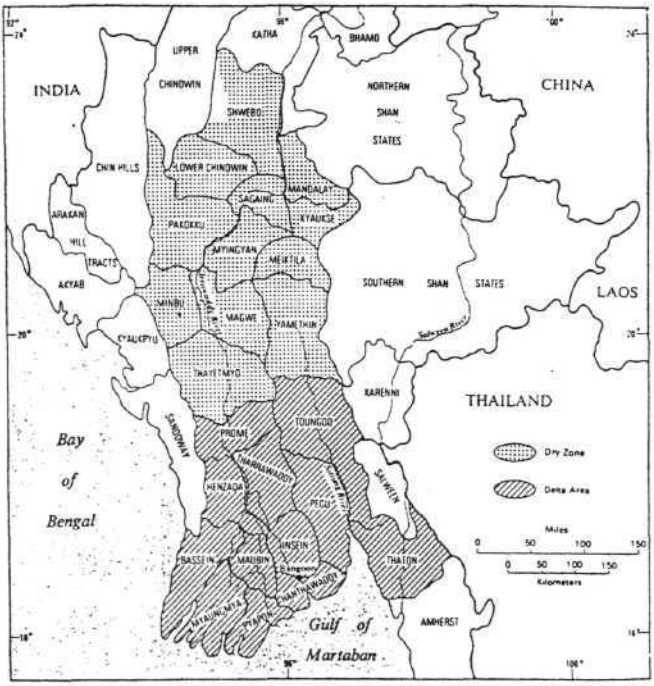


Fig.5.2 Some Uni-modal pattern of rainfall stations in Ayeyawady Delta region



Source: Adas, 1974,

Figure(5.3) Map showing Dry Zone Area and Deltas Region of Myanmar intense rain and poor water holding capacity. The nutrient levels are not sufficient even for the minimum requirement of plant growth. The soil water deficit in the Dry Zone as a whole and in Lower Sagaing usually occurs during December to July. In Magway Division, the soil water deficit period is slightly shorter-December to May, while Mandalay normally has to face the longest soil water deficit period November to August. Sheet and gully erosion have also reduced the productivity of the soil. Land degradation is the most serious problem of this area. As mentioned previously, there are two agriculturally important soil types in this area, namely luvisols, vertisols. Both soils are subjected to land degradation of one form or another. The luvisols, which occupy the upper periphery and rolling and undulating topography, with light texture and loose structure, suffer from both wind and water erosion. The luvisols are completely devoid of organic matter for cementing soil particles, which are easily blown away during summer windstorms. Water erosion damages soil with gentle slopes on rolling and undulating topography during the rainy season. Therefore, coarse layers are exposed in most of the luvisols of this region, negatively affecting the crop production.

On the other hand, the heavy clay low land vertisols are affected by salinity and acidicity due to saline irrigation water on one hand and bad drainage and salt accumulation by the water flow down from the upper periphery, on the other hand. In this way the soils are identified as Low Potential Production Area (LPPA) or arid and semi-arid area and are degrading due to the reduction in soil depth, fertility, moisture holding capacity and productivity. Genetic erosion in these areas has occurred but no statistics are available to present the facts and figures. However, circumstantial evidence indicates that there were woodlands in this area, which were a sanctuary for endemic flora and fauna.

The Dry Zone is one of the distinct natural regions of Myanmar as a resource poor area. Based on mean annual precipitation, 22 out of 26 townships in Mandalay Division, 18 out of 25 townships in Magway Division and 18 out of 34 townships in Sagaing Division are classified as being in the Dry Zone. The zone covers approximately 677,000 sq.km or (17 per cent) of the total land area. The present population of the three Divisions is estimated at 14.2 million, and this places a heavy

Monkey point. The lower part of Ngamoyeik chaung is called the Pazundaung creek. The Bago River, which rises in the Bago Yoma, enters the Division from the east and flows into the Yangon River near Thanlyin.

The average rainfall for Yangon is over 260 mm, and the average annual temperature is 25 C. The hottest months are March, April, and May with the average temperatures around 29.5'C. The coolest month is January with an average temperature of 25 C. The number of rain days for Yangon is about 125 days a year. The climate is hot and wet enough for tropical rain forests but most of these have been cleared for cultivation of rice and other crops. Thus, the lower alluvial lands are almost entirely cultivated, and the most important crop is rice. The delta is, thus, formed as the rice bowl of Myanmar.

The Ayeyawady Delta experiences the Monsoon climate, receives heavy rainfall, with annual rainfall more than 80 inches (2000mm) that decreases northward. The delta is almost composed of alluvium, except Twante and Myaungmya districts. Like the rest of the country, the climate of Ayeyawady division is the tropical monsoon type with well-defined wet and dry seasons.

According to the seasonal rainfall distribution pattern, Ayeyawady delta region is included in the group of July maximum. During the three months of June, July and August delta region receives more than 500 mm at Bago, Pathein, Yangon, Hmawby, Hinthada, and Maubin. Among these three months, the rainfall variations at Pathein, Yangon, Hmawby, and Maubin are not significant whereas the others are fairly considerable.

5.2 Environmental Problems of Dry Zone and Ayeyawady Delta Region

5.2.1 Land degradation

The original vegetation of **Central Dry Zone** is described as Savanna woodland that consists of short deciduous trees often widely spaced and a ground flora composed of different species of grass. Over the years, much of the natural vegetation in the Dry Zone has diminished and the land has gradually become degraded due to cutting for shifting cultivation and wood fuel. This adversely affects both natural and artificial forest regeneration. Consequently, the people in the Dry Zone are now facing wood fuel shortages and the high wood fuel prices are making it difficult for them to meet their daily requirements. As a result of increased population, shifting cultivation, Wood fuel extraction and other human activities, very little of the original natural vegetation remains and- a degraded form of trees were found in many places of the Dry Zone.

Land degradation is the most serious problem of this area. As mentioned earlier, there are two agriculturally important soil types in Dry Zone, namely luvisols, vertisols. Both soils are subjected to land degradation of one form or another. The luvisols, which occupy the upper periphery and rolling and undulating topography, with light texture and loose structure, suffer from both wind and water erosion. The luvisols are completely devoid of organic matter for cementing soil particles, which are easily blown away during summer windstorms. Water erosion damages soil with gentle slopes on rolling and undulating topography during the rainy season. Therefore, coarse layers are exposed in most of the luvisols of this region, negatively affecting the crop production.

On the other hand, the heavy clay low land vertisols are affected by salinity and acidity due to saline and sodic irrigation water on one hand and bad drainage and salt accumulation by the water flow down from the upper periphery, on the other hand. In this way the soils of Dry Zone are degrading due to the reduction in soil depth, fertility, moisture holding capacity and productivity. Genetic erosion in this area is occurred but no statistics are available to present the facts and figures. However, circumstantial evidence indicates that there were woodlands in this area, which were a sanctuary for endemic flora and fauna.

Land degradation in the Myanmar Dry Zone is becoming a matter of serious concern for its negative implications on the livelihood of the rural population and the environment on which they largely depend. An increasing population in combination with unfriendly climatic conditions triggers the rapid misuse of the land and over-exploitation of natural resources. As a consequence, soil erosion by water and by wind and the progressive removal of the vegetative cover are becoming common features observable in many parts of the Dry Zone. Therefore, land degradation is a most dangerous form of negative ecological process, taking gradually irreversible forms as the process advances and accelerates.

Land degradation, however, is not only confined to the Dry Zone. It is also a severe problem in the Southern part of the Ayeyawady Delta where valuable mangrove forests are being degraded and some inhabitant species are in danger to be depleted. Accordingly, a preventive measure ecosystem management of mangrove area is being made with the co-operation of UNDP as well as National and International NGOs. Water logging and flooding are two major problems affecting the sustainable agricultural development of this area .The Delta is often hit by the annual tropical storms, especially in the coastal and delta region. Inadequate draining systems and silted waterways due to the soil erosion of the upper low potential production area make this low land area waterlogged and inundated. Delay in sowing of crops due to water logging, in undulation and annual flooding reduces due to the water logging, inundulation and annual flooding reduces the crop yields considerably. In some areas, no crops can be grown at all during the rainy season due to the stagnation of water. Water logging and flooding not only reduces agricultural activities, but also cause the spread of water borne diseases among the population of the surrounding areas. The average of surface water irrigation in this area is negligible and there is no ground water irrigation here. Therefore, there are no dangers of acidicity and ground water salinization in delta region. But salinization due to flooding and seawater encroachment is a problem in this area. Many areas along the coastal regions and low-lying delta regions are subjected to annual tidal water encroachment - causing soil salinization. Severity of the salinity is not very pronounced during the rainy season in which rather salt tolerant rice crops are grown. The salinity effects appear greater after the rain stops, and a second crop is almost impossible in this salt affected area.

5.2.2 Desertification

The main area affected by desertification and drought is the Dry Zone in the central part of the country. According to mean annual rainfall of less than 1000 mm, about 10 percent of the total area of the country can be identified as the Dry Zone. However, the total area of Sagaing, Mandalay and Magway Divisions and their population in 1997/98 were approximately 26 percent and 34 percent respectively of the country total.

According to characteristics of identified drought using rainfall series, the worse droughts that hit the area were during 1979 andl980. The second worse drought that hit Lower Sagaing and Mandalay (but not Magway) took place during 1982 and 1983. The third worse drought hit the whole area of the Dry Zone during 1993 and 1994. Droughts of equal magnitude also hit lower Sagaing Division during 1969 and 1970, and Mandalay and Magway Divisions during 1994 and 1995. Except for the interval between the second and third worse droughts of some 10 years, recurrence of droughts in the Dry Zone seems to be showing up at shorter intervals.

The Dry Zone is characterized by less than 1000 mm of rainfall annually (less than in other parts of Myanmar). The area shrinks in wet years and expands dramatically, especially northward and southward, in dry years. The central core (dry) area is confined to Pakokku, Nyaung Oo and Myingyan districts which are the hottest places in Myanmar and where the mean annual rainfall is less than 600 mm. Annual mean rainfall as well as mean rainy days over the dry zone during the last three decades (1968 to 1997) clearly indicates a declining trend. The Dry Zone is prone to droughts. As the Potential Evapo-Transpiration (PET) in the area is about twice the annual rainfall, the ratio of annual rainfall or precipitation to Potential Evapo-Transpiration falls within the range of 0.05 to 0.65 as specified in the United Convention to Combat Desertification in Myanmar.

The soil water deficit in the dry zone as a whole and in Lower Sagaing usually occurs during December to July. In Magway Division, the soil water deficit period is slightly shorter-December to May, while Mandalay normally has to face the longest soil water deficit period - November to August.

Farm households in this area are constrained by low and unreliable rainfall, thin soils, and denuded ground and forest cover. The majority of them, possessing smallholdings, are subsistence farmers. They grow cash crops such as cotton, sesame, pulses and beans, although there is also some rain-fed rice cultivation, mostly for own consumption. Seasonal vegetables such as onions, garlic, chilies, and tomatoes are also grown on alluvial soils. They practice mixed and multiple cropping system as well as crop rotation in order to reduce crop losses and retain soil fertility. Poorer farm families and agricultural labourers supplement their incomes by cutting wood fuel or making jaggery both of which have contributed to over exploitation of forest resources and deforestation.

According to the assessment of change of forest conducted in 1990, the actual forest area had decreased at an annual rate of 220,000 ha or 0.64 percent of the actual forested area of Myanmar during a period of 14 years from 1975 to 1989. Forest Department data also revealed the annual deforestation rate in Sagaing, Mandalay and Magway Divisions to be 0.68%, 1.48% and 4.07% respectively. Table (5.1) shows the areas of the degraded forest and forests affected by shifting cultivation were 181,842 acres (18.4%) and (2,804,174) acres (13.0 %) of total area (21,557,459) acres of Dry Zone. These areas were more than the closed forest area 4,250,596 acres. Clearly, deforestation in the Dry Zone, especially in the more heavily and densely populated Divisions of Mandalay and Magway is more serious than the national average. Table (5.1) shows different types of land use categories in the administrative area of the Dry Zone.

The Dry Zone is still one of the most important agricultural areas in Myanmar. There is still over 55 percent of fairly productive land for agriculture (Table 5.1). Most of the crops grown in this region are typical "Ya"(dry farming) crops such as cotton, maize, pulses, millet, groundnut, sesame, and so on. Although there is some rain-fed rice cultivation, multi-crop cultivation is the traditional farming system in this area.

burden on the lean resources and fragile environment of the zone. With an average population density of 99 persons per sq. km, it is the third most densely populated region in Myanmar. Water is scarce; vegetation cover is thin and soil erosion severe. The region is characterized by low annual rainfall ranging between 20 and 40 inches, with high variability and uneven distribution. The undulating land, composed mainly of clay and sandy loams with natural low fertility, is subjected to severe erosion under rain and strong winds. Such an environment, with its natural limiting factors has led to severe environmental degradation. With declining inputs, both in terms of organic and inorganic materials, agricultural productivity is decreasing annually. Compounded by increasing population pressure, high competition for naturally thin vegetation and tree cover (for fuel wood and livestock fodder), the region is suffering rapid environmental degradation.

Ayeyawady Delta is located in the southern part of Myanmar and is the largest rice producing region in the country, contributing 37% of total national production. Ayeyawady delta region comprises the most important part of Myanmar. It consists of the broad valley of the lower course of Ayeyawady and its large delta and the narrower valley of the Sittoung and its delta. Separating these two alluvial plains is the low range of the Bago Yoma, covered with valuable forests.

It consists of the broad valley of the lower course of the Ayeyawady its large delta, and the narrower valley of the Sittaung and the much smaller Sittaung delta. Separating these two alluvial plains is the low range of the Bago Yoma, covered with valuable deciduous forests. Yangon is situated at the southern end of the Bago Yoma, and so commands both valleys. The rainfall is good, over most of the true delta it is more than 80 inches (2,000 mm.), but decreases northwards. At the southern end of the Bago Yoma evergreen forest is found, but farther north is Monsoon forest of teak, pyinkado, and other valuable trees. It is the nearness of these forests to Rangoon and the sea, which had made them especially important. The lower alluvial lands are almost entirely cultivated, and by far the most important crop is rice. All other crops are of little importance. This part of Myanmar is thickly populated except in the forests. The cultivators are mostly Bamars, but there are many Kayins also who have settled in the delta. The towns of the region are mostly collecting centers for rice-examples are Hinthada, Pathein, Maubin, and Bago. Notice how well Yangon is situated, so that it can collect the produce of nearly all parts of Myanmar and send it to foreign countries.

The topography of the area is characterized by gentle rolling plains, which can be divided into deep-water, lower, and upper terrace. The differences in slopes between the upper and lower terraces however vary by only about 5 to 10 percent. Most of the government's new irrigation infrastructure was established in these areas. The Ayeyawady delta consists of interminable and fertile plain, which is 180 miles long and 150 miles wide. The Delta of Ayeyawady is gradually extending seawards and the gulf of Mottama is slowly silting up and getting shallower, that the land is gaining on the sea. Most of the delta area falls under the present Ayeyawady Division, Yangon Division, and Bago Division. The Delta is comprised of Pyay, Toungoo, Thayawady, Bago, Hinthada, Pathein, Pyapon, Myaungmya, Hanthawady, Maubin, Hanthawady, Insein, and Thaton Districts.

Yangon Division is in the eastern part of the Delta region and has been built up mostly from recent alluvium and other sedimentary rocks, especially sandstone. The Bago Yoma, as it continues southwards enters this Division reaching as far as Yangon. A low laterite ridge is found and the hill on which the Shwedagon pagoda stands is regarded as part of this ridge. The continuation of this ridge is found again across the river in Thanlyin. There are also some spurs of the Bago Yoma on either side of Ngamoyeik chaung. The landscaspe within Yangon and its surburb is undulating. Names of Myenigon, Shinsawpu gon, Gyopyu and Mahlwa gon indicate areas slightly higher than the rest.

There are three rivers within the Division and all three flow into one main river, which enters the sea just south of Yangon. The first is the Myintmakha, further south it is joined by Panhlaing on its right bank, as it continues southwards, the Bawle joins the Hlaing River which is flowing in the same direction in the east, and the river thus formed is known as the Hlaing or the Yangon River. The Ngamoyeik has its source in the Bago Yoma and flows southward to enter the Yangon River near

Table (5.1) Land use categories in the administrative area of the Dry Zone

Forest Category	Area (acres)	Area (sq.miles)	(%)of total
Closed forests	4,250,596	6641.55	19.7
Degraded forests	181,842	2837.25	8.4
Forests affected by S/C*	2,804,174	4,381.52	13.0
Agriculture	11,962,396	18,691.24	55.5
Water body	302,178	472.15	2.0
Other land use	422,273	170,892	1.4
Total	21557459	33,683.53	100

** Shifting Cultivation , Source: Forest Department, Myanmar 1997.*

The main cause of deforestation in this area is woodcutting and charcoal making. There is a common belief that the Central Dry Zone was once a thickly forested area; but due to the heavy woodcutting for brick making to construct numerous Pagodas during the time of ancient Myanmar kings, the area was gradually turned into semi-desert like conditions. The Forest Department (1989) appraised that the Dry Zone area has 68,444 km2 of closed forest, 18,344 km2 of degraded forest and the forest affected by shifting cultivation (25-75%of land cover) was 27,207 km2 or about 24% of the total forest area of Dry Zone.

Myanmar as a whole has 24.3% of non-forested land whereas this Dry Zone area has more than 37% of non-forested land. This figure indicates the extent of deforestation for dwellings and cultivation purposes. Other statistics shows that the quality of the forest is also degrading due to human influences, and aridity of climate. From 1975-89, the closed forest areas have decreased in Mandalay and Magway divisions, except in the Sagaing division. Even the degraded forest areas have declined to give way to upland crops and shifting cultivation. The population pressure on this area can cause further destruction of forests and its quality.

Table 5.2 Different Deforestation Rates of Actual Forests of Myanmar

Sr.No	Period	Interval	Actual Forest cover Lost During the Period (sq. km)	Deforestation Rate of Actual Forests Percent of Total Land area
1	1955-1975	20	62242.9	0.5
2	1975-1989	14	31121.4	0.3
3	1989-1997	8	39375.4	0.7
Overall	1955- 1997	42	132739.7	0.467

Source: Dry Zone Greening Department, Yangon, Mvanmar, 1997.

Table.5.2 shows the rate of deforestation of actual forest in Myanmar, from 1955 to 1997. According to the table, within 20 years from 1955 to 1975, the deforestation rate was 0.5%; from 1975 tol989, within 14 years, 0.3%; from 1989 to 1997 within 8 years, 0.7%, and from 1955 to 1997 within 42 years the rate was 0.46% respectively. Erosion susceptibility data of Sagaing, Magway and Mandalay Divisions is shown in the Table 5.3 below:

Table 5.3 Susceptibility data of erosion in Sagaing, Magway and Mandalay divisions **(acres)**

Divisions	Slight	Moderate	Critical	Grand Total	%
Sagaing Division	5292357.275	226362.4	3434.608	5522154.24	25.62
Magway Division	7839612.168	2257853	284657.5	10382122.24	48.16
Mandalay Div:	4968876.658	555614.1	128692	5653182.72	26.22
Dry Zone Total	18100846.1	3039829	416784.1	21557459.1	100

Source: Drv Zone Greening Department, Yangon, Myanmar, 1997.

Out of the total area of Dry zone (21557459.1 acres), the susceptibility of erosion in Magway Division is 48.16%, 26.22% in Mandalay Division and 25.62% in Sagaing Division. Magway Division; thus, seems to be in the highest position of erosion among the three divisions. But, most of it (7839612.168 acres) is in the level of slight erosion; only 284657.5 acres are in critical stage. In Sagaing Division, the area of erosion in critical stage is 3434.608 acres while 128692 acres exist in Mandalay Division. All of these areas in critical stage are urgently needed to be in the consideration for soil conservation.

5.2.3 Deforestation

Deforestation is generally regarded as the first step along the road to desertification. Deforestation degrades the vegetation cover and makes the soil more vulnerable to erosion by subsequent over cultivation and/or over grazing. The productivity of agricultural land is likely to decline as a result of soil degradation. Accordingly to mitigate the effect of desertification and the greening of the Dry Zone occupies a place of special importance in the government's environmental protection endeavours.

According to government's Agricultural Statistics of (1987/88 to 1997/98) productivity of crops show an increasing trend between 1972/73 and 1982/83, for some crops by double or more than double the previous level. It may be attributed to the impact of "green revolution" (and greater utilization of inputs, especially chemical fertilizers) in Myanmar that took place around 1974-75. The same pattern of increasing productivity trend is also observed for Magway Division between 1982/83 and 1996/97. In Sagaing and Mandalay Divisions however, per unit area for some crops indeed remained stagnant or declined slightly during the same period. But, there were also some crops whose productivity continued to increase. This may be due partly to the fact that many of the crops grown in the area are drought tolerant, and partly to greater input utilization stemming from incentives provided by agricultural liberalization in the late 1980s. In other words, decline in productivity resulting from soil degradation as generally assumed, is not evident at least in terms of aggregates at the Division level.

Mangrove forests in **Ayeyawady delta** region have been exploited beyond their capacity due to the needs for wood fuel, charcoal and other forest products. A study suggested that from a total of 481593 hectares of mangrove area in Myanmar in 1974, 356,136 ha were left in 1990. During this 16 year period there was an average annual loss of 7841 ha or 1.63% of the whole mangrove forest area, which is much higher than the figure for the annual forest area loss of 0.64% for the whole country.

The large population of wood fuel users indicated a very adverse effect on the growing stock of the mangrove forests (Ohn,U,1999). The study also estimated and projected the woodfuel trade/ flow to Yangon from some States and Divisions of which the Ayeyawady Division is the chief exporter. The woodfuel trade/flow is shown by year as below:

Wood fuel trade/flow to Yangon (Million adt)

State/ Division from	1990	2000	2005
Ayeyawady	**1.2**	**1.0**	**1.0**
Taninthayi	**0.1**	**0.3**	**0.5**
Rakhine	**0.1**	**0.1**	**0.2**
Bago	**0.2**	**0.7**	**0.5**
Magway	**0.2**	**0.1**	**0.7**
*** Yangon Consumption**	**1.8(* 2.7)**	**2.2(3.48)**	**2.4(*4.3)**

Source: Myanmar Energy Sector Investment and policy Review by World Bank Team, May 1991

The figures indicate that in Yangon wood fuel consumption in 1990 was estimated at 2.7 million air dry tons (adt), of which 1.8 million adt was imported and 1.2 million from Ayeyawady Division. For the year 2000, Yangon's consumption was projected at 3.46 million adt, of which 2.2 million adt was to be imported with 1.0 million adt from Ayeyawady Division. For the year 2005, wood fuel consumption in Yangon is projected to be 4.3 million adt, of which 2.4 would be imported, with 1.0 million adt from Ayeyawady Division.

Large parts of reserved forests in Ayeyawady delta, except Meinmahlat kyum wildlife sanctuary, have been degraded, deforested, and mostly depleted due to excessive wood fuel /charcoal production and paddy field encroachment. Mangrove forests in the delta had been excessively exploited and eventually turned into agricultural lands. According to some assessments the mangrove forests have been undergoing depletion at a rate 2.4 times higher than that of the depletion of forests in the country, which highlights the need to urgently implement management strategies for the mangrove ecosystems.

