EFFECT OF AGRO-CLIMATIC VARIATIONS ON HIGH YIELDING VARIETIES OF RICE

A Case Study of the Lower Brahmaputra Valley

Dissertation Submitted for the partial fulfilment of the Degree of Master of Philosophy

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This is to certify that the dissertation entitled "Effect of Agro-Climatic Variations on High Yielding Varieties of Rice - A Case Study of Lower Brahmaputra Valley" submitted by Rangadhar Sahu for the partial fulfilment of the degree of Master of Philosophy, is a bonafide study to the best of my knowledge. All the quotations, extracts and ideas of other studies have been duly referred.

This dissertation may be placed before the examiners for evaluation and necessary formalities.

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DECLARATION

The author hereby declares that with the exception of the guidance and suggestions received from his Supervisor, Dr. Majid Husain, Reader and and Head, Department of Geography, School of Environmental Sciences, North Eastern Hill University this thesis is author's own unaided work. It is based on the research work carried out in the Department of Geography, North Eastern Hill University and the field work conducted in the area during the period of his research.

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ACKNOWLEDGEMENT

This study was made possible by the award of the Junior Research Fellowship by the North Eastern Hill University Shillong. This dissertation was prepared under the supervision and guidance of Dr. Majid Husain, Reader and Head, Department of Geography, North Eastern Hill University, Shillong. His valuable comments, advice and suggestions at various stages of the work has improved and enriched this study in the aspects of Agricultural Geography of Lower Brahmaputra Valley. But for his pain staking effort in going through this manuscript several times, this dissertation would not have come into its final shape. The author therefore, expresses his deep sense of gratitude to him.

Much of the credit for the work the author did in his field work goes to the personnels of the Department of Agriculture, Government of Assam and India Mateorological Department Gauhati. Specially the author remains grateful to Mr. H.R.Halder the former Assistant Soil Chemist in the Soil Testing Laboratory of the Directorate of Agriculture, Government of Assam, Gauhati for his constant co-operation in procuring the necessary data and information on different aspects of soils in Assam.

The author is grateful to Mr. A.C. Mahapatra, Lecturer, Department of Geography, North Eastern Hill University for his valuable comments and suggestions in processing the data. His continuous encouragement at different stages of the dissertation had been very helpful. The author also expresses his sense of gratitude to Dr. R.C. Sharma, former Dean, School of Environmental Sciences and Head of the Department of Geography and Dr. R. Gopalakrishnan, Lecturer, for providing encouragement and inspiration.

The author acknowledges the help rendered by his friends and colleagues who remain unnamed. Although the author has taken help and guidance from a number of people, the responsibility for the analysis of the work is entirely his.

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CHAPTER - I

INTRODUCTION

Agro-climatology is a new branch of Science in which a relationship between the prevailing climatic conditions and their influence on crop distribution and production is studied. Such studies vary from topical to regional and macro to micro regions. The average weather conditions vary from region to region and even at the microlevel very striking differences are found in temperature, rainfall, rate of evaporation and soil moisture. These variations in the climatic parameters affect favourably or adversely the crop acreage, production and productivity of different crops in a given region. In the field of agro-climatology, useful techniques for estimating climatic environment have been evolved by using plant indicators and it has become possible to quantify the relationship between prevailing weather conditions and the resultant productivity and production. It has therefore great socio-economic and applied importance to study and to interpret the impact of the weather and soil conditions on the high yielding varieties of rice in a predominantly rice growing region of the country, known as the lower Brahmaputra valley.

In India during the last fifteen years serious efforts have been made at the governments and individual levels, to increase the production of all cereals in general and that of rice and wheat in particular. But interestingly enough while the productivity of wheat has shown an optimistic upward trend, no major break-through could be made in the case of rice - the major staple crop of the country. There may be random socio-economic and technological factors responsible for set-back in the acreage and productivity of rice, but probably the physical environmental conditions have a decisive influence on the outturn of rice which needs to be investigated, systematically in relation to a rice growing area of the country.