5.2.4 Wood fuel Use in Myanmar

The role of traditional fuels, such as firewood, charcoal, crop and animal residues, etc., is of great importance in South East Asia countries and a number of studies reveal that in 1991 the low consumers of traditional fuels, as a percentage of traditional fuels, as a percentage of the total annual energy consumption are China (24%) and Malaysia (10%) while the moderate consumers are Indonesia (29%), Philippine (47%) and Thailand (26%). The high consumers are Laos (89%), Vietnam (76%) and Myanmar (78%) respectively.

Most of developing countries in the world depend for a large part on biomass as a source of energy, not only domestic use but for industrial applications as well. This is particularly true in the case of Myanmar where 84% of the total amount of energy consumed is biomass based, notably wood fuel and charcoal. The remaining 16% consists of commercial sources of energy like oil, gas, and electricity.

The authorities acknowledged the heavy reliance on wood fuel and its possible adverse impacts as early as the fifties. Several wood fuel supply and demand studies were carried out by the Forest Department of Myanmar (e.g." The wood fuel Situation in Burma", a case study carried out for Asia pacific Forestry Commission in 1959). In 1968 another study on the wood fuel and charcoal situation was carried out by the Planning Department of the Ministry of Planning and Finance. This study formed part of a country review on energy in Myanmar. Besides these studies, the Forest Department and the UNDP/World Bank carried out other studies. These studies indicate that wood fuel problems existed.

With 47% of its land are being forested, Myanmar can still be considered fortunate when compared to other Asian countries. However, due to the continued heavy reliance on wood as a source of energy, the wood fuel situation has become critical in several areas. Various surveys and studies on energy situation in Myanmar have indicated that, out of 14 states and divisions, one state and six divisions: Mon state, Yangon, Ayeyawady, Mandalay, Bago, Magway and Sagaing Divisions can be classified as fuel deficit areas.

In Myanmar, although coal, electricity, crude oil, and various types of biomass such as wood fuel, charcoal, agricultural residues and animal dung are important energy sources, wood fuel (wood fuel & charcoal) dominates energy use, more than 70 per cent of renewable energy consumption depends upon forest resources. Few rural homes in Myanmar have a supply of gas or electricity. Thus there is heavy reliance on wood fuel, resulting in the depletion of forest cover in marginal forests outside the reserve forest areas. Despite the fact that Myanmar still has about 50% of its land area covered with natural forests, an assessment of forest cover changes in 1990 revealed an alarming annual loss of 0.22 million hectares, or o.64% of the total forest area, mainly due to shifting cultivation , encroachment and illicit cutting. Woodfuel consumption in Myanmar in 1990 was estimated at about 20 million tons and was expected to reach 23 million tons in the year 2000. The demand / supply position shows a growing deficit situation, which is expected to increase further.

During the last decades Myanmar experienced a rapid depletion of natural forest resources that has resulted in much hardship for the people living in rural areas, especially for the women and children who have to spend more of their time and energy gathering wood fuel and biofuels from more distant locations. In the rural areas wood fuel is used almost exclusively for household cooking together with a limited amount of agricultural residues such as cotton and pigeon pea stalks, sugar cane bagasse, paddy straw, rice husks, sesame stalks, and palm leaves.

While the utilization of wood fuels is increasing, their supply is becoming more and more deficient in many areas. Even if the per capita consumption of wood fuel has declined because of increasing resource scarcity, the rapid growth of population and a changing energy use pattern will inevitably, ensure a shift to alternative fuels. Other than wood fuel, coal briquettes are considered to be suitable alternative energy for cooking and for some cottage industries. Briquette production is gaining momentum in Myanmar.

In 1991, the World Bank assessed energy resources and revealed a 14% share of biomass in the world's primary energy consumption. Biomass provided 35% of all energy to 72% of the world's population. In Myanmar biofuels play an important role in energy consumption and wood fuel and charcoal are vital for household cooking and heating in some remote areas. The wood fuel consumption of urban people is slightly less than that of rural people because of the availability of alternative and other non-conventional energy such as gas, coal briquettes, and electricity, hi Myanmar, the consumption pattern of wood fuel varies significantly from one state / division to another. Water heating and room heating are major applications in Chin, Shan, Kachin, Kayah state, for which wood fuel are inevitably used. The annual total wood fuel consumption from 1970-71 to 2000-2001 is given in the (Table 5.4).

According to FAO data for the year 1994-95 in Myanmar, the wood fuel consumption was 19 million cubic tons, with the forecast of 20 million cubic tons in 2000-2001 for household cooking. These data are exclusive of wood fuel used in cottage industries such as brick making, potteries, tobacco curing, jiggery boiling, and condensing milk. It is indicated that the actual demand for wood fuel by these industries is as much as 4 times greater than that suggested by the recorded data.

The main sources of wood fuel supply are natural forests, local supply plantations, and roadside trees and homestead gardens. In the 1970s kerosene was generally the main source for household cooking in urban areas. In those days, kerosene and stoves using kerosene was 47.69 million gallons and consumption was 96 million gallons in 1977. Insufficiency of kerosene to meet the demand led to giving priority to the production of petrol/diesel. Indeed the production of kerosene has been declining over the years. This led to a change in the dominant source and form of energy for cooking, and wood fuel became important for both urban and rural areas. About 24% of the total population in Myanmar live in urban areas and get wood fuel and charcoal by self-collection or purchasing or both. In Yangon City, more than 50% of the residents use charcoal, which comes from delta mangrove forests whose ecology is seriously threatened due to over exploitation.

Myanmar's forests, even when in degraded form, can yield considerable amounts of wood fuel for local consumption. By reintroducing local supply reserves, opening cutting coupes, strict departmental control and efficient popular participation, these degraded forests can still yield considerable wood fuel volume using only natural regeneration methods.

Table 5.4 Consumption of Wood fuel in Myanmar (Thousand cubic tons)

Sr No.	Year	Wood for fuel	Wood for Charcoal	Total
1	1970-71	9972	432	10404
2	1971-72	9967	633	10600
3	1972-73	10108	528	10636
4	1973-74	11149	711	11860
5	1974-75	10490	705	11195
6	1975-76	10873	849	11722
7	1976-77	11337	1143	12480
8	1977-78	11678	1128	12806
9	1978-79	12452	1920	14372
10	1979-80	12545	1587	14132
11	1980-81	13049	1818	14867
12	1981-82	13608	1851	15459
13	1982-83	14334	2295	16629
14	1993-84	15045	2157	17202
15	1984-85	15752	1587	17339
16	1985-86	16741	2598	19339
17	1986-87	16972	2442	19414
18	1987-88	17223	2544	19767
19	1988-89	17383	2283	19666
20	1989-90	17660	2646	20306
21	1990-91	17913	2094	20007
22	1991-92	17668	1947	19615
23	1992-93	18003	2403	20406
24	1993-94	17988	1254	19242
25	1994-95	18018	774	18792
26	1995-96	18070	1026	19096
27	1996-97	17781	1044	18825
28	1997-98	18110	1053	19163
29	1998-99	18444	1059	19503
30	1999-2000	18784	1071	19855
31	2000-2001	19122	1077	20199

Sourrp • FA n RWF.DP in Asia. Field Document No. 3.2000.

Wood fuel for rural households is generally obtained from pruned or pollarded branches of trees or even from bushes. In the Dry Zone of Central Myanmar Gandasein (prosopis juliflora) (although it has dangerous thorns, interlocked -grainy wood, and is hard to split) is widely used by the rural people, including its roots. In Dry Zone the preferred species for wood fuel is Sha (Acacia catechu), white Kokko (Albizzia lebbek), Mezali (Cassia siamea) and Eucalyptus are also used as wood fuel.

According to the table mentioned above it should be noted that Wood fuel to Charcoal ratio is 3:1 Wood fuel consumption for cottage industrial purposes is excluded from this table. In the table we can see that from the year 1970-71 to 1989-1990 wood fuel consumption in Myanmar continuously increased, but after 1990-91, it decreased as government has banned cutting wood in order to protect the mangrove forests from degradation.

Myanmar's heavy reliance on wood fuel has eroded its supply sources and it was forecasted that the more accessible forests would be exhausted to the extent that the more remote forests would have to be tapped in the foreseeable future, involving rising market prices. The high consumption of wood fuel, if allowed to continue without adequate management of existing resources, can not only adversely affect the supply sustainability of wood but also degrade the physical environment in coming years. In order to solve the cute problems of supply shortages and rising market prices, and restore the ecosystem, the Forest Department has initiated a massive programme of block reforestation and some 177 thousand hectares of woodfuel plantations have been raised by 1997, however, the annual woodfuel plantation target of 10 to 15 thousands hectares is considered inadequate to meet the gap between demand and supply.

5.2.5 Alternatives to Woodfuel

Charcoal is preferred after wood fuel. Charcoal is generally burnt either in earth pits or brick and mud kilns. The conversion rates from wood to charcoals are far below what could be achieved through systematic charcoal burning. The brick /mud kilns were estimated to have a recovery rate of between 9% and 14% by weight and the earth pits kilns ranged from 6% to 12%. In addition, 10% or more is lost as fires prior to final bagging. With improved production procedures, the recovery rate could be increased from 25% to 45% for brick kilns and 20% for the earth kilns .It is assumed that one third of charcoal by volume will be obtainable from systematic depletion and the use of alternative wood fuel substitutes is encouraged.

Households and cottage industries in the Divisions of Mandalay and Ayeyawady, especially for condensing milk, commonly use **bamboo** as fuel. The dry bamboo can easily be harvested and dry bamboo bundles can be purchased in the markets in Meiktila, Myingyan, and Kyaukse districts and some areas of Ayeyawady Division. Although the annual production of bamboo is over 900 million pieces, the consumption of bamboo as fuel is low.

The net area under various agricultural crops including mixed and multiple crops is about 30 million acres annually and there **by products (agricultural residues)** such as straw, rice husk, stalk can be used for energy. Out of 17 million tons of straw, 89% is used as fodder. About 1 million tons of stalks and other residues are used for cooking and heating each year and in 1990 this was estimated as about 1.42 million tons of coal equivalent.

Energy from animal residue (dung) obtained from cattle, buffaloes, and Sheep/goats .the country's livestock population (in millions) in 1997-98 amounted to cattle 10.6; buffaloes 2.4 and sheep/goats 1.7 (in millions) respectively. The potential for cattle dung is 9 million tons of coal equivalents approximately. In the past, cattle dung was often used as a source of energy but lately, it has been used more as fertilizer than as fuel because of scarcity of chemical fertilizer.

Coal was an alternative fuel in the past but is no longer used for power generation. There are many coal out-crops in the country but two major sources of supply uncovered are Kalaywa (83 million tons reserve) and Namma (3 million tons reserve), and various new fields are under investigation. In the past, about 265,000 long tons of coal were imported from India annually and Myanmar railways consumed 60% while the Yangon Electric supply Board consumed 23% of the imported coal. According to provisional data, the production of coal in 1997-98 was 3700 long tons at the annual growth rate of 6% compared with the production figures for the last 3 years.

Crude oil energy used in Myanmar obtained from four main oil fields: Chauk, Yenangyaung, Mann, and Htautsha-bin produced 6.1 million US barrels in 1997-98.The production of crude oil has gradually decreased from 10 million barrels produced annually in the 1980s. Consumption of petroleum products such as petrol, diesel, aviation fuel and other by-products has increased in parallel with the development of the industrial and transport and communication sectors. While the rate of crude oil production has gradually decreased by about 2 to 10% annually, the consumption rate annually increased by about 1%. To meet the demand, crude oil is 12.8 million US barrels, which is double the current production figure. Natural Gas production has gradually been increasing and detail statistics are as follows:

Table 5.5 Natural gas production from 1992/92 to 1997/98

Particulars	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Natural gas	28303	35977	45599	54025	58579	68540
Compressed-natural gas	51	65	68	72	92	113

Source: Energy Department ofYangon, Myanmar,1998.

According to the table, the natural gas production has been increasing year after year because the SLORC government has taken the collaboration of TOTAL Company of France and by the high technology Myanmar could produce the offshore gas from Gulf of Mottama. Mainly the Myanmar Electric Power Enterprise (MEPE) manages the present sources of Electric power in Myanmar. But other organizations also have installed capacity, which they generate and manage by themselves. MEPE has 606 interconnected power stations such as 95 hydropower, 12 thermal, 32 gas turbines, and 467 diesel stations. According to the provisional data, MEPE generated 4205 million kilowatt hours in 1997-98 and the consumption units by industrial, domestic, hospital, office, school, and miscellaneous amounted to 2502 million kilowatt hours. Domestic consumption was 1138 million kilowatt hours representing

45% of total consumption. Because of power supply constraints, most of the rural people live without electricity and urban people are faced with shortages. In Myanmar the urban population is only about 11 millions (2.2 million households representing24% of the total population of 46.5 millions (1997-98). One household of moderate living standard consumes about 2000 kilowatts hours for lighting, cooking, use of refrigerator, fan, and television, etc. per annum. Thus, the 1138 million kilowatt hours consumed in 1997-98 are only adequate for 0.6 million households. This means that 75% of the urban people are faced with power shortages.

5.2.6 Wood fuel crisis in Myanmar

Majority of people in Myanmar earn their livelihood in agriculture and live in rural areas. By the year 2005, as the population reaches 50 million, the demand for Wood fuel will also increase accordingly. Hence, it is highly probable that unless alternative sources of fuel is provided the rate of depletion of unclassified forests will be aggravated, particularly in the Dry Zone. The rural poor, having no other alternative sources of energy for cooking, rely only on wood fuel collected from adjacent degraded forests and are extending their collecting into the unclassified forests. For people living in areas without any forest cover the wood fuel shortages are a day-to day problem. Myanmar has a peculiar situation of energy supply and demand in comparison to most of its neighbouring countries. Wood fuel consumption in Myanmar in 1990 was estimated at about 28 million air dry ton (ADT) or about 36 million m3. The annual average growth in wood fuel consumption is estimated at 2% since 1980 and rural households who meet their subsistence energy needs from self-collection account for about 75% of the consumption. Charcoal is estimated to be 4-5% of total wood fuel consumption and mostly in Yangon. The demand/supply position clearly shows a growing deficit, which is expected to widen as the years pass by. Myanmar's heavy reliance on wood fuel has adversely impacted its supply sources in different areas. Supply shortages and rising market prices have been frequently observed phenomena. Today, 7 out of 14 states/ divisions have been affected with supply deficit and the situation in the others is also expected to worsen in the coming years. They are Yangon, Ayeyawady, Mandalay, Bago, Magway and Sagaing Divisions and Mon state.

Deforestation and the decline in the forest cover of the Dry Zone is attributable to over cutting of woody biomass for Wood fuel due to population growth, inadequate supply and high cost of non-wood energy sources and inefficient utilization of wood fuel. In this connection, it is worthy to note that (i) 81 percent of the energy in Myanmar comes from biomass; (ii) that the household sector dominates energy consumption with an estimate of 87.2 percent; and (iii) that consumption of wood fuel accounts for 84.1 percent (78.3% of Wood fuel and 5.8% of charcoal). It may further be noted that with the exception of Ayeyawady, other areas especially, Mandalay, Sagaing and Magway Divisions are areas with serious wood fuel deficits.

Myanmar's forests in Bogalay, Laputla, and Maulamyaing kyun of Ayeyawady Forest Division have been managed systematically since the early twentieth century. These mangrove ecosystems are fragile but essential to support the sustained production of fisheries and inland rice cultivation. They provide the coastal dwellers with shelter, protection from the ravages of severe winds and with timber for domestic uses, Wood fuel, charcoal, and many other forest products.

To meet the needs for Wood fuel, charcoal and other forest product, these mangrove forests have been exploited beyond their capacity. Large parts of reserved forests in Ayeyawady delta, except Meinmahlatkyum wildlife sanctuary, have been degraded, deforested, and mostly depleted due to excessive Wood fuel /charcoal production and paddy field encroachment.

These tidal forests (mangroves), according to 1942 estimates, covered 671492 acres as shown in the (Table 4.10). Due to the ever increasing demand for firewood and charcoal by Yangon city and for various forms of forest product, produced by the local population, the 1990 estimate, indicate that mangrove forest have been reduced to 438,000 acres. Mangrove forests in the delta had been excessively exploited and eventually turned into agricultural lands. According to 1950 assessments the mangrove forests have been undergoing depletion at a rate 2.4 times higher than that of the depletion of forests in the country, which highlights the need to urgently implement management strategies for the mangrove ecosystems.

The price of wood fuel has exorbitantly increased as destruction of mangrove forests has caused a shortage of wood fuel. The people in the village use shrubs, brushwoods and the leaves of coconut as fuel. In the townships woody stems of climbers, shrubs and roots or stems of mangrove and non-mangrove species are sold in the market. There is no marketable surplus from the delta. The charcoal sold at the market is imported from outside the area.

In rural communities, Wood fuel is collected from different sources including forest lands e.g. local supply reserved forests and non-forest lands e.g. agricultural fallows, village wood lots or trees growing on farmlands, homesteads, water lands, garden lands. However, data on Wood fuel availability from these sources are inadequate in Myanmar. Information on the production, management and end use of Wood fuel from non-forest areas plays a significant role in the proper planning of wood energy systems needs to be improved.

5.2.7 The wood fuel crisis in Dry Zone and Ayeyawady Delta

The present case study is an attempt to focus on the two study regions: (1) the less rainfall area - the Central Myanmar, Dry Zone area, Sagaing Division -Sagaing, Monywa and Shwebo districts, and (2) the heavy rainfall area - lower Myanmar, Ayeyawady delta region, Ayeyawady Division (Pathein, Hinthada and Myaungmya district). The first section of the study is of Dry Zone area in Sagaing Division and will discuss the wood fuel collection, the wood fuel production, and marketing which is accelerating forest degradation in Central Myanmar. The second section will focus on the Ayeyawady delta region where wood fuel collection from non-forest area, caused the mangrove forest degradation. The discussion of the Dry Zone wood fuel crisis is at a district level and is largely based on secondary data from Myanmar government, the Forest and Energy department of the Sagaing Division. This is a macro-level analysis that provides an over view of the wood fuel situation and compares the three districts of Sagaing Division in the Dry Zone. The analysis of the Ayeyawady Division is at a micro level, and is based on both primary and secondary data, the primary data generated from fieldwork in three villages of Ayeyawady Division.

Section A

5.3 Case Study of Dry Zone Area: Central Myanmar Dry Zone, Sagaing Division (Sagaing, Monywa and Shwebo Districts)

5.3.1 Forest cover and Land use Pattern in Study Area

The study area, Sagaing Division of the Dry Zone includes only 3 districts with 18 townships. The total area of Sagaing Division is about 5.52 million acres (2.23 million ha). According to the information based on interpretation of Landsat imageries taken in 1995 and 1996, the area of closed canopy forest is 1.14 million acres (0.46 million ha) 20.7%, and that of degraded forest is 0.38 million acres (0.15 million ha) 6.9% and hence the actual forest area is 1.52 million acres (0.61 million ha) 27.6%. The forest area affected by shifting cultivation is 0.15 million acres (0.06 million ha) 2.7% and agricultural land is 3.64 million acres (1.47 million ha) 65.9% of the total area of Sagaing Division (see Table 5.4).

The soil texture is mostly sandy loam and loamy sand. The PH value is mostly above 8. The percentages of organic matter content ranges from 1.5 to 3.6 and is generally below the minimum requirement. The extractable nutrients are also below the minimum requirement for plant growth.

Table.5.6 Forest cover and Land use of Sagaing Division(in million)

Sr.No	Types of Land use	Area in acres	Area in ha	percent
1	Closed canopy forest	1.14	0.46	20.7
2	Degraded forest	0.38	0.15	6.9
	Forest affected by S/C	0.15	0.06	2.7
4	Water& others	0.21	0.9	3.8
5	Agricultural land	3.64	1.47	65.9
6	Total	5.52	2.23	100

Source: Forest Department, Sagaing Division, 1998.

Out of the total actual forest area of 1.52 million acres (0.61 million ha) in the division about 83.2% is located in Shwebo district 15.2% in Monywa district and only 1.6% in Sagaing district. Out of the actual forest area of 1.52 million acres (0.62

million ha) in the study area, about 0.7 million acres (0.28 million ha) has been constituted as reserved forests and 0.2 million acres (0.08 million ha) has been formed as protected Forests for proper intensive management under the Forest Department.

In Shwebo district, there are 23 reserved forests and 4 protected public forests covering 0.70 million acres (0.28 million ha), which is about 55% of its total actual forest area. In Monyvva district, there are 6 reserved forests and 5 protected public forests covering 0.21 million acres (0.09 million ha), which is about 92% of its total actual forest area. In Sagaing district, there is only one protected public forest covering about 18,100 acres (7300 ha), which is 76% of its actual forest area (see Table.5.7).

Table 5.7 Legal Status of the Forest Area (in thousands)

Sr. No	District	Actual Forest		Legally Protected Forest		Percentage of actual reserved & protected forest
		Acre	Ha	Acre	Ha	
1	Shwebo	1268.3	513.3	696.0	281.7	55
2	Monywa	232.3	94.0	213.4	86.4	92
3	Sagaing	23.7	9.6	18.1	7.3	76
	Sagaing Division	1527.3	616.9	927.5	375.4	61

Source: Forest Department, Sagaing Division, 1998.

The table shows that Monywa and Sagaing have high percentage of reserved and protected forest due to necessity of current situation. Because of high population density, the current situation is needed to reserve and protect the forest to control the deforestation.

5.3.2 Per Capita Forest and Population Density

In the Dry Zone area of Sagaing division, the population is about 2.89 million and per capita land area is 1.9 acres (0.8 ha) whereas per capita forest is 0.5 acres (0.2 ha) and per capita agricultural land is 1.3 acres (0.5 ha). For the whole country, the per capita land of the union average is 3.5 acres (1.4 ha), per capita forest is 1.8 acres (0.7ha) and per capita agricultural land is 0.5 acres (0.2 ha). The per capita forest area is lowest in the Dry Zone when compared to the rest of Myanmar.

The average population density in the study area is 335-person/sq mile (129/ sq. km), which is nearly double that of the Union average (181 person/ sq.acre = 70/sq. km). In Sagaing Division, Sagaing District is the most thickly populated area with 516-person/ sq. mile (199/ sq. km), (see Table 5.8).

According to the present situation of the forest cover, land use pattern and population density, the study area urgently needs to intensively conserve the existing natural forests and to extensively establish new forest plantations especially in Sagaing and Monywa districts, otherwise, the people will suffer more not only wood fuel shortages but also food and fodder shortages.

Table 5.8 Percapita Forest and Population Density

District	Per Capita Forest		Population density	
	Acres	Hectares	Per sq mile	Per sq km
Shwebo	1.1	0.4	243	94
Monywa	0.2	0.08	413	159
Sagaing	0.03	0.01	516	199
Division-Avg	0.5	0.2	335	129
Union-Avg	1.8	0.7	181	70

Source: Forest Department, Sagaing Division. 1998.

5.33 Wood fuel Consumption

According to the data collected in the three townships: Sagaing, Monywa and Shwebo by Greening Department of Dry Zone, the total number of households in the study area is about 476,000. Out of these, only a few (7%) are capable of purchasing electricity, gas and fossil fuel for their daily needs. Most of urban dwellers and nearly all of the rural people still depend on wood fuel and forest waste (70%). Some people (23%) have to use agricultural and animal waste.