Like other developing countries of the world, in India the high yielding varieties of rice were introduced in the early sixtees. The innovation, immitation and diffusion of the high yielding varieties have revolutionized the agricultural land-scape and it was earnestly hoped that the new agricultural strategy will be helpful in overcoming the problems of poverty, hunger, under-nutrition and malnutrition in the country. But unpredictable nature of monsoon and its total or partial failure often puts the wheel of progress backward. The indigenous and the high yielding varieties have their own charecteristics and require appreciably different agro-climatic conditions. There is a striking difference between the local traditional varieties of rice and the recently introduced high yielding varieties. It is because of the necessary care and package inputs given to the HYV rice which give higher returns than that of local varieties.

The local varieties give a reasonable yield provided the supply of moisture is adequate especially during its vegetative and growth period. In the case of High Yielding varieties it has however, been noticed that there is a spectacular difference between the average output of rice in terms of kilogram per hectare, so far as the various agricultural systems e.g. shifting, subsistence and intensive typologies; and the package, partial package and non-package programmes are concerned.

Looking at the inter-regional and intra-regional varietions in the productivity of HYV of rice, it can be said that, the agro-climatic factors like amount of rainfall and moisture, sunshine and cloudiness, heat-budget and variability and fluctuations of rainfall over the sowing, growing, flowering and harvesting periods of the crop affect directly and indirectly its productivity.

The focus of the present study will be, firstly on a general assessment and evaluation of the physical environment and its variation, and secondly on a relationship between the agro-climatic conditions and success or failure of different High Yielding Varieties of rice in a particular region selected for study - The Lower Brahmaputra Valley.

Plan of Work and Methodology:

In order to have a general understanding about the climatic variation of the Brahmaputra Valley, different climatic indices have been prepared and the statistical techniques called the multiple regression and stepwise regression analysis have been applied to ascertain the estimated values of the yield per hectare which depends not only on socio-economic factors but also multiple agro-climatic conditions. The effect of every additional factor on the yield estimation have been studied with the help of stepwise regression analysis. Therefore, it has been felt necessary to explain the dependent phenomenon i.e. yield here by all of its possible explanatory variables which are exclusively in the present case soil and climatic in nature.

On the other hand the stepwise regression will be able to explain how the parameters get changed when new variables are added one by one in the model. First, it explains us the contribution of an added variable in explaining the dependent variable here yield, by seeing the changes in the value of R^2 which is called the co-efficient of determination. Secondly it explains whether a new variable is worth considering in the model or not.

It also helps to keep a watch over the changes in the values of regression co-efficients and their standard errors.

In the present case, the variables chosen to explain the productivity of high yielding varieties of rice in the Lower Brahmaputra Valley are nutrient index, soil texture index, p^H index rainfall, temperature and relative humidity.

With the help of multiple regression and stepwise regression analysis maps of Lower Brahmaputra Valley have been prepared, showing the existing picture of performance of HYV in the region and a geographical interpretation of the maps have been made to arrive at certain interesting findings.

Data base :

The data utilized in the present work is based on the yield estimation survey of the high yielding varieties of rice conducted by the Directorate of Agriculture, Government of Assam. Other relevant data on agro-climatic parameters was obtained from the different government sources like the records of the Indian Meteorological Department, Soil Testing Laboratories of the Government of Assam. Moreover, the author conducted field survey in the area under review to obtain first hand information and data of the region a out soild conditions, agricultural practices, the levels and dynamics of productivity and the performance of HYV of rice in the Lower Brahmaputra Valley.

Study Area :

The present study is confined to a substantial part of the Lower Brahmaputra Valley comprising the districts of Goalpara, Kampup and Nowgong.. As a climatic region Brahmaputra Valley appears to be unique in itself. It records over 400 cm of rainfall, the soil is highly fertile, being deposited by the Brahmaputra and its tributaries. The agro-climatic conditions have made the valley as an area of monoculture of rice in which more than 70 per cent of the gross cropped area is devoted to rice. The study of relationship between the weather conditions and the growth of high yielding varieties of rice has great socio-economic relevance not only because rice is the leading crop of the region but also because the High Yielding Varieties are not very successful over the greater parts of the country especially in the rain-fed areas. It will be a meaningful attempt to establish a spetial relationship between the average weather, condition and performance of HYV in the rice growing region of North-East India. The findings may be useful for agricultural land use planning of the valley the 'Rice Bowl' of North East India.

Literature Review :

Though climatic studies in relation to various

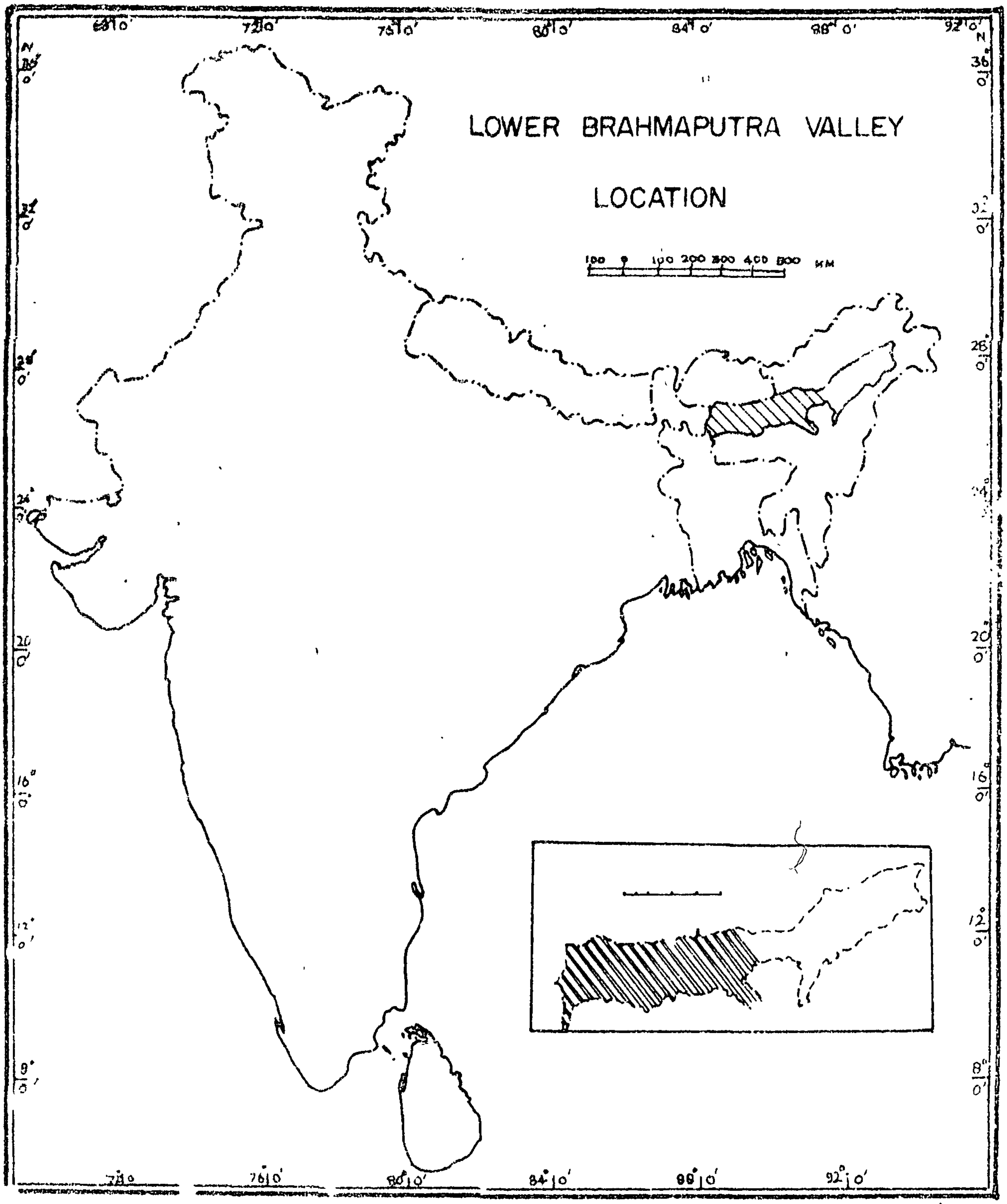
LOWER BRAHMAPUTRA VALLEY
LOCATION
100 0 100 200 300 400 500 KM

Fig. 1

crop production and distribution and specially rice have been attempted by several research workers, a similar study with the exact objective of the present is hardly noticed anywhere. It is however, worth while to give a brief account of the work done in this direction.

Yoshida (1977 a)[1] is of opinion that a dry season crop which gets more sunlight in the tropics with appropriate management normally yields higher than a wet season crop. Satake (1976)[2] while working on sterile type cool injury in paddy rice plants says that low temperature stands unfavourable for the growth of rice crop and supported his statement with the evidence that during the last 90 years 22 crops were affected by cool temperature in summer. Bhattarai (1970)[3] having worked on the performance of IR-8 in Kathmandu valley (Nepal) has drawn conclusion that this valley appears to be the most favourable for the growth and production of IR-8 which returns about 9 tons per hectare because non-protected nurseries are prepared for seedlings when the air temperature reaches 18 to 20°C. The valley is situated on 1324 metre above the sea level.

The crop is normally harvested when the air temperature falls below 13°C. Hence, in the tropical climate, rice can be grown at any time of the year, provided the fields are properly irrigated. Tanaka and Vergara (1967) say that the temperature domiwates for about 30 days from flowering to maturity in the tropics but for 65 days in South Wales Australia and Hokkaido Japan.

Different varieties slightly influence the duration of the ripening period. Generally, greater grain size varieties take a longer time to mature (Yoshida 1977 b)[4] Day length is of little importance for the ripening period Satake (1976)[5] opines that the rice plant is perhaps the most sensitive to low temperature about 9 days before flowering leading to young micro-spore stage. Areas having low temperature both day and night are affected by spikelet sterility. Satake and Yoshida (1978)[6] in a joint venture again say that rice is also most sensitive to high temperature at flowering, Temperature beyond 35°C at flowering might increase spikelet sterility.