5.3.3.1 Household use

Due to the energy consumption pattern for household cooking, about 81% of energy comes from wood fuel and forest waste in Shwebo district, where the actual forest area is concentrated. On the other hand, wood fuel consumption decreased to 65%in Monywa district and 58% in Sagaing district where the wood fuel is being supplemented by agricultural and animal waste up to 25% and 35% respectively (see Table.5.9)

The wood fuel consumption is estimated to be about 390,000 cu tons in Shwebo district, 290,000 m tons in Monywa district and 155,000 cu tons in Sagaing district, respectively and a total of 835,000 cu tons in the Dry Zone area of Sagaing Division (see Table 5.10). According to the table, Sagaing district has lesser households using the woodfuel than Shwebo and Monywa as the Actual Forest Area and total no of household in Sagaing are lesser than the two areas.

Table 5.9 Ener^>y consumption by Type of Fuel (Number of households)

Type of fuel	Shwebo District		Monywa District		Sagaing District		Sagaing Division	
	Nos.	%	Nos.	%	Nos.	%	Nos.	%
Electricity and fossil	8733	4.6	16579	9.3	7612	7.1	32924	7
Wood fuel and forest waste	155890	81.3	116060	65.4	61933	58.0	333883	70
Agricultural and animal waste	27080	14.1	44810	25.3	37274	34.9	109164	23
Total	191703	100	177449	100	106819	100	475971	100

Source: Forest Department, Sagaing Division, 1998.

Table 5.10 Wood fuel consumption for household cooking

District	Total number of households	Nos. of households using wood fuel	Wood fuel consumption	
			Cu tons	M3
Shwebo	191,703	155,890	390,000	552,200
Monywa	177,449	116,060	290,000	410,600
Sagaing	106,819	61,933	155,000	219,500
Sagaing Division	475,971	333,883	835,000	182,300

Source: Forest Department, Sagaing Division, 1998.

5.3.3.2 Institutional and Community Use

In the study area, in addition to household use, wood fuel is also utilized by some institutions and communities such as training centers, boarding schools, monasteries, meditation centers etc. As they are mostly non-profitable institutions, they are used to collecting wood fuel for daily cooking at a minimum cost. Some monasteries have their own woodlots nearby under systematic management for wood fuel supply throughout the year. Some training centers and boarding schools have to collect the wood fuel by themselves from the natural forests or woodlots by pruning, pollarding and coppicing the trees.

On the other hand, some institutions have to buy the wood fuel at the current local price and therefore some have tried to use wood fuel substitutes such as agricultural residues and forest waste in order to reduce the fuel cost. According to the data collected in the townships, the wood fuel consumption by institutions is 6,500 cu tons in Shwebo district. 16,000 cu tons in the Monywa district and 4,900 cu tons in Sagaing district, totaling about 47,400 cu tons in the Dry Zone area of Sagaing zone.

5.3.3.3 Commercial Use

In each town and some villages, there are cafeterias, hotels, restaurants; food processing shops, bakeries etc and the number of shops and wood fuel consumption varies from one place to another depending upon local requirements. In Shwebo district, wood fuel and charcoal are mostly used for commercial purposes, and agricultural residues, mainly rice husks are also used as a supplement to meet their requirements. In Monywa district, wood fuel and charcoal are the main source of energy and some cafeterias use coal briquettes produced by the North West command for the welfare of the army staff. In Sagaing district, the primary energy source is wood fuel and charcoal for commercial purpose, but large amounts of agricultural residues and coal briquettes have to be used as a supplement to fulfill their daily requirements (see Table5.ll). In the table Monywa and Shwebo have more of cafeterias, restaurants and bakeries using wood fuel for their profits as the cost of using wood fuel is much economical than using electricity in cooking. Not only for the consideration of profit, but also the distribution of electricity is not sufficient for high consumptions in commercial use. But in Sagaing district, the amount of using agricultural waste and Coal briquettes is higher than Shwebo and Monywa district. It indicates that measures taken to combat desertification and drought in Sagaing Division is successful to some extent.

Table 5.11 Energy consumption by commercial use

District	Number of			Fuel consumption by		
	Cafeterias	Restaurants	Bakeries	Wood fuel (cu tons)	Agricultural waste (tons)	Coal briq: (Nos)
Shwebo	214	88	57	4270	400	--
Monywa		85	23	3715	--	3500
Sagaing	103	37	15	2300	5400	100,000
Sagaing Division	549	210	95	10285	5800	103500

Source Forest Department. Sagaing Division. 199S.

5.3.3.4 Small scale cottage and home industrial use

In the Dry Zone area of Sagaing Division there are various kinds of small-scale cottage and home industries here and there depending on the availability of raw materials in the vicinities. These also require large amounts of fuel for continuous operations. Based on the data collected in townships by the Energy and Planning Department of Sagaing Division, there are about 3085 jaggery boiling units. 536 pottery kilns. 57 brick kilns. 16 evaporated milk plants. 11 lime kilns. 4 alcohol distillation plants etc. Most of them utilize wood fuel as a main source, but some of them also use agro-residues and coal briquettes as a supplementary source, and only a few totally depend on agro-residues such as rice husk. According to the (Table 5.12) in Shwebo district most of wood fuels are used by Pottery kilns, bricks kilns and jaggery boiling units while Sagaing and Monywa wood fuels are being used for boiling jaggery making pots and evaporating milk. The use of wood fuel and agro residues by Shwebo district is less than that of Monywa and Sagaing districts because of less density of population compared to the two districts. But there is no use of coal briquettes in Shwebo district while Sagaing and Monywa use 100.000 and 3500 of briquettes respectively. And there is no use of agricultural waste in Monywa district while Sagaing district uses 5400 tons and Shwebo district uses 400 tons of agricultural residues. In order to reduce the wood fuel utilization in the division, the agricultural residues and coal briquettes usage also should be encouraged uniformly.

Table 5.12 Energy consumption by industrial users

District	Number of				Fuel consumption type		
	(aggery railing unit	[5]ottery dins	Brick kilns	Evaporated nilk and others	Wood fuel (cu tons)	Agro-residues	Coal briquetts
Shwebo	21	205	i i	1	7020	400	-
Monywa	1499	198	30	14	10505	2585	6200
Sagaing	1565	133	5	16	35120	8910	100,000
Sagaing Division	3085	536	57	31	52645	11895	106200

Source: Energy- Planning Deparrmenr. Ministry of Energy:, and Sagaing Division, 199S.

5.3 Wood fuel Substitutes

Wood fuel and charcoal are still extensively and increasingly used by domestic, institutional, commercial and industrial sectors everywhere in the Dry Zone area of Sagaing Division. As the forests within the study area cannot supply a sufficient amount of wood fuels to meet the demand, most of the large sized wood fuel and charcoal has to be imported from outside the Dry Zone area by boat, road and rail. As a result of the transportation costs the people suffer from higher wood fuel prices in addition to wood fuel shortages. Due to the wood fuel shortage in the local area and the high price of imported wood fuels, the people have begun using various kinds of wood fuel substitutes such as agro-residues, wood waste, animal waste (cow dung) etc., which are locally available at low cost or free of charae.

5.4.1 Agro-residues

Agricultural residues are available in the fields or nearby sites as well as the agro-processing mills and factories in the vicinity of the urban area. The common agro-residues being used in the study area are rice husks, groundnut shells, paddy stalks, wheat stalks, sesame stalks, cotton stalks and pigeon-pea stalks since there are large areas of rice fields, and cultivated areas with various kinds of cash crops such as wheat, cotton, groundnut, sesame, pigeon-pea, etc. Some agro-residues are used for fodder, organic manure and building material in rural areas. But most of them are being used as alternative fuel not only for domestic cooking but also for commercial and small-scale industrial uses, even in urban areas.

In the study area, agricultural residues such as rice husks and groundnut shells are widely used in milk plants. Stalks of various cash crops and leaves of toddy palms are also used as the main source of fuel in jaggery boiling.

Table 5.13 Availability of agro-residues (in thousand tons)

District	Rice husks/ groundnut shell	Stalks of crops
Shwebo	153.6	3.2
Monywa	5.3	43.6
Sagaing	31.1	58.4
Sagaing Division	190.0	105.2

Source Energ) Planning Department. Sagaing Division. I99S.

In the (Table 5.13) the total rice husk/groundnut shell and stalks of crops utilization in Sagaing division is 190 thousand tons and 105.2 thousand tons respectively. Out of which the utilization by Shwebo district is 153.6 thousand tons and Monywa uses 3.2 thousand tons. 5.3 and 43.6 thousand tons, and Sagaing districts use 31.1 and 58.4 thousand tons.

5.4.2 Wood Waste

The wood waste widely used in the study area includes saw dust, mill off cuts, and other wastes obtained during the processing of saw mills, re-cutting, carving and furniture making. The sawmill produce off cuts as by products and these are reprocessed at the re-cutting mills into small planks for making boxes. While making boxes there are many small and short pieces of planks rejected as useless. These rejected pieces of planks are bundled into a suitable size for sale as wood fuel. The users prefer this type of fuel as it consists of assorted timber species some of which have high calorific value and convenience in use. Larger sizes of mill off-cuts are generally used for commercial cooking, boiling and heating, whereas smaller sizes and bundled pieces are used in domestic cooking.

The sawmills and re-cutting mills also produce sawdust, which is now used for both domestic and home industrial purposes. Saw dust is used in some yarn dyeing centers and evaporated milk plants. Table 5.14 shows the availability of wood waste in the division. Total mill off cuts and other waste in the Sagaing division is 17400 thousand tons and Saw dust is 3000 thousand tons. Out of which Monywa has the greatest amount 12900 thousand tons of mill off cuts and 2600 thousand tons of sawdust. Shwebo has 4100 thousand tons of mill off cuts and 300 thousand tons of sawdust when Sagaing has the least amount, 400 thousand tons of mill off cuts and 100 thousand tons of sawdust because Sagaing district has more urban area than Shwebo and Monywa districts and most of saw mills are distributed in Shwebo and Monywa districts where forest resource is more abundant.

Table 5.14 Availability of wood waste (thousands in tons)

District	Mill off-cuts and other waste	Saw Dust
Shwebo	4100	300
Monywa	12900	2600
Sagaing	400	100
Sagaing Division	17400	3000

Source: Energy Planning Department, and Sagaing Division.

5.4.3 Animal Waste

Animal waste such as cow dung was previously widely used as natural manure in the crop fields but not it is also used in domestic cooking and heating in some areas suffering wood fuel shortages. According to the data collected, the annual waste is abundantly available in Shwebo district as animal husbandry is widely distributed in Shwebo district, but only some people in Sagaing and Monywa districts use it as substitute fuel for their daily cooking. (Table 5.15) In the whole Sagaing division, total animal waste is 103.300 tons. Out of which. Shwebo district has 100.000 tons, Sagaing district has 3200 tons, and Monywa district has 100 tons respectively.

Table 5.15 Availability of animal waste

Districts	Animal Waste (tons)
Shwebo	100.000
Monywa	100
Sagaing	3200
Sagaing Division	103.300

Source linerg}- Planning Department. Sagaing Division, I99S.

5.4.4 Coal

Coal is available at Thit-Chauk mine in Kalewa townships, Sagaing Division. The mine has a large coal deposit with an animal production of about 18.000 tons. There are some briquette machine to produce coal-briquettes in the Dry Zone area the coal briquettes have been introduced as wood fuel substitutes in some brick-kilns, tea shops etc. Due to its bad smell, it is still hardly used in domestic cooking by urban dwellers, but some households in outskirts use it with special cook stoves designed for it.

5.5 Production, Marketing of Wood fuel and Wood fuel Substitutes

5.5.1 Production of Wood **fuel**

Wood fuel and charcoal are the main sources of energy for the majority of the people in the Dry Zone area of Sagaing Division. Wood fuel is obtained from natural forests, wood fuel plantations, village wood lots, road-side trees and home garden of punning, pollarding, coppicing and sometimes, by felling the trees. The people living along the riverbanks collect driftwood and use it as wood fuel.

(a) Natural Forest

Though most existing natural forest in the Dry Zone area are not at present suitable for producing wood fuel, the rural people regularly collect wood fuel from the nearest forests regardless of the distance from their home villages. In the study areas, except in Kamtbalu Township, wood fuel extraction and charcoal processing for commercial purposes are strictly prohibited. As there are some degraded forest areas in Kamtbalu Township which have to be clear felled and replanted with valuable species such as teak, some of the inferior quality species of small sizes and burnt logs left there are allowed for wood fuel and charcoal processing.

According to its annual work plan, the forest department and the Dry Zone greening department are implementing natural regeneration works in selected areas of degraded natural forests to increase natural regeneration and to improve the quality of the forests by coppicing the damaged valuable species, by eliminating weeds and inferior species, by pruning the branches of some trees, etc. During these operations, woody materials such as stems branches are distributed to the local people, giving priority to the workers involved in forest conservation works. As those wood fuels are only meant for domestic use. they are transported to their home by bullock carts or carried on human shoulders. These forest conservation works can provide about 0.3 cubic ton of wood fuel per acre. As the target for natural regeneration work in the Dry Zone area of Sagaing Division during this current year (1998-99) is 3000 acres (1214 ha), in the wood fuel about 900 cubic tons is expected to produce (1622 m7ha).

(b) Forest Plantations or Woodlots

Forest plantations have been an important source of wood in Myanmar ever since the forest department established village supply wood fuel plantations many years ago. During the period between 1979 and 1992. an average of about 14,400 acres (5828 ha) or only 23% of the total area under forest plantations, was established as wood fuel plantations. From 1993 onwards, the annual area established as wood fuel plantations increased to over 30,000 (12141 ha) with priority given to meeting the basic needs of the local population, in line with Myanmafs Forest policy.

The Dry Zone greening department is also planning to establish various kinds of forest plantations including village supply wood fuel plantations for local supply. In the Dry Zone area of Sagaing Division, about 12.775 acres (5170 ha) of wood fuel plantations had been established between 1994 and 1997. In 1998-99, the Department planted 8,100 acres (3278 ha) including 3670 acres (1485 ha) of wood fuel plantations of 45% of the total area under plantation, in order to supply wood fuel on a continuous basis. Some of the village supply wood fuel plantations have been transferred to local communities as community forests to be managed by the communities and utilized for their own benefit, in consultation with the departments concerned.

The rotation of wood fuel plantations varies from 5 to 10 years depending on mean annual increment of the species, type of soils and spacing and local climate conditions. Generally, 5 years rotation is suitable from both the silviculture and economic point of view, and the output of wood fuel of that plantation is estimated to be 5 cubic tones per acre per year. Hence, it is hoped that the wood fuel plantations of the study will provide 18,350 cubic tons (25.890 m^3) from the year *2003-2004.*

(c) Non-Forest Area

A large amount of wood fuel is obtained from non-forest areas including village and community woodlots. agricultural farmlands, marginal and wasteland, home gardens and roadsides. The rural people rarely buy wood fuel from the markets instead; they collect it from non-forest lands, in addition to the natural forests, and to meet their daily needs.

Some wood lots are protected and managed by the community or the rural people near or around their compounds. They harvest the wood fuel by pruning and pollarding the trees on an alternative basis so that they can meet the needs throughout the year.

In the vicinity of the villages, there are also marginal and wasteland areas with natural trees of various native species. The people collect the wood from dead and dyeing trees by cutting the branches of live trees to use as fuel. In some acutely wood fuel deficit areas, the people have to gather wood fuel by pollarding, coppicing and sometimes by up-rooting the stamps.

Along the farm boundaries, there are some naturally grown or planted trees which are maintained for multiple uses such as plot demarcation, windbreak, natural manure, wood fuel, food, fodder and shade. Similarly, most of the rural people have home gardens in their own compounds, which are fairly large, compared to those of the urban areas and generally there are a few fruit and shady trees. Some of the rural households collect wood fuel from these trees for domestic uses.

Along the country roads and village tracks, there are many big trees, which have been planted for shade, and for aesthetic and greening purposes. But some are too old and very large and therefore need to be pruned or felled for safety. The dead or dying trees also need to be eliminated for replanting with fast growing species. Some local people cut them into pieces of various sizes, small size for domestic use and large size for commercial purposes. Due to insufficient natural forests and immature forest plantations, most of the rural people in the Dry Zone area of Sagamg Division, rely on these non-forest area for wood fuels.

5.5.2 Marketing of wood fuel and wood fuel substitutes

In the rural areas, most of the people collect the wood fuel nearby natural forests, farm boundary trees, roadsides trees etc.. by pruning, pollarding and coppicing. They rarely buy wood fuel from the market. Where it is difficult to gather the wood fuel free of charge they substitute some agro-residues such as rice husks, ground nutshell, and stalks of crops and cow-dung.

The urban people on the other hand, have to buy wood fuel from the market at the prevailing price. Most of wood fuel collected locally is used for domestic cooking and large size wood fuel imported from outside the Dry Zone area is used for commercial purposes. The price of wood fuel and charcoal in some townships is shown in the table below:

Table 5.16 Price of woodfuel in some Townships (in Kyats)

Sr. No	Township	Large-sized Wood fuel	Bundle Wood fuel		
			Large	Medium	Small
1	Shwebo			Ks.15 per bundle of 1.15'Xg-2'	Ks.7/- per bundle of 1-1.5 Xg-r
2	Kambalu	Ks.840/-per ton of 1-1" X g-0.7' short poles	Ks.50/- per bundle of 1 - 1.5'Xg-l		
	Yeu	Ks.715/- per 100 pieces of 15" X 4" X 2'"			Ks.1.5 per 5 pieces of 1"X1"X1"
4	Monywa	Ks.1200/-per stacked tonof8"X5"Xl'	Ks.24/-per 10 pieces of 13"X2"X1"		
5	Sagaing	Ks. 1900/-per 100 pieces of 1-1.5"X g-5" short poles		Ks. 10/-per 4 pieces of rx2~xr	Ks.6/-per 12 pieces of rrxg-r
6	Myinmu	Ks.2300/-per 100 pieces l-l-8"Xg-1.3"	—	—	—

Note: 1-1.y\' g-2' = length I 5 feel A girth 2 feet. 15"X4"X2" = length 13 inches, width 4 inches, thickness 2 inches.

Source: Energy- Planning Department. Minislty of Energy. Sagaing Division. 199S.

When analysis is made on the price of wood fuel in some townships, we can see that in urban areas where population is crowded, and the demand for fuel is high. This is the cause of wood fuel price being higher in some Townships. For example, price ofwoodfuel of Monywa. Sagaing and Myinmu Townships are 1200/ks, 1900/ks and 2300/ks while Kambalu and Ye-u township's wood fuel prices are 840/ks and 715 /ks respectively. Even in Kambalu and Myinmu Township's wood fuel price is different as the transportation cost is added due to the difficulty in communication. A similar situation is seen in the price of charcoal in some Townships. A large quantity of charcoals are brought from the wood fuel sources of the Southern Shan state forests and northern Bago division forest, closed to Dry Zone area. The price of charcoal in remote areas is <ienerally higher than that in near by sources. Thus, the prices of charcoal in Shwebo. Khin U. and Wetlet townships are higher than those townships

which are having smooth transportation routes and are close to the wood fuel source areas.

Table 5.17 Price of charcoal m some Townships (1998)

District	Charcoal		
	90 lb bag	45 lb bag	30 lb bag
Shwebo	Ks.500/-	Ks.300/-	--
Khin u	Ks.600/-	Ks.300/-	--
Wetlet	Ks.450/-	Ks.250/-	--
Taze	Ks.350/-	Ks.180/-	Ks.160/-
Monywa	Ks.350/-	Ks.220/-	Ks.120/-
Salingvi	Ks.350/-	Ks.175/-	Ks.150/-
Yinmabin	Ks.350/-	Ks.200/-	Ks.120/-
Bulalin	Ks.350/-	Ks.200/-	-
Sagaing	Ks.400/-	Ks.250/-	-
Myinmu	Ks.400/-	Ks.225/-	Ks.120/-
Ngazum	--	Ks.250/-	Ks.200/-

Source: Euerg)' Planning Deparlinent. Sagaing Division. 1998

In order to encourage the local people to reduce using wood fuel. Government initiated the rice husk and coal fuel briquettes and distributed in the districts, (see Table 5.18). In the table from 1997-98 to 200-2001. the numbers of distribution of briquettes were increased especially in Shwebo and Monywa districts. Moreover, the efficient cook stoves were introduced and delivered to the districts, (see table 5.19). Both Tables show that Sagaing district has a smaller no of distribution compared to Monywa and Shwebo districts, because being a capital district of the Division: it was given priority to utilize the electricity. In addition city people are able to purchase gas stoves, electric stoves and other substitutes than the rural people.

Table 5.18 Production of Rice husks and Coal briquetts(in thousands)

Districts	1997-1998	1998-1999	1999-2000	2000-2001
Shwebo	--	289	583	778
Monywa	20	289	583	778
Sagaing	--	122	334	444
Sagaing division	20	700	1500	2000

Source: Dry Zone Greening Department, Sagaing Division. 1998

Table 5.19 Production of efficient cook stoves (in thousands)

Districts	1997-1998	1998-1999	1999-2000	2000-2001
Shwebo	-	3.5	5.25	7.0
Monywa	0.35	3.5	5.25	7.0
Sagaing	0.34	2.0	3.00	4.0
Sagaing division	0.69	9.0	13.50	18.0

Source: Dry Zone Greening Department. Sagaing Division, 199S.

5.6 Remedial Measures to Ameliorate Wood fuel Shortage

One of the main tasks of the Dry Zone greening department is to swiftly ameliorate the wood fuel shortage and to achieve a balance in the wood fuel supply and demand in the long run. According to the first four year plan (1997-98 to 2000-2001) the following operations have implemented to achieve the planned targets for re-greening of the Dry Zone area and for sufficient supply of wood fuel and other forest products required by the local people.

5.6.1 Establishment of Forest Plantations

With the objectives of regreening the Dry Zone area, conserving the environment, soil and water, and meeting basic needs of the local people for wood fuel and other forest products, the Department has established forest plantations amounting to about 8000 acres (3237 ha) every year.

The types of forest plantations being established in the Dry Zone area of Sagaing Division one village supply wood fuel plantations, agro-forestry plantations, watershed plantations, experimental-research plantations and regreening plantations on hills, mountains, farms, roadsides etc. Village supplies wood fuel plantations and agro-forestry plantations are generally formed in the vicinities of villages as they are intended to supply the forest products to the local villagers. Watershed plantations have been established in the watershed areas of the constructed dams for soil and water conservation.

Choice of species depends on the type of plantation, its objective, site conditions and local requirements. For village supplies wood fuel plantations, Sha (Acacia Catichu). Tama (Azardica indica), Kokko (Albizzia lebbek), Mezali (Cassia siamea). Eucalyptus spp. And Bausagaing (Laucana leucocephla) are commonly used. For other plantations, native species are mostly planted with the partial addition of some fast growing and soil improving exotic species.