Results of the 'Maximum growth rate experiments" conducted as a part of internationally co-ordinated photo-synthesis projects by the local productivity group in Japan reach the conclusion that the mean daily temperature before heading stage generally gives positive correlation with rice yield. Murata and Togar (1972)[7] find out that the daily temperature range during the six weeks period around the heading stage is positively correlated with yield.

So far as the effects of climatic factors on the rice productivity is concerned Munakata et al (1967)[8] found out a parabolic relationship between temperature and rice yields with optimum point at around 21°C. Matsushima and Manaka (19 57)[9] are of opinion that 22°C in the optimum temperature for ripening stage of rice and higher temperature than 25°C adversely affect ripening of rice grains.

De Datta et all (1970)[10] failed to find out the negative influence of temperature on yield of India varieties sown every month during the year at IRRI. Its because higher the temperature, higher is the solar radiation which is associated with higher yield.

Solar radiation is the most important limiting climatic factor for rice yield. This is otherwise called sunshine hours during the period from hooting to active grain filling in middle and southern regions of Japan(C Murata,Y, 1975)[11]. It was observed that a close relationship exists between solar radiation during the said period and rice yield. Murata and Togari after analysing the effect of climatic factors on the rice productivity at different localities in Japan, predicted the yield on the basis of daily solar radiation at tillering stage, daily solar radiation during the yield production period and the temperature parameters.

Very High and very low rainfall are devastating in nature, so far as rice yield goes. Sreenivasan and Banerjee (1973)[12] establishing a relationship between yields of the K-42 variety of rice and the rainfall found that the cumulative influence of rainfall on rice is not unfavourable. But rainfall immediately before harvest brought the yield down. Murata and Togari (1972)[13] reached the inference that the daily amount of rainfall during the reproductive stage is negatively correlated with yield of rice. The next inference they obtained is the daily relative humidity which has got always negative correlation with rice yield. It could be because of the rainfall and cloudy weather which decrease the amount of solar radiation increase relative humidity. So that the grain yield gets reduced. Specially when there is rainfall during reproductive phase.

Ozaki (1972)[14] with the help of correlation method made a long range forecast of drought damage to rice.

In addition to climatic factors, soil parameters play a vital role in success and failure of rice productivity. Ryu et al (1971)[15] arrived at the conclusion that alluvial plains of Korea, with moderate drainage responded better in yield than poorly drained soil. In local valley areas, it was observed that the productivity was quite higher in imperfectly drained soils than that of moderate. Even within a same type of soil series productivity came out to be different because of differences in chemical properties of surface soil.

Choudhury and Ghildyal (1970)[16] studied the effect of submerged soil temperature regimes on growth yield and nutrient composition of rice plant and arrived at the conclusion that soil temperature greatly influences the vegetalive and reproductive growth of plant. 32°C and 20°C were the maximum and minimum temperatures at which highest yield rate was obtained. A tendency was observed in the grain size to be higher and straw to be lower in N, P, K concentration at the above particular critical temperature.

To sum up the investigations made by different researches it is infered that there is still a need to find out new mathematical and statistical models to study the integrated effect of the multiple independent agro-climatic variables on the per hectare yield of different high yielding varieties of rice in a typical climatic region. The above findings appear to be more specific in nature than general. And the studies have been made only taking most of the individual parameters into account. The present study is an attempt to explain the dependent variable i.e. yield with the help of several independent paremeters of climate and soil.

CHAPTER - I

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CHAPTER - II

RICE : DOMESTICATION AND ENVIRONMENTAL ADAPTATION

There is no unanimity among the botanists, anthropologists and archaeologists about the history and domestication of this food crop. A number of hypothesis and conjectures have been made by the experts about the domestication of different crops. A leading Bio-geographer Sauer opines that plant domestication was started in the Neolithic Period and probably by some progressive fishing folk, in the mild climate of South-East Asian forests as this area seems to be ideally suited for fishing culture during the Pre-historic period.

A significant contribution to the modern knowledge of the main centres of origin of cultivated plants has been made by N.I. Vavilov, a Soviet bio-geographer. His researches coupled with archaeological findings indicate the main areas of domestication and the formation of primary breeding culture.[1] Out of eight major geographical locales of wild ancestors of Modern cultivated plants as suggested by accumulated evidences, the gene-centre of rice has been proved to be the South East Asian countries along with a large number of domestic plants. This gene-centre occupied the greater parts of the mainland of South-East Asia India, Burma, Thailand, Indo-china, Malaysia and Indonesia. Sauer is of opinion that the most ancient domestication of plants appeared within this genecentre.[2]

Rice, according to Botanists, owes its origin to the habitat of wild species. The cultivated species are therefore, said to have come from these wild one's. However, the origin of rice culture dates back to such countless ages that its tiresome to trace out the exact point of time and space, rice became a cultivated field crop. Even its cultivation dates to the earlier age of man and said to be the first cultivated crop in Asia being domesticated in about 6000 B.C.

The Anthropological Survey of India discovered in 1970 four terraces beside the Ravi River Valley, situated in the South West of Kashmir which approximately dates to Pheistocene or Ice-age. Carbonised paddy grains of about 1000 to 800 B.C. are found in excavations from Hastinapur along the right bank of the Ganga in Meerut District of Uttar Pradesh. Impressions of Paddy grains on clay and remnants of husks have been noticed in Lothal area of Gujurat and Southern part of Mahenjodaro and Harrappa before 2300 B.C. (CSIR 1966).