Table 5.20 Forest plantations in the Division 1997-98 to 2000-2001 (Area in acres)

Districts	1997-1998	1998-1999	1999-2000	2000-2001
Shwebo	1000	3600	3060	3060
Monywa	1805	2210	2580	2580
Sagaing	770	2290	2360	2360
Sagaing Division	3575 (1447 ha)	8100 (3278 ha)	8000 (3237 ha)	8000 (3237 ha)

Source: Dry Zone Greening Department. Sagaing Division. 1998.

According to the (Table 5.20). in the whole Sagaing division from 1997-98 to 2000-2001 Forest plantation was increased from 3575 acres to 8000 acres due to the Greening project of dry Zone and the combat of desertification and drought was taken place.

5.6.2 **Conservation of the natural** forest

Existing natural forests are not yet sufficient in quantity and quality to meet the basic needs of the local people. Consequently, the Dry Zone Greening Department, in cooperation with the Forest Department, has tried to extend the reserved forest and Protected Public Forest areas so that they can be strictly protected under the forest law and scientifically managed according to the annual work plan of the Department.

According to the annual work plan, the Dry Zone greening department is intensively protecting some of the natural forest selected form among the degraded forests, giving priority to that close-by the thickly populated areas. The intensive conservation works include field survey and demarcation of the selected forest area, provision of educative labels and signboards, patrolling of forest guards and watchmen to prevent illegal cutting, fixing and encroachment. As the existing natural forests, in due time, will be able to provide the fuel, food, fodder, and building materials to the local people, the Department is now implementing conservation measures for those forests in collaboration with the people living in nearby villages.

In addition to conservation activities, natural regeneration (NR) activities are also being carried out in some selected natural forests with fairly dense and good growth. The main objective is to improve the natural regeneration of some valuable species and at the same time to provide some wood fuel by eliminating weeds and unwanted trees, coppicing the damaged valuable trees and pruning the lower branches of commercial species. As it is estimated to produce about 0.3 ton of wood fuel from one acre of natural regeneration, this operation could provide about 900 tons in 1998-99 and 1500 in 1999-2000 and 2000-2001.

In order to regreen the Dry Zone area, cultivation of natural forest and Natural regeneration works has being started intensively from 1997-98 to 2000-2001 (See Table 5.21, 5.22). With this rate Dry Zone could return into a green area by the year 2050.

Table 5.21 Cultivation of natural forests (areas in acres)

Districts	1997-1998	1998-1999		1999-2000	^000-2001
		By Department	By People		
Shwebo	12,000	12,000	18,000	30,000	30.000
Monywa	6,000	6,000	9,000	15,000	15,000
Sagaing	2,000	2.000	3,000	5,000	5,000
Sagaing Division	20,000 (8094 ha)	20,000 (8094 ha)	30.000 (12,141 ha)	50,000 (20,235 ha)	50,000 (20,235 ha)

Source: Diy Zone Greening Deportment, Sagaing division, 1998.

Table 5.22 Natural Regeneration works *{Area in acres)*

Districts	1997-1998	1998-1999	1999-2000	2000-2001
Shwebo	-	1500	2500	2500
Monywa	-	1000	1750	1750
Sagaing	-	500	750	750
Sagaing division		3000 (1214 ha)	5000 (2024 ha)	5000 (2024 ha)

Source Dry Zone Greening Department. Sagaing Division. 1998.

5.7 A Case study of Ayeyawady Delta region, (Kyunyarshay, Yaedwingon and Tbeinlargutsu villages)

5.7.1 Background information of the study area.

Ayeyawady region is located between 15' 42' N and 18" 31' N latitudes and 19" 11' and 96'20'E longitudes. It borders Bago division in the north and the east. Yangon division in the east. Rakhine state in the west and the Bay of Bengal in the south. The **present** status of land use in Ayeyawady division is given in (Table.5.23).

Table 5.23 Land use types of Ayeyawady Division in 1998

Categories	Area (ha)	%
Reserved Forests	720,258.19	20.50
Public Forests	190.286.11	5.41
Agriculture lands	1,729.011.33	49.21
Waste lands	187,931.04	5.33
Unproductive lands	686,921.08	19.55
		100.00

Source: Land use department. Yangon. Myanmar. 1998.

The total number of households in Ayeyawady division is 1,195, 364 and the total population is 6.4.35.636 persons. The majority of the populations live in rural areas. Rural people collect wood fuel from a variety of sources, e.g. forest lands, waste lands, homestead, trees growing on farm lands, wood lets, agricultural fallows and garden lands. The majority of Wood fuel comes from non-forest areas. Generally, these areas belong to the farmers and gardeners. Some areas belong to the government and the communities. Wood fuel is collected for self-use and the surplus is sold or distributed to other households. Most of the wood fuel used in Ayeyawady division comes from villages. Wood fuel is collected from both forestlands and non-forest lands. However, data on the production from non-forest areas have not been collected as yet and consequently its contribution to the socio economic status of the rural people cannot be assessed.

In this case study, thus, a detailed study was conducted in three villages in Ayeyawady division, namely Kyunyarshay village in Pathein District, Yaedwingon village in Hinthada District and Theinlargutsu village in Myaungmya District .The study focused mainly on the production of wood fuel, method of collection of wood fuel, utilization and its contribution to the socio economic status of rural communities from non-forest sources namely garden lands, homesteads and wastelands .The growing stocks on non-forest lands have been surveyed and assessed and their supply estimated.

5.7.2 Objectives of the Micro-level village study

A reliable energy database containing data of fuel production and people who do not depend on forestlands for meeting their total energy requirements is necessary for the development of sustainable energy policies and planning for the future. Therefore, the present study aimed to: -

(1) determine the production of wood fuel from non-forest areas;

(2) investigate the contribution of non-forest area based wood fuel production to the socio-economy of rural communities; and

(3) predict the potential supply of wood fuel production from non-forest sources.

5.7.3 Methodology

There are five districts in Ayeyawady division. Out of five districts, which are having non-forested areas, only three districts were selected randomly. The selected districts include Pathein, Hinthada and Myaungmya. After the selection of three districts, one township from each was selected randomly. The selected townships were Kangyidaunt Township from Pathein District. Zalon Township from Hinthada district, and Myaungmya Township from Myaungmya district. The final step was to randomly select one village from each selected township. During the third stage, villages situated closed to forested areas were not considered. The sample villages were Kyunyarshay from Kangyidaunt Township in Pathein district, Yaedwingon village from Zalon Township in Hinthada district, and Theinlargutsu village from Myaungmya Township in Myaungmya district.

5.7.3.1 Sampling design for households

Lists of households for the selected villages were prepared. There were 134 households in Kyunyarshay, 180 in Yaedwingone. and 213 in Theinlargutsu. The households were visited to collect the relevant information on the availability of wood fuel, use of wood fuel, ownership of garden lands and socio economic status of the villagers. The data collected for each household were compiled, computed and analyzed.

5.7.3.2 Estimation of tree density on non-forest areas

(a) Trees on homesteads

For the enumeration of trees on homesteads, sample households were visited. All the trees within the household periphery were recorded by girth and species. Using the volume equations development by the National Forest management and Inventory (NFI) for Ayeyawady division, the volume of individual trees was calculated and completed.

(b) Trees on garden lands

The wood volume of trees on garden lands was estimated from the data gathered on rectangular sample plots of 0.40 hectare. The entire tree above and up in girth were measured at breast height during the survey. Girth measurements were taken up to the nearest after which calculation of the tree volume was earned out.

(c) Trees on farm and wastelands

In the case of Theinlargutsu village, the location of the sample plots was determined in the following manner:

Theinlargutsu village is situated on the side of Theinlar chaung (stream). The area outside the village was divided into eight sections. Two sections were selected as sample plots at random, the trees of 1 foot (girth breast height) and above growing on the sample plots were measured, except for those trees growing on garden lands. In the case of Yaedwingon village, farm and water lands are located only on one side of the village. The area was divided into four sections and one section was selected randomly. All trees in the sample were measured. Kyunyarshay village is located on the side of a stream and the water lands are divided into four sections. One section was randomly selected as a sample plot.

5.7.4 Study of Kyunyarshay village

5.7.4.1 Profile of Kyunyarshay village

Kyunyarshay village is located in Kangyidaunt Township in Pathein district.

The village has from 16' 50' to 16' 56' North latitude and 94' 46' to 94' 48'East longitude. In the North, the area beside delta chaung is flat. In the West, are paddy fields, and garden lands are found in the east. A portion of the area in the south is a grazing land connected to which water land is covering the rest of the southern part. The topography slopes gently down from the north towards the south and the East. The annual rainfall ranges from 109 inches to 119 inches. Maximum rains are received during the period of June, July. August and September. The minimum and maximum temperatures are 17 C and 36 C respectively.

5.7.4.2 Land use status

The current land use in Kyunyarshay is stated in Table 5:24 below:

Table 5.24 The status of land use in Kyunyarshay village

Category	Area (ha)	%
Village lands		0.63
Agricultural lands	64.75	18.25
Garden lands	77.61	21.87
Waste lands	62.32	17.56
Grazing lands	147.95	41.69
Total	354.85	100.00

Source: FieldM-ork. I99S.

Referring to the Table (5.24), Total area of Kyunyarshay village is 354.85 Sq. ha. Out of the area, grazing lands are 147.95 ha (41.69%), Garden lands are 21.67%, agriculture lands are 18.25 %. waste lands (17.56%) and village lands are 0.63% of the total area of the village. No trees other than clumps of bushes are found growing both on water lines and on grazing lands. Virtually, all agricultural lands are paddy fields bearing no trees.

5.7.4.3 Social and economic situation

The population of Kyunyarshay village was 672 persons in 1998. There are 134 households with 370 males and 352 Females. Kyunyarshay has one state primary school, one dispensary and one monastery. It is possible to go from Pathein Township to village by car throughout the year. During the dry season, it is possible to go from Wayanchung village to Kyunyarshay village on foot or by bike but only by boat during the rainy season.

In terms of the occupation of the people, 54% of the households are labourers, 17% of households are wholly dependent on agriculture. 13% of the households are engaged in gardening, 12% of the households are partially dependent on agriculture, only 1% of the household are working as government servants and 3% in other services. Out of 72 labourers, 24 are engaged in selling wood fuel. The rest grow betel leaf and vegetables and some work for daily wages. The distinctive feature of the village is that every household mainly earns its living by selling betel leaf from gardens, which comprise the main household economy in Kyunyarshay village.

5.7.4.4 Survey of households

Each sampled household was visited and the head of the household was interviewed. The data collected is presented below: -

(a) Family size versus wood fuel consumption

Generally, most of households cook food twice daily but some households cook three times. Wood fuel is mainly used for cooking. During the rainy season, lasting for four months, fires are lit for the cows using both wood fuel and bamboo fuel. During the winter season, leaves and bamboo fuel are mainly used for heating. However, this practice is not very popular among the villagers because of the risk of fire. Distribution of sample households by family size and wood fuel consumption is given in the (Table 5.25).

According to the table, the no of households in (7-9) family size group is 2 and they used 3.62 cu tons of woodfuel per year, the no of households in 4-6 family sizes is 9 units and the yearly wood fuel consumption is 2.67. There are 3 households in the group of 1-3 family size and their average yearly woodfuel consumption is 2.31 respectively. It can be seen that the larger the family size, the greater total amount of woodfuel consumed, but if per capita wood fuel use per year is calculated, the pattern changes. The lowest per capita use is by the medium size family group, followed by the large households. The small sized family groups are found to have the highest per capita use of wood fuel.

Table 5.25 Distribution of sample households by family size and wood fuel consumption

Family size (person)	Average number of Persons per household	No. of households	Average yearly wood fuel consumption per household (cu tons)	Per capita Wood fuel use in cu tons
1-3	3		2.31	0.77
4-6	4.8	9	2.67	0.55
7-9	6	2	3.62	0.60

Source: Field-work. 199S-99.

(b) Types of fuels and methods of production:

In Kyunyarshay village, the two types of fuels are wood fuel and bamboo fuel. The wood fuel accounts for 60% while the bamboo fuel accounts for 40%. Wood fuel cannot be collected from agricultural lands, farms or water lands, since there are no trees growing on them. Wood fuel mostly comes from garden lands. However, wood fuel is not available from the garden lands on which Htiyowa {Thyrsostachys-samensks) is planted. When cashew (Anacardium accidentale) plantations are young and fruiting, wood fuel cannot be collected from those areas. Wood fuel can be available from pure apple plantations where other trees such as jackfruit. brinjal (djankol). bean and mango trees are grown. Weeding operations are carried out twice annually in pineapple garden small trees are cleaned and they become wood fuel. The amount of wood fuel collected is between 4 to 6 cartloads on an area of 0.40 hectare from each weeding. Wood fuel is also obtained from felling, pruning and pollarding of old, dead and drying trees. When the trees planted on garden lands and homesteads reach pole size, the owners sell the trunk of the trees but they use other biomass as wood fuel. It is observed that within some families, a certain amount of wood fuel from their own lands is set aside for their own use and the surplus is shared among their relatives. Some owners of the garden lands sell the whole underbrush of their gardens to the labourers on piecework. The villagers collect the wood fuel from the trees growing within the vicinity of the houses felling, pollarding, and pruning. Bamboo is used as supplementary fuel and sent to Pathein for sale.

(c) Sources of wood fuel

During the dry season, bullockcarts are used to transport the wood fuel from the garden lands with the permission of the owners, wood fuel can be collected from garden lands only for self-use and within the carrying capacity of the area. Men mostly undertake wood fuel carrying although women and children sometimes do. Normally there are three days between two consecutive collections of wood fuel. Individual collectors can cany wood fuel amounting to 50 bundles at a time. The minimum and maximum distances from the center of the village are 32.8 and 40km respectively. (1 bundle = 16inches in length and 8inches in girth). Table 5.26 gives the distribution of households according to the sources of Wood fuel.

Table 5.26 Distribution of households according to the sources of woodfuel

Types of Source	No. of households	%
Own land	6	42
Market	4	29
Collection from garden lands	4	29
Total	14	100

Source: FieUhork. I99S-99

According to the table out of 14(42%) house holds. 6 households (29%) collect wood fuel from their own land 4 house holds (29%)purchase from **the market** and 4 house holds get wood fuel from garden lands.

(d) Pricing. Marketing and modes of transportation

The price of a bundle of wood fuel (16" in length X 8" in girth) is 5 Kyats. One cartload is equivalent to 400 bundles of wood fuel. Wood fuel is sold at the local village market. The traders come to the village to buy the wood fuel. The wood fuel bought is sent to Pathein (capital city of Ayeyawady division) by boat. In Kvunvarshav. 32 households are involved in the wood fuel trade: each household earns at least Kyats 10,000 annually from selling wood fuel.

(e) Estimation of tree population

The main tree species growing naturally in and around the village include Kanyin (DipteroCarpus Spp), Thabye (Eugenia Spp), Mezali (Cassia sia mea). Taung-thale (Garcizia Cowa), the other found scattered here and there are Leza (larger stromia spp) and Thitsein (Terminalia belerica).

The data from the sample plots in the field and water lands surrounding the village are summarized. For each source of non-forest areas in the village, growing stocks are given in table (Table 5.37). A total of 55.08 ha were taken as a sample area for all sources in Kyunyarshay village. A summary of growing stock by species growing on homesteads of sampled households is presented in the table 5.27 below:

Table 5.27 Trees enumerated on 14 households

Study Group	Total Trees Enumerated	Average Girth (inches)	Total Volume (cu ton) Solid Volume
* Group-1	4	2'0"	2.0
Group-2	18	26"	5.0
Group-3	74	2'0"	21.0
Group-4		26"	5.0
Group-5	36	2'6"	5.0
Total	155	1l'6"	38
Average/household	11.1	98'5"	2.71

Source: Fieldwork. 199S-99

** Group refers to the study group that sun-eyed a specific study area in the village.*

5.7.5 Study of Yaedwingon village

5.7.5.1 Profile of Yaedwingon village

Zalon Township in Hinthada district, the village lies from 17'20' to 17'33' North latitude and 95'75' to 9544'East longitude. In the North, the area is flat with gardens. Htone chaung is located in the west and paddy fields are found in the East. Paddy fields and dry cultivation lands are found on the area in the south. The topography is generally flat. The annual rainfall ranges from 72 inches to 76-inches. Maximum rains are received during the months of June, July and August. The lowest temperature is 11 C and occurs mostly in January. April is the hottest month with the maximum temperature of about 40 C.

5.7.5.2 Land use status

The current land use in Yaedwingon village is given the table (5.28).

Table 5.28 Status of land use in Yaedwingon village in 1998

Category	Area (ha)	%
Village lands	9.39	3.43
Agricultural lands	220.28	80.56
Garden lands	37.26	13.63
Unproductive areas	2.48	0.91
Embankment areas	4.02	1.47
Total	273.43	100.00

Source. Lund use Depariinenl Ayeyuwudy Division. I99S.

According to the table, the area of Yaedwingon village is 273.43 acres. Out of the total area, agricultural lands are is 220.28(80.56%). Garden lands area is 37.26 acres (13.63%). village lands area (which belongs to all villagers) is 9.39 acres (3.43%), Embankment area (prone to floods) is 4.02 acres (1.47%) and unproductive areas is 2.48 acres (0.91%). As the villagers are engaged in agriculture 80.56% of the village land is occupied by cultivation. Kokko trees are growing here and there in the paddy fields and kokko, Kanaso. Mani-awga, Thabye. Pyinma, and Ma-u trees are growing sparsely on garden lands.

5.7.5.3 Social and economic situation

The population of Yaedwingon village was 672 persons in 1998. There are 180 households with 420 males and 457 females. Yaedwingon has one state primary school, one dispensary and one monastery as in Kyunyarshay village. Yaedwingon is 6 miles away from Zalon Township. During the rainy season it is possible to go by power scooter directly from Zalon to the village, in the dry season, it is possible to go by power scooter from Zalon to Nandawkyun village, and Nandawkyun to Yaedwingon. a distance of 3 miles, by bullockcart. The distribution of households by occupation in Yaedwingon village is given in table (5.29).

Virtually all labourers are involved in different jobs including rice growing, dry cultivation, fishery etc. The labourers also earn money by selling the trees and making Wood fuel fuel for owners of garden lands. Out of the 180 households in the village. 92 households (51.11%) are working as labourers, 62 households (34.47%) are partially dependent on agriculture. Those households who are wholly dependent on gardens are 16 or (8.88%) and wholly dependent on agriculture households are only 9 or (5%) of the total of the village. From the figure, we can observe that most of the villagers are poor families earning by their labour.

Table 5.29 Distribution of households in Yaedwingon village according to occupation

Sr. No	Occupation	No of households	% of house holds
1	Wholly dependent on agriculture	9	5.00
2	Partially dependent on agriculture	62	34.47
	Wholly dependent on gardens	16	8.88
4	Government Service	1	0.55
5		92	51.11
	Total	180	100.00

Source. Fiektwork. 1998-99.

5.^,5.4 Survey of households

All sampled households were visited and the head of each household was interviewed, the data collected is presented below: -

(a) Family size versus wood fuel consumption

Some households properly cook food twice daily, while some cook three times. Wood fuel is mainly used for cooking. During the rainy season, fire is built for cows using tree stumps and roots together with rice husks. However, heating is not common in the village. Distribution of households by family and wood fuel consumption is given in table (5.30).

Table 5.30 Distribution of sample household by family size and wood fuel consumption.

Family Size	Average persons Per household	No. of Households	Average yearly wood fuel consumption per household(cu tons)	Per Capita Wood fuel use per year
01-03	2.6	-i j	1.24	0.47
04-06	5.3	12	3.20	0.60
07-09	7.3	-i j	3.38	0.46

Source: Field work 199S-99.

When wood fuel consumption of the village is analyzed, we found that in the family size of (7-9). even though there are 3 households, their average yearly consumption of woodfuel is 3.38 cubic tons. In the family size of (4-6) are 12 households who consumed annually on an average of 3.20 cubic tons. The smallest family size group (1-3) has 3 households and their yearly average consumption is 1.24 cubic tons. Thus, the bigger the family size, the greater the consumption. But if per capita use is considered, this picture changes. The larger households show the least per capita wood fuel use. followed by the smallest households. It is the medium sized households that record the highest per capita use. unlike that observed in Kyunyarshay village where the group reported lowest per capita use of wood fuel.

(a) Types of fuels and methods of production

In Yaedwingon village, the main types of fuels are Wood fuel, maize stems and other biomass of bushes. Nearly 100 out of 180 households use bioniass of bushes and maize stems together with Wood fuel. Wood fuel accounts for 75% while the other biomass fuel accounts for 25%.

A large quantity of wood fuel in Yaedwingon comes from garden lands. Some households obtain Wood fuel from homesteads. Wood fuel is available from pruning and pollarding of the trees growing on garden lands, farms and wastelands, and from the felling of dead, dying and old trees. Pollarding of Kokko trees is earned out once in three years for Wood fuel. Old trees such as Kokko. Pyinma, and Ma-U are felled and their trunks used for housing and boat making. Roots, branches, lop, and tops are used for Wood fuel.

(c) Source of Wood fuel

During the dry season, the owners of the garden lands get the laborers to fell the trees and made wood fuel (generally measurement (12"" x 5" x 1"). The owners maintain a certain amount of wood fuel for their own use and the surplus is sold. Some villagers collect the Wood fuel from the garden lands, in the fields around natural ponds and lakes, and from trees growing wild.

(d) Pricing, marketing and modes of transportation

The price of a piece of wood fuel (12" in length x 5" in breadth x 1" in thickness) is K 1.50. One cartload is equivalent to 500 pieces. A piece of Wood fuel is sold in Zalon township at a price of K 2.50. or 3.0. A cartload of lops are sold at a price ofKyats 200.The common mode of transportation is by boat.

(e) Estimation of tree population

The main tree species growing naturally in and around the village include Ma-U, Thayet, Ma-ni-aw-ga. Kokko, and Sit. The others found scattered around the village are Htein and Pyinma. The data collected on the sample plots on homesteads, garden lands, and farms and wastelands are given in Appendices 3. and 5. A total of 49.08 ha were taken as a sample area of all non-forest sources in Yaedwingon village.

See table (5.31) below:

Table 5.31 Trees enumerated on 18 homesteads

*GROUP	Total Areas Enumerated	Average girth (inches)	Total Volume (cu ton) Solid Volume
Group-1	-	--	--
Group-2	20	3"20"	9.0
Group-3	60	2"6""	21.0
Group-4	35	2"0"	8.0
Group-5	14	2'0"	1.0
Total	129	9¯6"	39.0
Average/household	7.16	0.6"	2.17

*Source: Field work) 199S-99). *Group refers to the study group thai survey a specific area in the village*

5.7.6 Study of Theinlargntsu village

5.7.6.1 Profile of Theinlargutsu village

Theinlargutsu is a village within Myaungmya Township in Myaungmya District. The village is located within 16' 20' to 16'26' North latitude and 94'46' and 94'50 ' East longitude. The topography gently slopes towards the north, the south and the West. Paddy fields. Nipa palm (Nipa fruit cans) plantations, and inundated areas are found in the flat area. Predominant type of soil observed in the village in sandy-loam. The annual rainfall ranges from 97 inches to 110 inches. The minimum and maximum temperatures are 30'C and 39.5' C respectively.

5.7.6.2 Land use status

The present status of land use in Theinlargutsu village is shown in the table 2.32. Among the land use patterns, plantations and inundated lands are the highest in percentage covering about 61.98% with garden lands 19.39%, agriculture lands 11.35%. unproductive lands 0.55% while others are 5.70%, and village lands only 1.03%. The plantations and inundated lands are mostly Nipa gardens. Betel leaves garden and some are inundated lands, which is usually affected by floods. All agriculture lands are paddy fields. Various tree species are growing on garden lands and among them are Penne, Thayet. and Danyin. Trees are hardly found on grazing lands.

Table 5.32 Status of land use in Theinlargutsu village (1999)

Sr. No.	Category	Area (ha)	%
1	Village lands	7.52	1.03
	Agriculture lands	83.17	11.35
j	Garden lands	142.10	19.30
4	Plantations & inundated lands	453.97	61.98
5	Unproductive lands	4.05	0.55
6	Others	42.68	5.70
	Total	732.49	100.00

Source: Field work. I99S- 99/

5.7.6.3 Social and Economic Situation

The population of Theinlargutsu village is 1104 persons in 1999. There are 213 households with 584 males and 520 females. As in Kyungyarshay and Yaedwingon. Iheinlargutsu also has one state primary school, one dispensary and one monastery. The communications links are fairly good. It is possible to go from Myaungmya to Theinlargutsu both by car and by river throughout the year. Table (5.33) gives the distribution of households of Theinlargutsu village according to the nature of occupation.

In the village of Theinlargutsu total number of households are 213,out of which 75 households (35.21)% are working as labour, 47 households (22.07%) are partially dependent on agriculture. 71(33.33%) households are wholly dependent on garden, in the Government service are 8 households (3.76%) and the remaining 12 households (5.63%) are working in the other jobs. Overall based on the percentage of the various occupations, we can determine that this village relies on gardens and labour work.

Table 5.33 Distribution of households of Theinlargutsu according to occupation

Sr.No 1	Occupation	No. of Households	% of Households
1	Wholly dependent on agriculture		
i	Partially dependent on agriculture	47	22.07
	Wholly dependent on gardens	71	JJJJ
4	Government Service	08	3.76
	Labour	75	35.21
6	Others	12	5.63
	Total	213	100.00

Source: Fieldwork 1998-99.

All sampled households were visited and the head of each household was interviewed. The data collected are presented below:

(a) Family size versus Wood fuel consumption

Some households generally cook food twice daily but some also thrice. Distinction of sample households by family size and Wood fuel consumption is given in the table (5.34).

Table 5.34 Distribution of sample households by family size and Wood fuel consumption

Family Size (Persons)	Average Number of Persons per household	No. of Households	Average yearly wood fuel consumption per household (centres) total volume	Per capita Wood fuel use Per year
01-03	2.6		2.3	0.88
04-06	5.07	14	3.14	0.62
07-09	7.6	J	2.91	0.38
09 and above	13.0	1	3.38	0.26

Source: Fieldwork. 199S-99.

In Theinlargutsu village, there are 21 households. Among these households. 14 are included in family size of 7-9; 3 families in the size of 4-6 family size; 3 in the group of 1-3 family size, and 1 in the above 9 family size. When wood fuel consumption is assessed, in the family size above 9, 3.38 cubic tons were consumed. In the family size of 4-6 consumption is 3.14 cubic tons, in the family size of 1-3 group consumed 2.3 cubic ton on average annually, and 7-9 size groups consumed 2.91 cubic tons. The per capita wood fuel use per year shows a different picture. The larger the family size, the lower is the per capita wood fuel use. thereby suggesting economies of scale. In the largest family size of above 9 the per capita use is 2.06 while in the smallest family size of 1-3 the per capita use raises to 0.88.

(b) Types of fuels and methods of production

The owners of the garden lands mainly use Wood fuel from their garden lands but they use bamboo fuel just for starting a fire. The rest use both Wood fuel and bamboo fuel. Laborers mostly use bamboo fuel. Wood fuel accounts for 80% while bamboo fuel accounts for 20%. The owners of garden lands obtain Wood fuel by cleaning under bushes, felling, pruning and pollarding of old. dead and dying trees. Big trees are felled and the trunks are used as timber for housing. The remaining biomass is used as Wood fuel. A few persons in the village have to buy Wood fuel.

(c) Source of Wood fuel

With the permission from the owners. Wood fuel can be collected from garden lands only for self-use and within the area of carrying capacity. Villagers also collect Wood fuel from trees, which grow on farms and wastelands. Men and women mostly undertake Wood fuel carrying, but children sometimes do too. Villagers also use only bamboo as Wood fuel. Table (5.35) gives the distribution of households according to the sources of Wood fuel. Out of 21 households in the village. 17 households (66.7%) are collecting wood fuel from garden lands with free of charge and 7 house holds (33.3%) collect wood fuels from their own land.

Table 5.35 Distribution of households according to sources of wood fuel.

Type of Sources	No. of Households	Percentage
Own Land	7	
Market	--	--
Collection from garden lands (free of charge)	17	66.7
Total	21	100.00

Source: Fieldwork. I99S-99.

(d) Pricing, marketing and modes of transportation

A bundle of Wood fuel having a size of 8" in girth and 16" in length is sold at K 5 whereas a bundle wood fuel with 18" in girth and 25" length at K 7. Villagers in Theinlargutsu sell the wood fuel in the village. There are 30 households involved in selling Wood fuel and it is reported that each household annually earns about K (12,000) on the average. A trilogy full Wood fuel is sold at K 1,500 in Myaungmya.

(e) Estimation of tree population

The main tree species growing naturally in and around village are Peinne, Taungthayet. Ananbo, Tha-bye and Danyin. The data collected on the sample plots on homesteads, garden lands, and farms and wastelands are given in 6.7 and 6.8. A total of 147.81 ha were taken as a sample area for all the non-forest sources in Theinlargutsu village. A summary of growing stock by species grouping on sampled homesteads is given in table (5.36).

Table 5.37 reveals that in Theinlargutsu village total growing stock of trees is 19918, Yaedwingon village total growing stock of trees is 3377. and Kyunyarshay total growing stock is 17779. Growing stocks from garden lands is big in Theinlargutsu and Kyunyarshay. with 17757 and 17171 number of trees. Homesteads growing stock from Theinlargutsu is 917. Yaedwingon 927, and Kyunyarshay 608 in number of trees. Among the three villages, Yaedwingon has the least stock of trees and is probably ecologically the most degraded.

Table 5.36 Trees enumerated on 21 homesteads

* Group	Total Trees (Enumerated)	Average girth (inches)	Total Volume (cu ton) Solid Volume
Group-1	--	-	-
Group-2	-	-	-
Group-3	34	2"0"	8
Group-4	-	-	-
Group-5	5	1'6"	-
Total	39	3'6"	8
Average/Household	1.85	2"	0.38

Source: Field work 1998-99.

**Group refers the stitch' group that surveyed a specific area in the village.*

Table 5.37 Present growing stocks of Kyunyarshay. Yaedwingon and Theinlargutsu

Sr. No	Name of Village	Source	No. of Trees	Stock Volume (Solid Cu ton)
1	Kyunyarshay	i. Garden lands	17171	3946
		ii. Homestead	608	176
		iii. Farm, wasteland	-	-
		Total	17779	4122
2	Yaedwingon	i. Garden lands	2370	1185
		ii Homesteads	927	309
		iii Farms of wasteland	80	56
		Total	3377	1550
j	Theinlargutsu	i. Garden lands ii.	17757	4414
		Homesteads	917	235
		iii. Farms of wasteland	1244	252
		Total	19918	4901

Source: Field work. I99S-99

5.7.7 Wood fuel demand and supply situation: A comparison of the three villages

Wood fuel demand in 1998 for Kyunyarshay village was 737.86 cu tones (solid volume). Total number of trees growing on non-forest areas in Kyunyarshay village is estimated at approximately 17,800 with a volume of 4,122 cu tones. The present demand is being met from the village resources. This means that about one sixth of the standing biomass is being removed. In other words, about 3000 trees growing on non-forest lands are being removed to meet the 1998 fuel demand.

Wood fuel demand in 1998 for Yaedwingon village was 534.97 cu tones (solid volume). Total number of trees growing on non-forest areas in Yaedwingon village is estimated at approximately 20.000 with a volume of 41901 cu tones. The present demand is being met from the village resources. One third of the standing biomass and 1200 trees grown on non-forest land are being removed to meet the demands of 1998 requirements. This points to a faster rate of depletion of biomass in Yaedwingon village compared to the other two.

Wood fuel demand for Theinlargutsu in 1998 was 534.97 cu tones (solid volume). Total number of trees growing on non-forest area in Theinlargutsu village is estimated, approximately 20,000 with a volume of 4901 cu tones. The demand is being met from the village resources. About a quarter of standing biomass and about 5000 trees growing on non-forest lands are being removed to meet 1998 fuel demand of Theinlargutsu village.

5.7.8 Future Prospect for Supply and Demand Situation of the Study Area

To predict for the future prospect for supply and demand situation of Kyunyarshay village: -Assuming that the present stock below 1 feet girth is four times the stock above 1 feet girth, estimated allowable cut up to 2010 is 951.86 cu tones. It is apparent that one sixth of the tree population is to be removed annually to meet the local Wood fuel demand in Kyunyarshay village. Taking it roughly as 16% of total growing stock, at least 3000 trees need to be planted to maintain the status quota. For Yaedwingon village, assuming that the present stock below 1 feet girth is seven times the stock above 1 feet girth; estimated annual allowable cut up till 2010 = 555.25 cu tones.

At present one third of tree population is to be removed annually to meet local Wood fuel demand. Taking it roughly as 3.3% of the total growing stock, at least 2000 trees need to be planted to maintain the quota. Yaedwingon would have experienced an acute shortage of Wood fuel after the year 2000. The demand wood exceeds the potential supply of the village at that time. The present growing stock in Yaedwingon is relatively poor. It was, therefore, suggested that more than 6000 trees should be planted to have a good stock in and around the village annually.

For Theinlargutsu village, assuming that the present stock below 1 feet girth is five times the stock above 1 feet girth, estimated annual allowable cut up to 2010 is 1319.18 cu tones. It is observed that in Theinlargutsu village, a quarter of the tree population is to be removed annually to meet the local Wood fuel demand at present 25% of the total growing stock, at least 5000 trees need to be planted to maintain the status quota. Theinlargutsu will maintain a supply and demand balance until 2010. The present growing stock in Theinlargutsu is best among the study areas. It is. therefore, suggested that 6000 trees should be planted to have an adequate supply of biomass energy in the village (see table-5.38).

Table 5.38 Trends in demand and supply potential of wood fuel in the 3 villages up till 2010

Year	Kyunyarsliay Vil age			Yae ,mgor, Village			Thcmlar JUISU Village		
	1.84% growth rate	Estimated Demand (cu ton)	Estimated •AAC (Solid Volume)	Populati 1.84% growth rate	Estimated Demand (cu ton)	Estimated AAC (Solid Volume)	Populalio nat 1 84% growth	Estimated Demand (cu ton)	Estimated AAC (Solid Volume)
199S	072	757 S6	951 86	S77	534 97	353.25	1104	1069 78	1319 142
I'M')	6S4 36	751 45	951.86	S93 14	544. SI	335.23	1124.31	I0S9 46	1319 1S4
2000	699 96	765.26	951 36	909 57	551 S4	555.25	1145 00	110951	1319 1S4
2001	704 7S	779.54	951 S6	926 31	565.05	555 25	1166 07	1129 92	1319.184
2002	722.84	715 6S	95I.S6	943 55	575.44	5X3.23	1187.52	115071	1319.184
2005	736 14	S0S.2S	95 1.86	960 71	5X6.05	333._3	1209 38	1171.88	13I9.IS4
2004	749.09	823 16	951 86	97S 39	596 S2	555.25	1231 63	1193 45	1319.184
2005	765 98	S3S.3O	951 86	996 59	607.80	333._3	1254 29	1215.41	1319.184
2006	777 55	853 73	951.86	1014.72	61S9S	555.25	1277.57	1237.77	1319 1S4
2007	791 84	So9 44	951 86	1035.59	630 37	333 25	I300.S7	1260.55	1319 184
200S	S06 40	885.43	951.86	105241	641.97	555.25	1324.81	I2S5.74	1519 IS4
2009	821.24	901 72	951.86	1071.77	655 7S	555.25	1349 IS	1507.36	1319 184
2010	850.51	9IS32	951 86	10') 1 49	665.81	33 ,_3	1574.01	155142	1319.184

Source: Fielchvork. 1998-99

5.8 Summary

In the **Dry Zone:**

The present study indicates that electricity and other commercial fuels are used only by a small percentage (less than 7%) of house holds in the Dry Zone area of Sagaing Division. The existing actual forest are only 27.6% of the Dry Zone area of Sagaing division and quantitatively and qualitatively are not yet sufficient to meet the basic needs of the local people, especially in Sagaing and Monywa districts.

The natural forests in the vicinity of the villages are still being affected by- repeated cutting of wood fuel and are being encroached for cash crops planting, as a result, the degraded forest areas are gradually expanding in the Dry Zone area. As most of the wood fuel has to be imported, outside the Dry Zone by rail, road and boat, the people have to pay higher prices due to increasing transportation charges. This increases their burden. Due to the wood fuel deficit and its high price, the local people have been using various types of wood fuel substitutes such as agricultural residues, forest waste, animal waste, coal briquettes etc., contributing about 25.5% of the fuel consumed for household cooking.

Wood fuel substitutes are also widely used for some commercial purposes. Rice husks and groundnut shells are used in medium-sized evaporated milk plants and sawdust in small-scale units. Sawdust is also used for yarn dyeing and sugar mills in towns. Coal briquettes have been introduced to brick kilns and to some restaurants and teashops. Due to the weakness of forestry extension services, the full cooperation and active participation of the local people have not been achieved yet in forest conservation, forest plantation, and utilization of wood fuel substitutes.

In the Ayeyawady **Delta** :

Wood fuel is collected from three non-forest sources: namely garden lands, homesteads, and waste lands. Non-forest lands contribute significantly to meeting the wood fuel needs of the rural communities living in the study areas. Non-forest area based wood fuel productions are adequate at present and until the foreseeable future. Their contribution to the rural socio economy is also significant in terms of self-sufficiency, employment and household economy. Wood fuel consumption varies considerably; about 737.86 cubic tones in Kyunyarshay village and 534.97 cubic tones in Yaedwingon village while it is 1069.78 cubic tones in Theinlargutsu village. The minimum potential annual supplies up to 2010 are projected to be 951.86 cubic tones, 555.25 cubic tones and 1319.18 cubic tones for corresponding villages.

Annual incomes from sales of wood fuel collected from the three sources are estimated to be 320,000 kyats by 32 households in Kyunyarshay village. 84.000 Kyats by 16 households in Yaedwingon village, and 30 households in Theinlargutsu village estimate annual incomes from sales of Wood fuel collected from the three sources to be 320.000 kyats by 32 households in Kyunyarshay village. 84.000 kyats by 16 households in Yaedwingon village, and 360.000 kyats. In the light of growing population and booming market for wood fuel, the status quota of supply and demand in the villages could be upset. It is estimated that while wood fuel production from non-forest areas in Kyunyarshay and Theinlargutsu villages could be adequate up till the year 2010, as their demands in 1010 would be 918.32 cu tons and 1331.42 cu tons, and still not reached to the estimated ACC Solid volume of 951.86 and 1319.184 cu tons respectively. But, Yaedwingon would experience a severe shortage of Wood fuel after the year 2001 as the village's demand already reached over the estimated AAC solid volume 555.25 cubic tons since 2001. The actual estimated demand for Yaedwingon village is 665.81 cu tons for the year 2010. Thus, the required amount of 110.56 cu tons would be purchased from outside areas of the village. From this village study it is seen that Yaedwingon village is the worst affected in terms of biomass availability while Theinlargutsu village is the best placed in this regard.

CHAPTER-VI

CONCLUSION AND MAJOR FINDINGS OF THE STUDY

The first chapter presents an elaborate analysis of the importance of climate as a key in understanding regional differentiations and the study has shown the existence of a direct inter-relationship between the climate of Myanmar and its environment. It is, therefore, understandable that each and every human activity is shaped by the geographic influences. Critical analysis of diverse environmental regions, makes it clear that climate is the most fundamental and far reaching of the natural elements that control human life. In brief, climatic conditions have complex bearing on soils, vegetative cover, plants, crops, commerce and above all, human health. Even the surface of the land is modified to a large extent by the action of climatic elements; the type of climate largely controls natural vegetation and the pattern of our own land use. Man's efforts towards weather modification have lead to serious meteorological consequences.

Large scale human activities such as crop production, artificial precipitation, and hail suppression are some of the efforts directed towards weather modification of the environment. Even if our science and technology are capable of modifying weather and climate to a certain desired level, the innumerable international implications and the possible consequences should not be forgotten. It is due to growing awareness of its vagaries that under the understanding of the World Meteorological Organization (WMO) and with the active participation of the International Council of Scientific Union (ICSU) the United Environmental Programme (UNEP). the Food and Agricultural Organization (FAO), the UNESCO and other organizations, a number of programmes have been launched to meet the new challenges. These include the World Climate Programme (WCP). which has been divided into four components: the World Climate Research Programme (WCRP). The World Climate Applications Programme (WCAP), The World Climate Impact Studies Programme (WCIP) and the World Climate Data Programme (WCDP).

The chapter further discusses the general circulation of the atmosphere indicating that the upper atmosphere is constantly in motion. It has also attempted to understand global circulation of the atmosphere and its impact on rainfall, by developing simplified graphical models of processes that produce the system. It has defined the general circulation as the nature and course of average, long period patterns of the very basic simple trends of the atmospheric motion, on the large scale. In the other words, the general circulation means the movement of the atmosphere, giving characteristic system of wind and pressure that are either seasonal or all year round in nature.

The monsoon circulations are important to many countries of Asia and Africa because of their capacity to generate seasonal rains. Agriculture and the replenishment of water resources rely heavily on monsoon rains .The economy of many countries is thus, dependent on the timely arrival and subsequent distribution of rains. As the monsoon in Myanmar is one of the most important natural meteorological phenomena for the agricultural activities, each year these activities are regulated according to its behaviour.

The study also found that Global circulation pattern has some relationship with monsoon rains in Myanmar. The atmospheric circulations in winter (December, January, and February) exhibit substantial low frequency variability. This fluctuation often strongly influenced the temperature and precipitation due to major shift of locations and intensity of jet streams and storms. The primary circulation patterns, the ENSO (EL-Nino and Southern Oscillation pattern) is a major phenomenon of the tropical world with widespread repercussions with the global system and it has a marked relationship with rainfall variability of Myanmar. In the assessment of the monsoon rainfall and climatology droughts in Myanmar, during the period froml950 to 2000 the driest years were 1957-58. 1972 -73, 1977-78, 1982-83. 1986-1987, 1992-1993 and 1997-98. All the driest years coincided with the EL-Nino episodes except the year 1979. In this year drought was due to the failure of monsoon.

The second chapter on physical setting of Myanmar has depicted the physical and socioeconomic diversity of Myanmar. Physiographically. Myanmar is divided into four major divisions (1) The Sino-Myanmar ranges. (2) The Indo-Myanmar ranges, (3) The Rakhine Coast Area, and (4) the Inner Myanmar tertiary Basin. The range of Sino-Myanmar is more than 10.000 feet high and forms the water-divide line for the Ayeyawady and the Thanlwin rivers. The central portion of Indo-Myanmar Range is the continuation of Yunan highland and has an average height of about 3.000 feet to 4,000 feet. The Indo Myanmar Ranges on the west comprises a series of hills and form southern eastern extension of the Himalayas. Patkoi, Naga, Lushai, and Chin hills are more pronounced with heights over 10000 feet .The Rakhine Yoma lies in the south of the range and the average height of the Rakhine Yoma is 4000 feet in the north and about 3000 feet in the south. These Indo Myanmar ranges play a very an important role as barriers in distribution of rainfall in centra] Myanmar, selected as one of the case study areas, the **Dry Zone.** The Rakhine Coastal Area lies between the Bay of Bengal and Rakhine Yoma and is considerably wide in the north and tapers towards the south. The northern and middle portion of Rakhine Coastal strip is fringed with the near shore and off shores islands. The northern part the folded mountains align northwest to southeast. In the southern part, the coastline is much dissected by steep spurs of the Rakhine Yoma. All along the coast are numerous small river valleys and scattered sandy bays forming the scenic resorts and beaches in the region.

Indo Myanmar Ranges and Rakhine Yoma bound the Central Basin or the Inner Myanmar Tertiary Basin on the west and Eastern highlands on the east. It consists of flat alluvial plains and low uplands with some exceptions of mountain ranges and isolated hills. It can be divided into three portions: the northern most hilly region, the dry zone or middle section and the Ayeyawady Delta region.

The northern hilly region consists of river systems of upper Chindwin and upper Ayeyawady with elongated plains such as Hukaung valley. Putao. Mogaung and Indawgyi plain etc. In the middle section or the dry zone, the northern mountain ranges lower and the alluvial plains become wide. The Southernmost broad portion consists of large alluvial plains along the Sittoung valley and the wide extensive plains between the Bago Yoma and Ayeyawady River. Even on the western side of the Ayeyawady River, there are sufficient wide plains along the river, with an exception of rugged portion between Thayetmyo and Padaung Townships.

The delta of the Ayeyawady River begins at Myan-aung. The distance from the apex of the delta to the sea is roughly around 180 miles and the distance between the mouths of the Pathein and the Yangon River is approximately 150 miles. This delta region is narrow in the north and broadens southwards toward the sea. Thus, the Ayeyawady deltaic region constitutes the largest plain in Myamnar with an area of more than 12,000 square miles (31.068 sq Km). Through nine mouths linked by countless channels, the Ayeyawady River finally drains into the Katpali (Andaman) sea. The delta of Ayeyawady is gradually extending seaward, and the shelf of Mottama is slowly sitling up. The Ayeyawady River has a sedimentation rate which is the fifth highest in the world after the Yellow, Amazon. Mississippi, and Nile Rivers.

Myanmar is blessed with adequate drainage. The predominant north-south alignment of the mountain ranges of Myanmar is reflected in the direction of all rivers, large and small. Of the four main rivers (Ayeyawady, Chindwin, Sittoung and Thanlwin) of Myanmar the Ayeyawady is the largest river. The Ayeyawady occupies a total drainage basin area of more than 16,500 square miles.

Climatically, the most important feature in the climate of Myanmar is the attraction of seasons known as "monsoon". Myanmar furnishes one of the best examples of the "monsoon country'. The Southwest monsoon of Myanmar is one of the important natural meteorological phenomena for the agricultural sector of the country. It is found that over 80 per cent of the annual rainfall is received during the rainy season (mid May to mid October). The cold dry season begins with the retrieval of the southwest monsoon from October to February. Clear sky. fine weather, low humidity and temperatures and a large annual variation of temperatures are unreal features of rainy season. During the post monsoon months, depressions and cyclones originated in the Southwest and West central Bay of Bengal while the hot dry season (March to mid May) is a period of continuous and rapid rise of temperature. According to the classification of Koppen climatic types. Myanmar's climate can be classified into 6 types: tropical monsoon climate, tropical savanna climate, tropical steppe climate, sub tropical monsoon and sub tropical mountain climate, and Ice cap climate.