Inscriptions of rice in Chinese terms are found which date back to about second Millenium B.C. The crop has been identified as one of the most important food plants even 5000 years ago. Chi (1936) is of opinion that the first authentic record for irrigation of rice is traced out during Chow Dynasty 781-771 B.C. Around 1000 A.D. an early maturing variety called Champa is said to have been innovated to Fukien, Japan from Indo-China. According to world discovery short duration varieties were being grown in 11th and 12th century A.D. Towards 19th century, more and more areas werede devoted to these varieties.

From Indian mythology and legends it is found that, the ancient name of rice was 'Dhanya' which was on the other hand being interpreted as the sustainer of human life. During 6th Century B.C. Sudhodhan King of Nepal's (the then Indian territory) name was associated with rice. Sudhodhan a Sanskrit word stands for pure rice. Hindu offerings as rice to God goes back to antiquity. Tamil Puranas describe the particular varieties of rice for religious offerings. Rice is treated as the main offering to Lord Jagannath in Orissa since time immemorial. From Sasrutha's Materia Medica written in 1000 B.C., it is observed that there were different varieties of rice as per growth period, water need, nutritional value etc.

Japan is historically renowned for its excellent rice, Rice, poller in the clay discovered below lake Biwa and Shiga indicates that even it was being grown 2900 years ago (Japan Information Bulletin 1972). Rice cultivation is said to have been introduced into Kyushu, Japan from China in 100 B.C.

According to Japanese Mythology, it is said that rice had been grown in the heaven by the ancestors of Japanese Imperial Family and they celebrated giving the plant to one of their grandson of the emperor from the sacred garden to plant it in the field. So Japan is called as the land of rice.

Rice culture was introduced in Indonesia by Deutero-Malays while immigrating into this region about 1599 B.C. In Ceylon paddy was grown around 543 B.C. as a dry land crop. About 420 B.C. Singhalese Kings were getting tanks dug for irrigation of the rice fields. Paddy cultivation started declining due to outbreak of Malaria. Now the tanks are being revived to increase the area under rice.

Rice culture in Phillipines also dates back to antiquity Terraced rice fields built by Chinese in Luzon Island about second Millenium B.C. have been discovered. The inhabitants were chalked out by Malays, descendants of the present cultivators.

In most of the eastern countries Borneo, Sarawak, Indonesia, (Java, formerly called), people have been cultivating rice down the countries. In Asian countries rice cakes are symbols of every festival and stand for happiness and abundance. In Java, a legend goes with the following saying that, a girl is unfit for marriage when she is unable to cook a bowl of rice.

Cultivation of rice in western Asia started probably later than that of Eastern Asian countries. Therefore imports of rice from Eastern countries were expensive in early Rome. But no reference is found in Egyptian civilization. Even Bible does not have any reference on rice. Persians appear to be silent on history of rice culture. As a matter of fact the agro-climatic condition of the South West Asian countries were not conducive for the cultivation of rice. Rice culture got innovated to Italy from Orient through Venice.

Species :

"Oryza Stapfii Roschev and Oryza ghaberima steud are presumed to have been cultivated on the Margins of Neolithic Sahara. The historian Iba-Batouta (1350) mentioned the existence of rice in Nigeria which was certainly Oryza-glaberimma Steud. It was introduced into Northern Nizeria in the Sixteenth century. The earliest cultivation of Oryza SativaL. in Nigeria was about 1890 when upland varieties were introduced into high forest zone in western Nigeria.[3]

Red rice (Oryza glaberimma) is said to have originated from Niger-delta some 3500 years ago. Now these are being replaced in Africa by Oryza-Sativa. Portuguese probably introduced rice cultivation in Brazil and Spaniard in central and parts of South America. In U.S.A. rice cultivation started around 1646 as a cultivated crop.

The Genus-Oryza consists of twenty five species distributed over the tropical and subtropical regions of Asia, Africa, Central and South America and Australia. There are two types of these such as diploid (2n=24) and tetraploid. The former is more numerous than the later. The taxonomy seems to be very complicated and the relationship between some of the species is still a debatable point of discussion. Only two cultivated species are observed such as oryza-glaberrima steud and oryza Sativa Linn. being confined to west Africa as an upland crop. But now it has been replaced Oryza-Sativa.