Rakhine and Taninthayi coastal areas, and **Ayeyawady delta** experience tropical monsoon climate, with annual rainfall of more than 2500 mm, and mean temperatures of more than 25'C. A considerable extent of the tropical Savanna climate lies immediately to the north of tropical monsoon areas. The dry season is pronounced and thus the significant difference in climate lies in the rainfall regime.

The Central Dry Zone falls into climatic zone of Tropical steppe climate (Semi-arid climate) with mean annual rainfall less than 1250mm or 49.2inches and mean annual temperature above 27'C or 80.6' F. Subtropical monsoon and sub tropical mountain climate prevails on the higher sections of Indo-Myanmar ranges and Shan Plateau with mean January temperature below 18' C or 84'4 F. Areas having a mean temperature in summer, below 27'C (71'6F) are termed subtropical monsoon climate. Tundra climate occurs in the northern frontier areas of high elevation at 1000m (3281ft) and above. The mean temperatures of the warmest month in these regions are less than 10C (32' F) or less. The icecap climate prevails over the northern most part of Myanmar at an altitude above 4000 m (13780) feet, and the mean temperature of the warmest month in October is 32'F or less.

The rich geographical spread of land and rivers, natural waterways along coastline, mountain ranges of varying altitudes and suitable environmental conditions give rise to a rich variety of forest types. Mangrove forest (Tidal forest), beach and dune forest, Swampy forest. Dry forest. Evergreen forest, mixed deciduous forest, Deciduous Dipterocarpus or indaing forest and Hill and Temperate evergreen forests are some of the diverse vegetation types found in Myanmar. Although the general climate of Myanmar is monsoon with distinct seasons, the numerous transitions between the climates of different regions resulted on an abundance of different transitional plants. Depending on the amount of rainfall, the forest types vary accordingly, deciduous forest and deciduous dipterouscarp forest are common in areas of heavy rainfall and dry thorn forest are found in places with scanty rainfall.

Related to the climate and natural vegetation, soil formation occurred to alter the present types of soils in Myanmar. In Myanmar we find three distinct soil groups: Ferrasols, Cambisols and Acrisols are predominant. Other minor soil groups are Fluvisols, Gleysols, Arenosols, Nitosols. Vertisols, and Lithosols.

The population of Myanmar was counted as 16 million in 1941 and in 1983 census it rose to 35.3 million. It showed that the population has more than doubled in 42 years. In the years 1985, 1990, 1995 and 2000, the population increased to 37.6 million, 41.4 million, 45.1 million, and 49.1 million and the total population growth rate was 1.93, 1.74, and 1.80 respectively. Comparing the growth rate of rural population to the urban population we find that urban growth rate is higher because much rural population migrated to urban areas due to the job opportunities and better urban facilities. When the rural population growth rate was 1.77% between 1985-1990, urban population growth rate was 2.77 per cent. If growth rates are analyzed for the year 1995 and 2000, rural population growth rates were 1.41 and 1.29 per cent, while urban population growth rates were 2.69 and 3.17 respectively.

The population density of Myanmar has increased over time. In 1941. population density was 25 persons per sq.km, increasing to 43 in 1973 and 52 in 1983. In 2013, the projected population density of Myanmar would be about 93.95 to 120 persons per sq km. Spatially, the density is highest in the Ayeyawady Delta region, the Central Myanmar, the Sittaung Valley, Lower Thanlwin delta around Mawlamyaing plain, Rakhine Coastal area around Sittway Plain where fertile soils for agriculture are available and the communication and transportation mode is accessible. The Shan Plateau has **moderate density** of population while the mountainous regions such as Kachin, Chin, Kayin, Kayah States and Taninthayi division are having the lowest **density** of population.

The increase in **life expectancy** in Myanmar can be observed in three stages. Between 1911 and 1941, the average increase was 1.8 years for males and 1.7 years for females in every five-year period. During the years 1953 to 1973, the average increase was 2.5 years for males and 2.7 years for females in every five years period. In the decade of 1973 - 1983: the average increase in each five-year period was 2.2

and 2.4 years for males and females respectively. According to United Nations, 2000 Escape Population Sheet, Life expectancy for male was 60 and 63 for females in Myanmar.

Myanmar is experiencing relatively high **fertility** and declining **mortality** rates. A decline in mortality rate occurred during the post war period and the greatest reduction was in the decade 1960-70. During these 10 years, decline of mortality was because of the effort of the national health programmes, started by the Government of Myanmar. In the 1960s government's expenditure on the health centers rose and was more than double that of earlier times. Estimated rates in mid-year 2000 for maternal mortality is 140 per 100,000 and infant mortality (1-4 yrs), 70 per 1000.

Crude birth **rate** fluctuated within the range of 42 to 27 per thousand populations over the 30 years period. 1950-1980. It is apparent that the crude birth rate started to decline during the decade 1970-80. This may be due to the use of fertility control among women, especially the younger generation of urban areas in the age group of 25-34 years.

The proportion of the young population (aged between 1-15 years) was about 39 percent. This further increased to 41 percent at the end of 1980. In pre-war days the dependency ratios were stable at about 0.75 on the average. However the ratios started to increase in the post war period and reached their peak in 1973 at about 0.87. Although the dependency **ratio** had declined slightly to 0.82 in 1983, it was still high. This high level will continue until the next 15 years and decrease again to 0.58 by the year 2013.

Myanmar's population was about 46 million in 1996 and spread over 7 States and 7 Divisions. Many **ethnic groups** and subgroups are descended from one of the three major linguistic groups; the Mon-Khamers. The Tibeto-Myanmars and the Thai-Shans. Myanmar is a union of nationalities of as many as 135 groups, with their own languages, dialects, and their culture. The term Myanmar embraces all nationalities: the Bamar, the Kachin. the Kayah, the Kayin. the Chin, the Mon. the Rakhine and the Shan. Current estimates hold that approximately 68 per cent of the Myanmar is Bamars. while the remaining 32 per cent is the ethnic groups. The Shans (9%) and

Karens (7%) are the most numerous of the ethnic groups. The Bamars dwell largely in the central river valley. The other minor ethnic groups are living in the surrounding mountains and coasts contain seven distinct minority states; Chin. Kachin, Karen. Kayah, Mon, Arakan (Rakhine) and Shan.

In terms of **religious** diversity, most of the people from the Divisions of Shan State, Rakhine State and Mon State are practicing Buddhism. From the remaining States especially, Kachin, Kayah, Chin and Kayin, majority are Christians. The Buddhist percentage of the population-mainly is Bamars, Shans, Mons, Rakhines and some Kayins. Most people of Indian origin practice Islam and Hinduism.

Agriculture including livestock, fishery and forestry is the most important sector of Myanmar's economy. On an average, agricultural sector accounts for nearly 60 per cent of GDP. providing employment about 66 per cent of the labour force and contribute more than 60 per cent of export earnings. It is the main source of livelihood for nearly three quarters of the population who live in rural areas. In addition to this, the sector provides not only input for processing industries but also a growing market for domestic manufacturers. During the last four years, the structure of the economy has remained substantially unchanged. The service sector accounts for more than 30 percent of GDP. The share of **industrial sector,** which comprises of energy, mining, processing and manufacturing, electric power and construction, has remained at about 10 per cent. A glance at the ownership of production reveals that the private sector is the leading sector, accounting for 77% of real G.D.P. followed by the **state sector** with 22% and **cooperative** sector with 1%. in 2000-2001.

In Myanmar, successful cultivation depends not only on the suitable soil types, but also more importantly, on the appropriate amount of precipitation received within the area. The rainfall regime and the soils formation are inteiTelated to one another. In this study, therefore, the researcher concentrates only on rainfall among the various climatic elements because rainfall is very important and is a dominant climatic factor that shapes both physical and human environment of Myanmar.

Due to the country's location, physical features, and climate the characteristics of natural vegetation, soils, and fauna are also different. These natural geographic phenomena again control the socio-economic activities, the agricultural patterns, the human activities, the communication routes, accessibility of the region, custom and culture, the language, the complexion and the food habit of the people (all the human landscapes) and make them different from one region to another. Based on these spatial differences, **seven environmental regions** can be identified: the Rakhine Coastal Strip. The Taninthayi Coastal Strip, the Western Hills Regions, the Shan Plateau Region, the Northern Hills region. The Central Dry Zone Area, and the Ayeyawady Delta Region of lower Myanmar. Among the seven regions, the **Ayeyawady Delta** Region and the Central Dry Zone Area are chosen as the study areas for this research.

Chapter Three, on rainfall variability discusses the spatial and temporal distribution of rainfall and its patterns, both annually and seasonally. The seasonal distribution of rainfall for 45 stations in Myanmar is graphed to analyze the seasonal regime. Variation in annual total rainfall for 45 stations is calculated and isolines are drawn on the map. The annual rainfall for 45 stations is classified into three categories by using percentage criterion and evaluated by determining the abnormal condition for each station, and annual total rainfalls are plotted against on the graph. Trends of rainfall for 45 stations are studied and presented by graphs.

The pattern of rainfall is studied both in terms of spatial distribution and temporal distribution. When the spatial distribution of rainfall is evaluated, it is found that the amount of rainfall gradually decreases towards the Dry Zone from the neighbouring higher topography regions. However, it is discovered that the cause of least rainfall over central Myanmar is not because of less or late onset of monsoon, but because central Myanmar lies within the rain shadow area. It is also identified that topography plays an important role in the variability of rainfall. It is found that rainfall is lowest in central Myanmar and increases away from it in all directions from the month of May to November. The trends in **spatial distribution of rain days** are similar to that of the rainfall. The lowest value of mean rainfall intensity occurred in the Dry Zone in June, July and August, and out of Dry Zone, in May. September and October.

When the **seasonal distribution of rainfall** for Myanmar is evaluated, two modal rainfall patterns a **Uni-modal pattern (single maximum)** and **Bi-modal pattern (double maximum)** can be identified. In the uni-modal pattern the average monthly rainfall values are highest either in July or August. The first group of July maximum rain can be found along the coastal areas of Raldiine state, the Ayeyawady valley between the area under Pyay and the area of upper deltaic region, the Northern hills region (upper part of Sagaing Division and Chin state), Mogok, Thandaung and Pinlaung area. Stations included in this group are Sittway, Kyaukpyu, Thandwe, Hinthada. Thayawady. Putao. Myintkyina, Hkamti, Homalin, Mogok, Thandaung and Pinlaung. Most of these stations are situated in hilly regions. The region of the uni-modal pattern with August maxima extends nearly all of the Shan plateau, Bhamo area, lower parts of Ayeyawady, the Bago Division, the Sittoung valley, and the Kayin and Mon states. In this second group. Thibaw, Lashio, Taunggyi, Kyaington, Loilem, Bhamo, Maubin. Hmawby, Yangon, Bago. Pyinmana, Toungoo, Shwegyin, Thaton, Hpa-an, Mawlamyaine and Ye are included.

In **bi-modal pattern,** it can be found that rainfall values are high in two months (May or June and August or September), and this is due to the low frequency of Easterly waves during July and more frequency during August. The first maximum occurs in the very early rainy season in the months of May or June. The Second maximum occurs in the month of August or September. The second type is subdivided again into two groups based on the total rainfall. In the first group, stations in Sagaing Division. Kachin state. Chin state, the Dry Zone and the upper part of Ba°o Division are included. The included stations are Katha. Falam Mawlaik, Kalaywa. Mindat. Gangaw. Monywa. Shwebo. Mandalay, Nyaung-Oo. Minbu, Meiktila. Yamethin. Pyay and Loikaw. Each station has monthly peak values of less than 500 mm. In the second group, stations in Taninthayi Division are included and these are Dawei. Myeik and Kawthoung. The second group is characterized by the monthly peak values of more than 500 mm. Even within one month, these stations may receive monthly rainfall as much as 500 mm. In the first group, the bi-modal pattern may be due to the advance and retreat of the Inter Tropical Convergence Zone (ITCZ). The longest stay of this ITCZ zone is during the first week of June and the last week of September. Between the two maximums occurs a dry spell usually known as "July drought"' by agriculturists (Hla, 1983). The reason for double maximum for the Taninthayi Division is not similar to that of the Dry Zone region. It may be due to the three factors: this region is nearer to the equator and so that early rain received from the onset of Southwest monsoon may be much more in June; the second factor is related with the Northward shifting of the ITCZ (monsoon trough) during monsoon months thus the mean monthly rainfall in July is slightly less than that of in June; and the higher amount of rainfall in August may be because of the causes of Easterly waves in August.

The seasonal or temporal rainfall distribution is of vital importance in human activities especially in agriculture and is a decisive factor in the struggle for sufficient food supply as agricultural activities each year are regulated according to its behaviour.

According to the coefficient of variation, **the lowest variability** in rainfall is observed at Putao. the Eastern highlands, coastal **area of deltaic region** and the coastal strip of Taninthayi with a value of 10 per cent to 15 per cent. **The highest** variability is found in the core area of the **Dry** Zone with a value of more than 25 per cent. However, there is one exception with a high value of coefficient variation found in Shwegyin (25.66) %. which is located in Bago division, outside the **Dry** Zone. The rainfall variability is greatest in the central area and it decreases away from it in all directions. Low variability implies that the mean rainfall at a given location is reliable while high variability implies wide fluctuations about the mean value. Generally, it is obvious that there is an inverse relationship (r = -0.4026) between rainfall amount and rainfall variability. Annual rainfall is most variable in **Dry Zone** of Central Myanmar. This is critical as it is the Dry Zone that receives least rain and records highest variation, thus making it very vulnerable in terms of crop production.

Because of high variability of rainfall distribution in **Dry Zone,** the vegetative cover is thin, soil erosion is severe and has led to severe environmental degradation. With declining inputs both in terms of organic and inorganic materials, agricultural productivity is decreasing annually, compounded by increasing population pressure, high competition per capita for vegetation and tree cover for wood fuel and livestock fodder, the region is suffering rapid environmental degradation.

In addition, in the core rainfall deficient area of Dry **Zone** in some parts water is scarce and local people are facing difficulty for water supply because of seasonal drought occurrences. Thus, the government had to implement or initiate schemes for the drinking water supply and irrigation water supply to combat desertification. Under such a programme, a number of dams, check dams, reservoirs, tube wells, ponds, and river water pumping stations to pump water from Ayeyawady River were constructed to ensure cultivation.

It is necessary to know the time of onset and withdrawal of monsoon, its strength and duration that decides when, where and which types of crops are to be cultivated. It is interesting to note that even the pattern of cropping is done based on the anticipation of Southwest monsoon. The onset date of Monsoon in Myanmar is June 1 and the withdrawal date is October 15. From 1951 to 2000, there were some years when onset of the monsoon is abnormally early such as the years 195 k, **1963,** 19"Hand *]975"*. The years 1917, 19<?2-and 19 6?are years in which the arrival of the Southwest monsoon is considered late in Myanmar. Though the years of late monsoon arrival had no adverse effect on agricultural activity as water requirement was met by irrigation, the early monsoon were helpful for growing early oil crops and short staple cotton in central Myanmar and early jute cultivation in Ayeyawady delta region. However, heavy rainfall in late monsoon can destroy the young cotton plants in Dry Zone area.

As Myanmar is predominantly a monsoon region, wet and dry seasons are more or less distributed throughout the year. But in between these wet and diy seasons, some times there are spells of abnormal weather conditions (droughts or floods), which may have disastrous effects, especially in agriculture and its related economy in the country. Such dry spells at times lead to drought while excess of the monsoon rain leads to widespread flooding. For the whole of the country, the wettest years are 1952, 1959, 1961, 1965. 1970, 1971, 1973, 1984, 1985, 1988, 1989, and 1999. while 1957, 1958, 1972, 1977, 1979, 1983. 1986, 1987, 1991, 1992, 1993, 1994, 1997 and 1998 are the driest years. The extreme variations can be explained by certain characteristics of surface pressure anomalies over southern Asia, the 500-millibar pattern, disposition of Southern Oscillation, and the phenomena of El Nino, maximum sunspot and the period of Southwest monsoon.

The climate, rainfall and the topography have a direct bearing on the environment. Myanmar is well endowed with rich natural environment, which includes wild life, marine forest resources which cover more than half of the country. But more than 90% of renewable energy consumption depends upon forest resources. There is heavy reliance on wood fuel resulting in depletion of forest cover specially the mangrove forests outside the reserved forest areas. The agriculture sector forms the basic core of the natural economy of Myanmar nearly 76 per cent of the population resides in rural areas and is engaged in agriculture and animal husbandry. The role of agriculture in the economy of Myanmar remains dominant and thus has a direct bearing on all other socio-economic aspects of the country. Further, as agriculture in Myanmar is largely rainfed, the role of rainfall and its variability assumes critical significance.

Chapter Four of the study discusses the environmental situation of Myanmar. Land cover, forest resources, biological resources, and marine resources are examined as explanatory variables to measure environmental degradation in Section A. Based on the climate and, rainfall maps, two regions the **Dry Zone** and **Ayeyawady Delta** are identified for detailed study. In Section B, the study analyzes the environmental problems of the country by focusing on the production potential of areas-the low production and high production areas. The Low Production Potential Area (LPPA) includes the mountainous regions, arid and semi-arid regions. The mountainous region is **the** least favourable for crop production and development. Further, the LPPA is sub divided into: the deeply sloping area LI. the rolling and undulating upland area

L2, and the Arid and Semi-arid Area L3, depending upon their topography, climate and soils.

The deeply sloping area (LI) is highly mountainous and dissected with gradients, the atmospheric temperature is usually chilly and the annual rainfall is 2000-5000 mm. The mountainous red brown and yellow brown forest soils are the dominant soils of the area, which are low in fertility. This makes the area very unfavourable for returns on annual crop cultivation and soil erosion and landsides are common hazards of this area. It should be added that, in this area, shifting cultivation is seen as the major hazard to the environmental sustainability. The increasing population pressure has made the area under cultivation increase and the fallow land areas get bigger, causing more deforestation and soil erosion. Deforestation in this area was mainly caused by slash and burning for shifting cultivation. The study reveals the serious state of deforestation and the accompanying land degradation and ecological destruction in this region.

The rolling and undulating upland area (L2) region or Shan plateau is famous for its pleasant climate and scenic beauty. The most dominant agriculturally important soils are the Red earth popularly known as Terra Rosa, red lateritic soils or simply red. These soils are acidic and low in fertility due to removal of topsoil by surface water erosion and burning. The soil is almost devoid of organic matter making this as a low production area.

The L3 occupies the upper part of Ayeyawady alluvial plains and more than 75% of the total irrigated area of Myanmar is formed in this area. This L3 is found in the **Dry Zone** area. There are two main soil types (luvisols) and dark soils (vertisols) which are agriculturally important soils for the farmers. The soils are neutral to alkaline in reaction. A large area of upland and dry land cropping is subjected to wind and water erosion again reducing its potential for cultivation.

The main cause of deforestation in this area is attributed to woodcutting and charcoal making. The area today has gradually turned into semi-desert like conditions. Land degradation is the most serious problem in this area. The soil in this area is completely devoid of organic matter for cementing soil particles, which are easily blown away during summer windstorms.

High Potential Production Area (HPPA), consists of **Ayeyawady Delta** region, the Coastal strips and the Central plain regions. The central alluvial plain and **Ayeyawady Delta** regions are generally level plains with fertile soils: erosion hazards are very low because shifting cultivation is negligible except in some areas at the foot of the western and Dawna mountain ranges. Agriculture in this area is well developed and the farmers are aware of modern technologies and land and water development. These modern agricultural practices have resulted in a different set of environmental problems in this region.

Water logging, salinity, hazards of monoculture and fertilizer imbalances are a few of the major environmental problems of HPPA area. Water logging and flooding are two harmful phenomena affecting the sustainable agricultural development of this area. The HPPA is often hit by the annual tropical storms, especially in the coastal and delta region. Inadequate draining systems and silted waterways due to the soil erosion of the upper LPPA makes this low land area waterlogged and inundated. Delay in sowing of crops due to water logging, in undulation and annual flooding reduces due to the water logging, in undulation and annual flooding reduces the crop yields considerably. In some areas, no crops can be grown at all during the rainy season due to the stagnation of water. Water logging and flooding not only reduces agricultural activities, but also cause the spread of water borne diseases among the population of the surrounding areas. The average of surface water irrigation in this area is negligible and there is no ground water irrigation here. Therefore, there are no dangers of **acidity** and ground water salinization in HPPA. But salinization due to flooding and seawater encroachment is a problem in this area. Many areas along the coastal regions and low-lying delta regions are subjected to annual tidal water encroachment - causing soil salinization. Though severity of the salinity is not very pronounced during the rainy season in which rather salt tolerant rice crops are grown. The salinity effects appear greater after the rain stops, and a second crop is almost impossible in this salt affected area.

The HPPA is essentially a mono-cropping rice cultivation area. The benefit of rice mono cropping of this area is food sufficiency for the country and promotion of rice export to earn foreign currency. But there are environmental **hazards of monoculture.** There are the dangers of spread of insects, pest and disease which can thrive year after year on the same crop plant, especially HIV?s, the deterioration of soil structure due to the prolonged submergence; reduction of Fe and Mg which are toxic to plants; the rise of ground water table; and the depletion of the same type of nutrients from the soil nutrient reserves year after year, contributing to nutrient imbalances.

Another problem is the unbalanced application **of chemical fertilizers.** The farmers are very willing to apply urea because the immediate response of urea application can be seen by the instant green colouring of plants. But they are reluctant to use phosphorous and potash fertilizers whose effects are not immediately observable on the plants. Therefore, the long-term application of unbalanced chemical fertilizers can cause a serious nutrient imbalance in the soils, which can lead to soil deterioration and reduce crop production. The above facts indicate that nutrient imbalance exists and needs to be corrected immediately; otherwise it will lead to environment deterioration of the arable lands.

The other environmental problems of Myanmar are marine resources and mangrove forest degradation, desertification, water problems. Pollution problems, and wood fuel problems. Among the problems, the mangrove forest degradation in **Ayeyawady Delta** and desertification of **Central Dry Zone** have been concentrated by National Government and the International Organizations as the urgent current issues. Among the measures taken by the Government to combat desertification. **'"Greening Project for the Dry Zone"** is significant and most effective. Dry Zone Greening Department has been implementing the rehabilitation activities with major four main tasks: (a) Establishment of forest plantationsi(b) Protection and rehabilitation of remaining natural forests:(c) Initiating development and utilization of wood fuel substitutes; and (d) Development of water resources. **The Reforestation of Mangrove forest projects** funded by UNDP/FAO is another successful project for the development of Mangrove forests in Ayeyawady delta.

Though the environmental problem in Myanmar is not so high as compared to other Southeast Asian countries, both the government and non-governmental agencies are doing their best in this regard. The chapter reviews the recent institutional mechanisms set up for sustainable environmental management. Of the governmental organizations, the Ministry of Foreign Affairs (MFA), National Commission for Environmental Affairs (NCEA) act as a central management government agency on environmental matters. The NCEA's main mission is to ensure sustainable use of environmental resources and to promote environmentally sound policies in industry and in other economic activities. NCEA looks into policies on natural resource management, prepares environmental legislation for pollution control, monitoring and enforcement, promotes environmental awareness through public concentration and interacts with international organization in environmental matters.

The non-governmental organizations, which are active both directly and indirectly, include the Red Cross, the Union Solidarity and Development Associations (USDA). Forest Resources and Environment Development Association (FREDA), Wild Life Conservation Society (WLCS). California Academy of Shinu (CAS), International Centre for Integrated Mountain Development (ICIMD). Botanical Garden Conservation (BGC). and International Waste Management (IWM), Environmental Conservation and Prevention of Water Pollution (ECPWP).

Since more than 75% of population depends on agriculture, measures taken to improve the agriculture sector need to include a strategy for controlling desertification which is a growing problem. The present government has built innumerable dams and irrigation schemes, including many in the Dry Zone as a major measure to increase agricultural production. While this has helped to increase farm income and better the livelihood of the farm households it has had environmental fallouts. Myanmar Agriculture Service (MAS) has launched a programme throughout the country to introduce applicable and effective hillside farming techniques, like contour planting, formation of contour strip and contour bands, and shaping agriculture land techniques, research and development to generate higher productivity from the Dry Zone farming system.

The **fifth chapter** attempts a comparative study of two climatically different regions and the wood fuel situation in each of them. Myanmar has a peculiar situation of energy supply and demand in comparison to most of its neighbouring countries. Wood fuel consumption of Myanmar in 1990 was estimated about 2-8 million air dry ton (adt) or about 36 million tons. The annual average growth in wood fuel consumption is estimated at 2%. Since 1980 about 75% of the consumption is accounted by rural households who meet their sustained energy needs from self-collection.

In part Myanmar's heavy reliance on wood fuel has adversely affected its supply sources in different areas. Seven out of 14 states /divisions which are affected with wood supply deficits are Yangon division, Ayeyawady division, Mandalay division. Bago division. Magway division, Sagaing division and Mon state. Sagaing Division from Dry Zone area and Ayeyawady Division from Ayeyawady delta region, are the two areas identified as the study areas for a detailed analysis of the wood fuel crisis.

For the country as a whole, forest cover is 27.6% and the agricultural area is 65.4% of the total area. Among the districts in Sagaing division, only Shwebo district has high actual forest area (71.81%). In Monywa and Sagaing districts, the percentages of actual forest area are 17.01 and 2.8% respectively. If one looks at the energy consumption pattern for household cooking, about 81% of wood fuel and forest waste is accounted for Shwebo district, where actual forest area is concentrated, on the other hand, wood fuel consumption decreased to 65% in Monywa district and 58% in Sagaing district because the wood fuel due to scarcity, is being supplemented by agricultural and animal wastes upto 25% and 35% respectively.

In addition to household use. some institutions and communities such as training centers, boarding schools, monasteries etc also utilize wood fuel. Fuel wood consumption, for commercial use such as cafeterias, restaurants, bakeries account for 103,500 tones in the whole region under study, while for industrial use (small or big) accounts for 106,200 tons. As wood fuel is used right from household level down to industries, the forest (under stud)) in the Dry Zone cannot supply sufficient amount of wood fuel to meet the demand and most of the large wood fuel and charcoal has to be imported from outside the Dry Zone area by boat, road and rail. As a result of this, people suffer from higher wood fuel prices in addition to wood fuel shortages. Due to the above reasons, people have begun using various kinds of wood fuel substitutes such as agro residues, wood wastes, animal waste, etc which are locally available as low cost wood fuel substitutes. This may be seen as welcome fallout of the wood fuel crisis.

To compare and contrast the wood fuel production, consumption and marketing in the upper delta region of Ayeyawady division, three villages: Kyunyarshay. Yaedwingone and Theinlargutsu have been taken for an intensive study. We can see how wood fuel is being produced through wood fuel and bamboo fuel, the former accounting for 60% while the latter accounts for 40%. Firewood is also obtained from felling, pruning and pollarding of old, dead and drying trees. In Yaedwingone village, the main type of fuels is wood fuel, maize stems and other biomas of bushes. In Yaedwingone and Kyunyarshay village 75% of fuel is obtained, mainly, from wood fuel. Wood fuel and bamboo fuel are the two types of wood fuel found in Theinlargutsu village. About a quarter of biomass and about 5000 trees on non-forest lands are being removed to meet the fuel demand of these villages.

At present one third of tree population is to be removed annually to meet local Wood fuel demand. Taking it roughly as 3.3% of the total growing stock, at least 2000 trees need to be planted to maintain the quota. Yaedwingon would experience an acute shortage of Wood fuel after the year 2000. The demand of wood fuel exceeds the potential supply of the village at that time. The present growing stock in Yaedwingon is relatively poor. It was. therefore, suggested that more than 6000 trees should be planted to have a good stock in and around the village annually.

For Theinlargutsu village, assuming that the present stock below 1 feet girth is five times the stock above 1 feet girth, estimated annual allowable cut up to 2010 is 1319.18 cu tones. It is observed that in Theinlargutsu village, a quarter of the tree population is to be removed annually to meet the local Wood fuel demand at present 25% of the total growing stock, at least 5000 trees need to be planted to maintain the status quota. Theinlargutsu will maintain a supply and demand balance until 2010.

The present growing stock in Theinlargutsu is best among the study areas. It is, therefore, suggested that 6000 trees should be planted to have an adequate supply of biomass energy in the village.

To sum up from the study we can conclude that: -

(a) Both the study areas are having wood fuel problems, which have caused deforestation in the regions. With rapid deforestation the wood fuel crisis gets further aggravated as local supply sources get further reduced.

(b) Electricity and other commercial fuels are used only by a small percentage (less than 7%) of households in the Dry Zone Area of Sagaing Division, thus suggesting a very high dependence on wood fuel.

(c) The existing actual forests comprise only 27.6% of the Dry Zone Area of Sagaing Division and quantitatively and qualitatively are not sufficient to meet the basic needs of the people, especially in Sagaing and Monywa districts.

(d) The natural forests in the vicinity of the villages are still being degraded by repeated cutting for wood fueJ and are being encroached for cash crops cultivation, as a result the mangrove forests are decreasing and degraded forest areas are gradually expanding in the Ayeyawady delta area.

(e) As most of the wood fuel now has to be imported from outside the Dry Zone and Ayeyawady Delta regions by rail, road and boat, the people have to pay higher prices due to increasing transportation charges.

(f) Due to the wood fuel shortage and its high price, the local people have been using various types of wood fuel substitutes such as agricultural residues, forest waste, animal waste, coal briquettes etc. This contributes about 25.5% of the fuel needs consumed for household cooking.

(g) Wood fuel substitutes are also widely used for some commercial purposes. Rice herbs and groundnut shells are used in medium sized milk plants and saw dust in small-scale units, saw dust is also used for yarn dyeing and sugar mills in towns. Coal briquettes have been introduced to brick kilns and to some restaurants and teashops.

(h) Due to the weakness of forestry extension sendees, the full cooperation and active participation of the local people have not yet been achieved in forest conservation, forest plantation, and utilization of wood fuel substitutes.

(i) Both the Dry Zone Greening Project in the Dry Zone area and the Development of Mangrove Forests in Ayeyawady Delta are two recent attempts of successful afforestation programmes in Myanmar.

Summary

The study area consists of two different physical entities, viz, the Central Dry Zone region and the humid Ayeyawady delta region of Myanmar. Some reasons for choosing these regions are : the two regions are located on the passage of Ayeyawady river channel, they have fertile alluvial soils that are producing the largest amounts of rice and other crops: they consist of numerous large and small irrigation projects: they both support the highest density of population in the country; both regions have smooth communication routes on both western and eastern sides of the Ayeyawady river; having good conditions of accessibility and transferability of commodity flows at national and international level and the two areas have a high density of industries and manufacturing areas .These two areas are the most important zones for the economic development of the country and hence a comparative study becomes meaningful.

Based on the study a comparative analysis of these two regions reveals the following:

Ayeyawady delta region is humid with low variability of rainfall, soil fertility is high, it is rich in agriculture, has the highest density of population, is more developed in every sector of economy. Environmental degradation is high due to high loss of manarove forest due to high demand for wood fuel in the region.

The Dry zone has a semi arid climate with high variability of rainfall. Dry zone is dry because it lies in the leeward side of Western Mountainous ranges as a rain shadow area and does not receive much southwest monsoon rain unlike other locations in the windward side of the mountains. Being a semi arid climate area. Central Dry Zone experiences top soil erosion, with scarce vegetation and dry forest (thorn and shrubs forests). But. it has fertile soils by deposition of Ayeyawady River and its tributaries. In the history of Myanmar the Central Dry zone was the strategic location of Myanmar kingdoms. Mandalay, Inwa, Amarapura. Sagaing, Pinya, Bagan are the famous historical places of Myanmar. Till today. Central Dry Zone has a number of irrigation reservoirs, dams, water pumps, and canals in the area and agriculturally is the second most important area of the country. It has the second highest density of population. This explains why the government in pushing for development of the country has concentrated on the Ayeyawady delta region and Dry zone area. Both are lying in the Ayeyawady river basin as lowland areas, but because ot the differences in rainfall, the dry zone region is obviously lagging behind in development compared to the Ayeyawady delta region.

Although the physical environments are different, both regions are environmentally fragile or high-risk areas in Myanmar due to problems of high wood fuel needs. The natural forests in the vicinity of the villages are affected by repeated cutting for wood fuel and by being encroached for cash crops cultivation. As a result, the degraded forests are gradually expanding in Dry Zone region, making it into an area of desertification. A similar condition exists in Ayeyawady delta region where mangrove forest have been excessively exploited and reduced due to increasing demand of wood fuel and charcoal, and eventually turned into agricultural lands.

At a conceptual level, this study is an attempt to connect physical and human geography- to see how rainfall variability can be caused by and also causes environmental degradation. The study does not seek to establish cause relations, but rather it tries to understand the effect of rainfall on environmental change and vice versa. Myanmar is still dominantly an agricultural economy dependent to a large extent on rain fed agriculture. Hence any change in rainfall is critical to cultivation and crop production. Rainfall variability has increased in the last decades due to a number of combined reasons- some natural, some man-made. Human activity has created a degraded environment through deforestation, shifting cultivation, wrong agricultural practices and poor management of resources and inadequate government support.

This study argues that a degraded environment is linked to all these factors, the most important being decreasing and varying rainfall. The study establishes that while the Dry Zone area is more vulnerable to variability in rainfall, the humid region too gets affected. In the Dry Zone area the higher variability in rainfall gets reflected in the greater degradation of the environment as seen from the growing deforestation and desertification rates. The study argues that the Dry Zone being an ecologically fragile region needs immediate attention through sustainable policies. The more humid Delta region, too is in need of attention. While rainfall in this region is higher, it is also showing rising trends of variability, thereby putting the high density of population in this region to a greater risk in recent years. The example of the wood fuel crises in both the Dry Zone and the Delta region points to a rapid environmental deterioration. It is hoped that this study by addressing some of these issues will provoke planners to formulate ecologically sustainable policies keeping in mind the needs of the local populations. On the other hand, recognizing the fact that Myanmar is still dominantly an agricultural economy dependent to a large extent on rain fed agriculture is important. There is thus an urgent need to develop public awareness that any change in rainfall is critical to cultivation and the economy of the country. It is hoped this study would be a modest contribution to the limited but growing research and documentation on Myanmar. from an interdisciplinary perspective.

ABBREVIATIONS AND GLOSSARY

AVHRR	**Advanced Very High Resolution Radiometer**
NOAA	**National Oceanographic Association of America (the U.S)**
LANDSAT	**Earth Space Satellite of the U.S**
JICA	**Japan International Coorporation Agency**
FREDA	**Forest Resources and Environment Association**
USDA	**Union Solidarity and Development Association**
NCEA	**National Commission for Environmental Affairs**
SLORC	**State of Law and Order Restoration Council**
SPDC	**State of Peace and Development Council**
YA	**Dry crop farming**
TAUNG YA	**Shifting Cultivation**
AAC	**Annual Allowable Cutting**
WRM	**World Rainforest Movement**
LPPA	**Low potential Production Area**
HPPA	**High Potential Production Area**
ADT	**Air Dried Ton**
GBH	**Girth Breast Height**
lHoppus ton	**1.8024 Cubic Metres**
1$ Cu-S)	**6.173 Kyats (Official Rate of 31 Jan 1999)**
Myanmar Selection-System	**Selected Wood Cutting System for Silviculture Treatment in Myanmar**
State	**The Highest or First Order of Administration Unit in Hilly Regions of Myanmar**
Division	**The Highest or First Order of Administration Unit in Lowlands of Myanmar**
District	**The Second Order of Administration Unit of Myanmar**
Township	**The Third Order of Administration Unit of Myanmar**
Village tract	**The Fourth Order of Administration Unit of Myanmar**
Town/ Village	**The Last Order of Administration Unit of Myanmar**

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Appendix la

Annual Rainfall in Millimetre (1950-2000)

Year	Putao	Myintkyina	Bhamo	Thibaw	Lashio	Taunggyi	Kyaington	Loilem	Pinlaung
1950		2217	2427			1683			
1951		2068	1462			1554			
1952		1858	2349			1570	1000		
1953		2088	2049			1494	1340		
1954		1475	1523		1194	1253	1028		
1955		2184	1225		1422	1665	1392		
1956		1760	1888		1303	1427	1276		
1957		2056	1651		1160	1301	1015		
1958		1939	2187		1454	1466	1054		
1959		2523	2076		1750	1529	1287		
1960		2494	1405		1340	1226	1135		
1961	4220	2223	2029		1578	1880	1353	1441	
1962	4448	2157	1642		1378	1428	816	1096	
1963	4209	2182	1484		1362	1687	1355	1752	
1964	4309	3153	1887		1501	1457	1561	1379	
1965	4577	1746	1853	1417	1492	1595	1443	1287	
1966	4185	2451	1705	1384	1176	1575	1409	1472	
1967	3885	2460	1798	1374	1265	1622	1312	1471	2168
1968	4314	1848	1625	1486	1613	1769	1388	1351	2270
1969	3586	2078	1276	1040	1198	1221	1201	1347	2249
1970	3921	2284	1594	1251	1324	1538	1719	1722	2425
1971	4721	2170	1718	1496	1569	1548	1875	1346	2564
1972	3807	1812	1471	1177	1020	1558	1185	1290	1969
1973	4354	2677	2187	1756	1918	1546	1478	1763	2148
1974	4199	2264	1463	1263	1386	1410	1277	1415	2024
1975	4102	2328	1768	1156	1251	2008	1396	1640	1824
1976	3623	2032	1872	1399	1499	1391	1313	1543	2206
1977	3665	1946	2096	1654	1473	1449	1362	1648	1898
1978	3560	1989	1848	1289	1373	1594	1200	1491	1552
1979	3359	1578	2002	1016	1058	1326	880	1099	1509
1980	3921	2168	1652	1090	1492	1660	1154	1328	1709
1981	3578	2071	1964	1623	1356	1448	1404	1319	1940
1982	3958	1967	1838	1402	1303	1356	1284	1112	2104
1983	3679	2224	1970	1259	1526	1761	1122	1540	1886
1984	4159	2406	1669	11193	1496	1493	1093	1331	2018
1985	4214	2233	2460	1125	1361	1436	1143	1359	2410
1986	3235	2111	1692	1145	1340	1485	1052	1075	1571
1987	3674	2678	1324	1229	1392	1591	1407	1340	2127
1988	4059	2613	2046	1277	1100	1250	1247	1442	1724
1989	4221	2186	1634	1243	1399	1749	1190	1386	1639
1990	3960	1921	2072	1490	1104	1664	1286	1232	2096
1991	4707	1768	1940	1190	1341	1674	1429	1341	2475
1992	3596	2093	1758	1423	1160	1725	1173	1266	2200
1993	3905	2601	1657	1290	1290	1536	1110	1180	2041
1994	3846	1874	1594	1343	1343	1526	1263	1856	1897
1995	4917	2435	1723	1346	1504	1463	1377	1368	1980
1996	3827	2390	1860	1085	1236	1308	1256	1235	1722
1997	3818	2465	2110	1403	1199	1222	1010	1254	1556
1998	4116	2688	1600	1232	1102	992	593	994	1398
1999	5080	2037	2149	1103	1276	1513	1322	1660	2413
2000	4803	2044	1734	1258	1513	1342	1928	1492	1882

Appendix l.b

Year	Falam	Mindat	Hkamti	Katha	Mawlaik	Kalaywa	Shwebo	Monywa	Mandalay
		Annual Rainfall in Millimetre (1950-2000)							
1950				1891					711
1951				956					975
1952				1902					677
1953				1317					711
1954				1552					863
1955				1666					808
1956				2187					888
1957				1806					968
1958				1833					709
1959				2173					864
1960				1303					708
1961	1734	1481	5096	1573	1338	1512	579	753	871
1962	1488	2143	4235	1471	1381	1514	703	682	706
1963	1789	1632	4033	1295	1601	1504	694	826	947
1964	1641	1639	3508	1338	1692	1534	881	649	826
1965	1925	2022	3975	1652	2116	1624	1042	1193	950
1966	2117	1619	4623	1531	2129	1676	957	626	667
1967	1543	1239	3617	1142	1601	1695	664	689	813
1968	1578	2341	4229	1755	2033	1640	928	1109	1405
1969	1828	1739	3474	1213	1451	1343	770	760	740
1970	1877	1793	3465	1731	1889	2385	904	612	1006
1971	2002	1203	3236	1833	2144	2096	860	1042	745
1972	1119	1419	2780	910	1435	1512	768	709	703
1973	2043	2025	3772	2083	1987	1998	1122	1375	1249
1974	1519	1226^	4082	1221	1772	1763	957	724	1036
1975	1651	1177	4095	1547	1995	1709	998	1066	1269
1976	1332	1278	3568	1383	1790	1665	946	845	822
1977	1705	1080	2687	1918	1647	1408	783	921	762
1978	1125	1056	3953	1603	1772	1896	827	893	1215
1979	1074	2251	4923	1130	929	970	585	508	658
1980	1636	1301	3386	1082	1943	1849	1135	752	1092
1981	1178	1278	3003	1217	1465	1379	1345	824	862
1982	1362	1091	3674	1432	1670	1789	ASA	407	483
1983	1783	1645	3094	1650	1981	1956	1369	658	717
1984	1438	1440	3912	1717	1825	1727	1028	757	769
1985	1427	1363	4405	1439	1818	1802	746	544	822
1986	1504	1442	3127	1692	1525	1430	619	643	573
1987	1620	1369	5883	1144	1820	1427	656	745	937
1988	1213	1667	4521	1519	1960	1925	834	1014	814
_J989	1322	1589	4636	1472	1534	1454	959	722	648
_J990	1497	1408	4644	2307	2228	2110	739	601	712
_1991	1996	1366	5746	1332	1880	1631	749	519	753
_J992	1158	1401	3004	1445	1704	1502	1083	925	1285
_1_993	1323	1379	3751	1391	1747	1663	872	600	514
_J994	1566	1435	2339	1312	1633	1615	905	698	1009
_J995	1711	1317	4147	1703	1712	1602	928	918	982
-J996	1566	1475	3455	1509	1789	1597	1080	978	1026
_1997	1648	1428	3858	1883	1678	1534	603	592	902
-J998	1219	1122	4231	1052	1225	1179	727	489	700
^J_999	1591	1535	3603	1121	1709	1870	876	724	884

Annual Rainfall in Millimetre (1950-2000)

"""Year"	; Meiktila	Nyaung-Oc	Yamethin	Pyinmana	Minbu	Gangaw	Sittway	Kyaukpyu
1950	1169							
1951	875			1597				
1952	954			1380				
1953	998			1453			4902	
1954	921			1327			4415	
1955	873			1381			4819	
1956	1091			1547			5362	
1957	657			1230			3253	
1958	574			1010			4133	
1959	1046			1767			5558	
1960	669			1483			4455	
1961	763		1055	1545	659		4955	8912
1962	726		712	1090	844	1615	4533	4503
1963	985		784	1341	815	1633	4517	4972
1964	819		774	1601	1009	1164	4438	4712
1965	926	606	1043	1674	1260	1499	5798	; 5956
1966	757	606	493	1181	623	796	4706	3837
1967	716	504	686	1209	622	1364	4614	4214
1968	1082	628 :	1072	1159	846	1245	5810	4509
1969	722	571	865	1415	837	952	5457	5672
1970	979	862	856	1272	1181	1554	5434	4859
1971	1005	438	1022	1463	614	1267	2737	5164
1972	720	358	602	992	541	1016	3334	3541
1973	1171	923	1064	1624	1155	1642	4682	4385
1974	794	537	1063	1945	1046	1568	5353	5049
1975	1185	905	870	1990	812	1491	4112	3929
1976	887	610	1054	1369	1252	1061	4374	4030
1977	867	580	807	1295	693	1308	3919	4438
1978	684	731	976	1162	843	1672	4069	4180
1979	445	259	634	904	337	773	3964	3897
1980	564	687	733	952	664	1182	5578	4134
1981	765	772	729	1509	809	1199	3842	4421
1982	541	248	657	1062	529	1041	4746	4490
1983	791	674	1020	1244	672	1271	4277	4015
1984	737	655	1023	1152	793	1176	4755	4176
1985	793	527	1010	1311	734	1169	4218	4377
1986	785	615	866	1101	659	1208	3858	3587
1987	665	614	759	1211	788	1104	5152	4502
1988	771	789	822	1191	954	1108	4422	4018
1989	1053	743	900	1091	829	1150	4093	2819
1990	790	615	963	1509	768	1436	5917	4997
1991	1345	517	718	1298	516	1456	5533	5048
1992	914	596	873	1011	990	1061	4237	4740
1993	796	524	651	1450	658	1180	5164	5261
1994	522	501	686	1154	446	1615	5284	5884
1995	785	466	868	1431	1143	1445	5467	4425
1996	1053	717	840	1639	794	1578	5391	5509
1997	605 "	409	605	1426	728	1599	4311	4666
1998	441	360	550	871	403	1145	4257	3559
1999	719"	870	913	1631	935	1308	4376	4768
2000	583	528	746	1492	838	1083	4115	4289

Annual Rainfall in Millimetre (1950-2000)

Year	Pyay	Toungoo	Thayawady	Shwegyin	Bago	Hmawbi	Yangon	Hinthada	Maubin
T950					3124		3335		
1951	1201	2163	2104		2870		1995	2143	1803
1952	1674	2188	2513		3683		3192	2428	2555
1953	1223	2520	2383		3785		2858	2361	3674
1954	1447	2039	2066		2743		2265	2346	2186
1955	1407	1847	1753		2870		2926	1840	2085
1956	1308	1887	2201		3454		2460	2272	2302
1957	1057	1419	1827		2083		2161	1932	1929
1958	1342	1690	2163		2743		2117	1602	
1959	1396	1858	2089		3708		3083	2661	232"
1960	1272	1879	2022		3581		2435	2247	2016
1961	1489	2047	2425	7175	3949	3104	2862	2844	2366
1962	1351	1973	2053	5437	3475	2429	2423	2086	2393
1963	1074	1973	2526	5855	3448	2716	2860	2522	2931
1964	1360	2i""58~	2093	4030	3324	2519	2523	2679	2487
1965	1493	1906	2422	3784	3306	2897	2953	2144	2450
1966	1049	1959	1968	3217	3255	2505	2592	2243	2284
1967	1065	1767	2142	3492	3188	2121	2668	2286	2711
1968	915	1967	2425	3589	3288	2684	3179	2401	2704
1969	1463	1848	2093	3922	4188	2857	2535	2461	2516
1970	1333	2275	2269	3471	3827	2371	2936	2154	2092
1971	1130	2161	2208	3339	3214	2403	2476	2446	2274
1972	816	2061	1862	3630	3069	2318	2223	1855	2337
1973	1759	1958	2338	3335	3925	2941	2766	2413	2436
1974	1576	1946	2329	3366	3764	2941	3261	2203	2714
1975	1468	2537	2152	3611	3448	3043	2594	2217	2232
T976	1283	1656	2103	3675	3778	2790	2914	2205	1859
1977	1234	1917	1981	2887	2951	2127	2279	1917	1825
1978	1435	1661	2013	2904	3429	2170	2352	2121	2120
1979	734	2135	1723	2579	2820	1915	2267	1712	2030
1980	1091	1630	2569	3158	3157	2772	2715	2430	2544
1981	1275	2282	2584	2994	3530	2267	2633	2348	2702
1982	1085	1834	2720	3702	3805	2729	2767	2559	2375
7983	1267	1452	2275	2949	2796	2465	2816	2609	2394
1984	1245	1916	2202	3115	3257	2543	2379	3435	2088
1985	968	2141	2365	3816	3126	2769	3291	3691	2531
1986	1048	1689	1769	3350	2750	1865	2799	2790	2151
1987	1021	1850	2474	3016	2593	2113	2564	3251	2500
1988	1587	2223	2156	3244	3455	2312	2540	2054	24"14
1989	1117	1682	1922	2240	2758	2105	2555	1878	2470
1990	1222	2225	2683	3497	3734	2783	2792	2275	2464
1991	1082	1704	1879	3595	2999	2261	2127	1795	2089
1992	1374	1793	2056	2759	3211	2718	2439	1722	2702
1993	885	1736	2038	3291	3191	2577	2824	2206	2342
1994	985	2038	2406	3712	3464	2722	3072	72650	3052
1995	1371	2360	2227	2775	3169	2452	2552	2737	2766
1996	1309	2159	2395	3188	3255	2744	3047	2089	2050
1997	929	2348	2430	4608	3990	2686	3068	1489	2621
1998	788	{363	1594	2396	2373	2004	2436	1594	1552
1999	1318	2591	2374	3713	3525	2944	3523	1973	1938
2000	1708	1806	1979	3946	2973	2315	2577	2133	2002

Appendix l.e

Annua! Rainfall in Millimetre (1950-2000)

Year	Pathein	Loikaw	Hpa-an	Thaton	Mawlamyaine	Ye	Dawei	Meik	Kawthoungj
1950	3557						5332	4155	3767
1951	2495	1226			3701		5090	3796	3238
1952	3115	"1006			4999		5498	4188	4271 !
1953"	3234	1187			4623		6289	3567	4208
1954	2688	858			"4379		4769	3982	4290 j
"i955	2469	994			4602		5091	3598	3762 ;
1956	2467	1265			4685		3034	3712	~~04 !
1957	2349	1029			4250		4811	3395	3491 1
1958	2552	994			4556		4438	3255	4279 '
1959	3258	1245			4917		4965	3814	4001 i
1960	2343	1332			4517		5436	4324	4011
" 1961	' 2858	1304	5973	7339	6723		7598	4526"	4097 "I
1962	2658	876	5386	5918	4676		5617	3703"	3384
1963	3110	1096	5236	6418	5908		5637	3701	3328
1964	2797	"""'1537"	"3545	5472	4590		5157	4426	3970 j
" 1965	"3103	1148	4473	"5474	"5132 ""	5162"	5685	4394	3924]
1966	2954	1082	3804	5123	5263	5272	4639""""	3696	3752 "
1967	3644	1178	4563	5894	5794	6093	5722	4602	4039 i
1968	3298	1090	3812	5330	4193	5160	5002	3688	3822
1969	3216	1183	4764	6531"	5779	5167	5454	3813	3610
1970	2454	1259	4298	5856"	4672	5691'	"5880"""	3942	4201"
1971	303;f~"	1197	4709	5358""""	" 3965"	"4595" ""	5031" "	3911	3481"
1972	2722	1474	4267	4925	"3995	6175	"6255	4071	3175 "
1973	"3444""	1297	4239	5177	4125	4679	' "50"23	3905	4303"
1974	3374	865	4431	4983"	4499	4494	5672	3036	4415
1975	2763	1487	4699	5501	4784	5205	5731	4217	4487
1976	2921	776	4756	5168	4733	4663	5190	3969	" 3362
1977	2712	1196	4614	4854"	4970	4539"	" 4803" '	3836	3078
1978	3294	1038	4672	5295	5344	5970	6409	4701	4430
1979	2350	866	4504	4291	4673	4456	5018	4303	5725
"1980	2842	970	3772	5100 "	4364""	"4664	5209	"3926	" 3808
1981	3295	1086	4932	5986	5157	5791	6559 "	4274	3481
1982	3328	" 946	4999	6101	6170	5710	5433	3898	3673
1983"	2706	883	3288	4586"	3687	3215	4673 """	"4463	4436
1984	2637"	""9~iT"	4596	"5732	4560"	5410	4718	"3868	3954
1985	2722	"i 147	4248	5205	' 5485	5538	6561	3883	3960
1986	2256	874	3401	" "4723	3769	5339	5375""	" 4439"	4710
1987	2839	1181	3231	4482	3898	4440	4373	2869	3033
1988	2634	953"	3483	4573"	3962	4617	4285	" 4084	4875
1989"	2227	"878 ""	3709	5115"	4612"	3368	4561""	3260	4265
1990	2988	1003	3996	5448	4981	5059	"5568""	3598"	3506
" 1991	2905	1142	4615	5348	5069	4356	""55"i4" "	4210	3591
1992	2921"	886	3774	" 4155	4429""	5099	4582	2607	3117
1993	2139	770	3992	" 4967 "	4393	4633	4703	3472	3466
" 1994"	3405	1238	2367	6958	6908	6105	6061	4955	5336
"1995	2857	1063	3778	4761	4789	5583	5361"	4113	4981
"7996 ~	2653	1222	"3513	4211	4360"	4663"	5226	3858	5009
"" 1*997"	3027 ~"	" 863	""5281	"8149 "	5468	6973	6721	4839	4673
1998	1871	630	2657	3802	3437	3675	3758	3023	3289
1999	3004	905	5213	6189	6657"	6538 """	7208	4"020	5466
2000	3100	1035	4949	5568	4344	5943	5746	4202"	4823"

Appendix 2 Mean Monthly and Annual rainfalls (m tn

Station	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Putao	14	38	75	147	176	738	998	905	645	132	22	16	3906
Myintkyina	8	18	26	46	159	535	513	411	285	158	28	9	2196
Bhamo	6	11	14	48	161	349	392	409	210	130	41	16	1787
Thibaw	10	6	4	65	166	236	256	304	167	138	67	13	1432
Lashio	6	7	9	44	141	205	230	293	188	154	69	18	1364
Taunggyi	5	5	7	51	166	217	230	307	281	200	76	11	1556
Kyaington	16	8	16	43	160	175	236	243	171	128	79	23	1298
Loilem	6	2	7	41	177	191	181	274	250	184	72	14	1399
Pinlaung	11	4	5	43	170	305	336	317	208	133	57	11	1600
Falam	5	9	21	77	141	288	256	238	227	170	64	10	1566
Mindat	4	5	4	34	124	240	190	351	280	177	90	5	1504
Hkamti	7	11	29	75	198	784	1021	658	505	217	42	23	3570
Homalin	4	11	23	42	137	472	491	405	364	158	52	9	2168
Katha	9	7	16	55	180	290	233	282	232	141	49	11	1505
Mawlaik	2	6	13	43	152	312	262	364	299	205	42	8	1703
Kalaywa	2	4	10	37	162	295	255	348	297	197	54	8	1669
Shwebo	2	2	7	31	120	131	108	173	156	117	40	6	893
Monywa	2	2	2	26	101	106	71	131	161	134	42	6	784
Mandalay	4	2	2	38	144	129	78	133	156	133	38	7	864
Meiktila	8	1	2	27	134	102	79	200	150	158	35	11	901
Nyaung-Oo	5	1	1	14	63	76	38	83	124	125	41	8	579
Yamethin	6	3	4	32	143	106	101	121	153	138	47	10	864
Pyinmana	7	2	7	34	161	217	235	266	199	149	39	3	319
Minbu	2	1	2	18	112	142	95	128	134	128	46	5	313

Appendix 3 Mean Montly and Annual rainfalls (m m)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Gangaw	2	3	7	33	137	203	160	254	232	179	51	7	1268
Sittway	11	8	5	44	268	1091	1155	1025	537	289	106	17	4555
Kyaukpyu	5	8	3	32	248	1011	1228	1053	575	256	89	13	4521
Thandwe	2	1	1	17	299	1298	1478	1404	614	207	64	8	5393
Pyay	2	3	1	10	141	236	228	234	190	138	50	4	1237
Toungoo	7	1	4	28	194	377	425	447	278	149	45	12	1967
Thayawady	5	0	1	12	120	464	523	496	290	175	55	9	2149
Shwegyin	4	2	9	34	271	815	902	911	480	367	44	10	3849
Bago	3	2	5	33	294	711	751	799	477	226	37	7	3345
Hmawby	5	3	6	17	284	508	560	588	330	193	61	8	2543
Yangon	5	2	7	15	303	549	559	602	368	206	60	6	2682
Hinthada	5	2	2	12	196	517	583	516	327	139	67	3	2369
Maubin	4	1	7	27	265	476	517	520	334	190	65	5	2411
Pathein	5	3	3	13	278	613	631	670	365	205	86	11	2883
Loikaw	7	2	4	39	131	171	161	205	187	122	48	12	1089
Hpa-an	4	5	6	42	412	875	1046	1134	584	209	30	8	4356
Thaton	10	8	8	75	571	1123	1234	1326	749	292	46	8	5450
Mawlamyaine	4	6	6	66	317	1008	1134	1271	423	249	49	6	4539
Ye	4	3	8	57	500	1009	1118	1240	711	345	57	10	5062
Dawei	7	20	15	76	517	1233	1172	1342	767	333	43	5	5530
Myeik	19	51	53	128	451	783	740	868	482	302	73	13	3963
Kawthoung	17	15	30	112	487	642	561	696	617	369	153	34	3733
Mogok	3	10	11	88	350	494	529	516	349	251	104	22	2727
Thandaung	9	4	21	51	515	1051	1482	1416	717	321	123	28	5738

Appendix 4 Mean Monthly and Annual Rain Days

Station	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Putao	2.3	4.9	9.2	13.3	11.3	24.2	26	24.6	20.5	10.8	2.2	1 6	150.9
Myintkyina	1.1	2.3	3.3	5.8	11.2	21.7	23.4	19	14 1	8.9	2.8	1	114.6
Bhamo	0.8	1.7	2.5	5.6	11.3	20.3	21.1	19.1	12.7	8.9	2.9	1	107.9
Thibaw	0.3	0.9	1.4	6.5	11.3	15.4	13.5	16	108	9	4.8	1.1	91
Lashio	0.6	1	1.3	7	10.8	15	16.7	17.5	13.1	9.2	5.1	1.1	98.4
Taunggyi	0.7	0.5	1.1	46	12.1	17.4	18.4	20.3	178	12.8	5.7	1.2	112.6
Kyaington	1.3	1.1	1.9	4.4	12.8	15.8	18.7	16.9	13.2	10.3	6.6	1.3	104.3
Loilem	0.4	0.7	0.7	4.3	13	15.11	15.1	17.2	17	13.1	7.6	0.4	104.61
Pinlaung	0.5	0.8	0.8	4.4	12.2	25.4	24.7	25.3	187	12.7	6.6	0.7	132.8
Falam	0.9	1.5	2.9	77	10.6	18.8	18.4	19.5	16	9.2	4.5	0.9	110.9
Mindat	0.3	0.7	0.8	4.2	9.3	17.7	13.6	21	16.5	10.3	4.9	0.5	99.8
Hkamti	1	2.1	3	6.6	10.2	22.4	27.2	22	20.8	9.7	2.2	1	128.2
Homalin	1.3	2.3	4.3	7.7	9.2	18.4	19.5	17.1	15.5	3	2.7	1.2	108.2
Katha	1	1	2.5	5.8	11	14.3	12.5	15.6	12.3	8.6	3	0.7	88.3
Mawlaik	1	0.9	2.5	6.4	9.7	16.7	13.3	15.5	13.9	9.1	4.2	0.4	93.6
Kalaywa	0.2	1	2.2	5.5	8.7	17.1	12.9	17.2	13.8	8.4	4.6	0.5	92.1
Shwebo	0.2	0.4	1	3.3	6.6	9	6.5	9	8.3	6.3	2.6	0.2	53.4
Monywa	0.1	0.2	0.2	3	5.9	7.1	5.1	7.2	8	**7**	2.5	0.1	46.4
Mandalay	0.5	0.3	0.2	3.4	7.8	7.1	5.6	8.8	7.8	7	2.7	0.7	51.9
Meiktila	0.1	0.2	0.1	2	7.2	9	7	9.6	9.2	5.3	2.4	0	52.1
Nyaung-Oo	0.1	0.2	0.4	1.4	4.1	6.5	3	7.4	7	5.8	2.7	0.1	38.7
Yamethm	0 1	0.2	0.4	3	7.9	9.6	0.7	10.1	9.1	7.7	3.5	0.7	62
Pyinmana	0.1	02	2.2	1.2	8.7	15.8	17.2	18.4	123	8.4	2.9	0.6	86.9
Minbu	0	0.1	0.1	1	5.2	10.7	3.6	11.1	9.6	7.5	3.4	0.6	58.9

Appendix 5 Mean Monthly ancl Annual Rain Davs

Station	J	F	M	A	J\	I	I	A	S	O	N	D	Annual
Gangaw	0.1	0.7	1.1	4	7.5	13.4	12.1	15.3	11.6	9.1	3.7	0.6	79.2
Sittway	0.7	1.3	0.3	2.6	9.6	25.2	27.8	26.2	18.6	8.6	3.4	0.8	125,1
Kyaukpyu	0.1	0.6	0.2	1.3	9.6	25.4	26.4	26.9	19.9	10	2.9	0.7	124
Thandwe	0	0.1	0.1	1.1	11.2	26.2	28	27.6	18.8	11.1	3.6	0.7	128.5
Pyay	0	0.1	0,2	2	8.4	20.4	21.4	22	14.7	9	2.8	0.8	101.8
Toungoo	0	0.1	0.2	2	9.4	21.9	24.8	24.5	16.2	8	2.8	0.8	110.7
Thayawady	0	0	0	1.1	9.6	22.3	23.8	23.4	16.6	11	3.9	0.7	112.4
Shwegyin	0.1	0.2	0.5	2.1	11.6	27.2	27.6	27.6	19.7	12.9	3.7	0.4	133.7
Bago	0.1	0	0.3	2.2	12.5	25.4	27	26.1	19.1	10.6	3.4	0.6	127.3
Hmawby	0	0	0.1	1.2	12.5	24.4	24	24.1	17.6	10.1	3.9	0.6	118.5
Yangon	0.1	0.1	0.2	1.3	12.8	24.6	25.6	26	19.7	11.6	3.4	0.6	127
Hinthada	0.1	0	0	1.1	8.9	22.5	23.2	24.2	15.7	9	3.4	0.1	108.2
Maubin	0.5	0	0.7	1.5	12.4	23.5	23.8	24.5	17.4	10.4	3.5	0.6	118.8
Pathein	0.1	0.2	0.2	1.1	11.3	23.8	24.7	25.8	19.8	17.3	5	0.7	130
Loikaw	0.6	0.2	0.8	4.1	10.6	15.3	14.9	16.5	13.5	9.1	4.5	0.7	90.8
Hpa-an	0	0.1	0.7	3	15.4	26.7	27.8	28.3	21.7	11	2.2	0.7	137.6
Thaton	0.1	0.5	0.6	3.7	17.4	28.7	28.7	29.4	22.1	13.7	4.2	0.2	149.3
Mawlamyaine	0	0.2	0.7	3.7	16.9	26.8	27.4	27.9	20.3	10.9	2.8	0.6	138.2
Ye	0.3	0.7	0.6	4.2	16.4	26.4	25.7	27.8	20.7	13	4.8	0.4	141
Dawei	0.8	1	1.2	3.9	16.2	26.4	27.3	27.3	22.1	14.5	3.7	0.6	145
Myeik	1.5	2.6	3.2	6.6	17.5	25	24.4	25.7	19.7	15.2	5.3	0.6	147.3
Kawthoung	1.9	1	1.7	6.8	17.1	22.2	20.9	23.2	19.9	15.5	9.6	2.9	142.7
Mogok	0.3	1	1	5.5	15.5	23.4	25.8	26	18.9	12.5	4.8	1.2	135.7
Thandaung	0.4	0.4	1	2.8	17.2	27.8	30	30.3	24.4	16	5.8	1.1	158.2

Appendix 6.a ? .ee species and **groups recorded by the National Forest Survey** and inventory °f Myanrnar (198? - 84)

oroup no. Jn.". no species	biieoies	
	Local name	Botanical name
	Kyun	*Tectona grandis*
	Pyinkado	*Xylia dciabriformis*
	Ingyin	*Pantacme siamensis*
	Padauk	*Pterocarpus macrocarpus*
	Tamalan	*Dalbergia oiiveri*
	Thitya	*Shores cbiongifciia*
	Binga	*Mitragyna rotundifolis*
	Hnaw	*Adina cordifolia*
	In	*Dipterocarpus tuberculatus*
	Kokko	*Albizzia lebbek*
	Sagawa	*Michelia champaca*
	Thadi	*Protium sarrata*
	Thinwin	*Milletia psndula*
	Thit-magyi	*Albizzia odoratissima*
	Thitsi	*Meianorrhoea usitata*
	Yemane	*Gmelina arborea*
	Yindaik	*Dalbergia cu'trata*
	Yinma	*Chukrasia tabularis*
	Panga	*Terminaha chebula*
	Pvinma	*Lagerstromia speciosa*
	Sandawa	*Cordia fragrantissima*
	Taukkyan	*Terminalia alata*
	Taukkyan	*Terminalia tomentosa*
	Taukkyan-ywet they	*Terminalia crenuiata*
	Taung-thayet	*Swintonia flohbunda*
	Taw-thaya!	*Mangifera caloneura.*
	Thabye	*Eugenia* Sjjp.
	Tharapi	*Calcphyilum kunstleri*
	Thit-e	*Casianopsis spp.*
	Yingai-gyi	*Gardenia coronaria*
	Yon	*Anogeissus acuminaia*
	Baing	*Tetrameies nudiflora*
	Chinyok	*Garuga pinnata*
	Didu	*Salmalia insignis*
	Gwe	*Spondias pinnata*
	Letpan	*Salmalia malabanca*
	Nabe	*Lennea grandis*
	Wetshaw	*f-irmiana coiorata*

Appendix 6.b

Group no. and *no.* of species	Species		1
	Local name	Botanical name	
	Pemne	*Artocarpus heterophyllus*	
	Pet-wun	*Berrya spp.*	
	Petthan	*Haplophragma ade. nophyllum*	
	Pin-tayaw	*Grewia elatostemoides*	
	Seikchi	*Bridelia retusa*	
	Sha	*Acacia catechu*	
	Shaw	*Sterculia spp.*	
	Sin-kozi	*Helicia terminalis*	
	Taw-thabut	*Polyalthia simiarum*	
	Te	*Diospros burmanica*	
	Tein	*Mitragyna purvifolia*	
	Thabut-gyi	*Miliusa velutina*	
	Than	*Terminalia oliveri*	
	Than that	*Albizzia luccida*	
	Thanat	*Cordia dichotoma*	
	Thanatka	*Linonia acidissima*	
	Thanbe	*Stereospermum neuranthum*	
	Thande	*Storeospermum personatum*	
	Thapan	*Ficus glomerata*	
	Thayet	*Mangifera indica*	
	Thetyin-gyi	*Croton oblongifolius*	
	Thinwin-bo	*Millettia pubinervis*	
	Thinwin-pyu	*Pongsmia pinnaia*	
	Thit-pagan	*Millettia brandisiana*	
	Thit-palwe	*Balanites triflora*	
	Thit-payaung	*Neonauclea excelsa*	
	Thitkya	*Juglans regia*	
	Thitmin	*Podocarous wallichianus*	
	Thitni	*Amoora rokituka*	
	Thit pok	*Dalbergia kurzii*	
	Thitsanwin	*Dalbergia paniculate*	
	Thitsein	*Terminaiia belerica*	
	Titswele	*Schrebera swietenoides*	
	Yingu-akyi	*Quercus helferiana*	
	Yingu-athe	*Quercus mespilifolia*	
	Yinzat	*Dalbergia fusca*	
	Ywe-gyi	*Adananthera pavonia*	
	Zaungbale-ywet-gyi	*Lagerstromia venusta*	
	Zaung-gyan	*Osyris wightiana*	
	Zaungbale	*Lagerstroemia villosa*	
	Zibyu	*Emblica officinalis*	
	Zinbyun	*Dillenia pentagnya*	

Appendix 6.c

Group no. and no. of species	Species	
	Local name	Botanical name
	Kuthan	*Hymenodictyon excelsum*
	Kyunbo	*Premna pyramidata*
	Leza	*Lagerstroemia tomentisa*
	Myaukchaw	*Homalium tomentosum*
	Pyaukseik	*Holoptelea integrifolia*
	Tayaw	*Growia tiliaefolia*
	Aukchinsa	*Diospros ehretioides*
	Bambwe	*Careya arborea*
	Bebya	*Cratoxylon neriifolium*
	Bwegyin	*Bauhinia variegata*
	Chinbyit	*Bauhinia malaLarica*
	Dahat	*Tectona hamiltoniana*
	Daukyat-gyi	*Helicia erratica*
	Gyo	*Scleichera oleosa*
	Gyok	*Diospros montana*
	H maik	*Cordia grandis*
	Kabaung	*Strychnos nuxblanda*
	Kathit	*Erythrina suberosa*
	Kyaung-dauk	*Pajanelia rheedii*
	Kyetyo	*Vitex pubescens*
	Kyun-gauk-nwe	*Vitex limonifolia*
	Kyun-nalin	*Premna latifolia*
	Laukya	*Schima wallichii*
	Lein	*Terminalia pyrifolia*
	Lettok-gyi	*Holarrena antidysenterica*
	Lettok. thein	*Wrightia tomentosa*
	Lezo-byu	*Lagerstroemia calyculata*
	Linyaw	*Dillenia parviflora*
	Lumbo	*Buchanania lanzan*
	Madama	*Dalbergia ovata*
	Ma-hlwe	*Markhamia stipulata*
	Momaka	*Salix tetrasperma*
	Mondaing-bin	*Lophopetalum wallichii*
	Myasein	*Parkinsonia*
	Myauk-okschit	*Michocarpus pentapetalus*
	Nagye	*Pterospermum semi-sagittum*
	Naywe	*Flacourtia cataphracta*
	Ngu	*Cassia fistula*
	Nibase	*Morinda tinctoria*
	Nyaung	*Ficus spp*
	Okshit	*Aegle marmelos*
	Palan	*Bauhinia racemosa*