In fact no one is sure of the exact habitat from where rice originated. However the evidences show that the centre of origin of Oryga Sativa Linn. is South East Asia, particularly India and Indo-china. Then it got diffused to different surrounding areas. From the mainland of the continent of Asia, rice spread towards south and east through the Malaya Archipelago with the flow of human culture and social interaction.

Varieties :

There are inumerable indigenous varieties of rice which have been identified historically through ages. As for example the Indica subspecies of Oryza Sativa are being widely grown in tropical regions of South East Asia where as the Japonica Sulas-pecies are grown in temperate countries such as central and North-China, Japan and Korea in accordance with their environmental adaptability.

After prolonged research on the varietal development of rice through hybridization, the high yielding varieties were for the first time, developed in Philippines between 1962 and 1966 and are now being tried out in different parts of India. Exotic varieties of paddy such as Taichung Native-I were introduced in 1965 in India. The HYV rice ripens the seed in about 105 to 136 days as compared to 180 days required by the local varieties. These plants are very sensitive to the surrounding weather con-ditions and their productivity greatly depends on the quality of the environment.

The new agricultural strategy in India, however, became fully operational in the Kharif season of 1965-66 when the propor-tion of high yielding varieties was taken up as the fulfledged programme over a large area and in this agricultural calendar about 17,000 hectares of land was devoted to high yielding varieties.[4]

Different varieties of rice grown widely in tropical and temperate countries such as South East Asia, Central and Northern China, Japan and Korea vary from each other because of their adaptability to the typical environmental conditions.

Generally Indica varieties are successfully grown in South East Asian countries. However, Japonica sub-species have been proved suitable in the countries like Japan, Korea, Central and Northern China where the climate is predominantly of temperate characteristics. Because of the world climatic vagaries, it is often felt necessary to study the varietal characteristics of rice in relation to various elements and factors of climate.

Those varieties suited to temperate climate are insensitive or weakly sensitive to day length, hence they can tolerate low temperature. But there are other types in tropical regions which have different degrees of sensitivity to sunshine and day length, thus susceptible to low temperature.[5]

There are three stages of growth of rice plants, such as vegetative, reproductive and ripening. The vegetative period is divided into basic vegetative phase and photo period sensitive phase where the short photo-period can induce floral initiation in sensitive varieties.[6]

The late and tall Indica varieties are photo-sensitive and fail to flower when subjected to photo-periods longer than 13 hours. High yielding varieties which have been recently introduced such as Jaya, IR-8, Ratna, IR-5, IR-20 etc. are quite weakly sensitive to photo-period. Thus only the less sensitive varieties can be grown successfully round the year in intensive cropping system. Photo-sensitivity[7] is helpful in particular environments such as flooded tracts of South-East Asia and regions where arrival of rainy season is delayed.

Climatic factors and Rice :

Climatic factors such as temperature, sunlight and rainfall are the major determinants of the growth and yield of rice. They directly affect the physiological process involved in grain production such as vegetative growth, development of spikelets and grainfilling. Indirectly the grain yield is affected by them through incidence of plant diseases and insects.[8]

Temperature :

Temperature is considered as one of the dominant climatic factors that affect the growth and yield of rice. There are critical high and low temperatures normally below 20°C and above 30°C in each phase of rice growth.[9] There are two most important ways by which the growth of rice plants are controlled.

1 - A critical high or low temperature of the environment under which the life cycle of rice can be completed.

2 - Temperature within the critical low and high determines the growth duration of variety under a given environment. On the contrary, the critical low and high temperatures vary from one growth stage to another. Hence, they differ according to variety, duration of critical temperature, divisional change and physiological activity of the plant.

Temperature also affects the rate of development of leafs. The number of leaves, developed in the main shoot before heading is fairly constant for a given variety. Therefore the number of days from sowing to flowering is constant for an insentive variety under a given temperature regime. Another effect of temperature on rice plants is that the rate at which the grain filling starts after flowering is considerably affected by temperature. So the temperature summation indices are prepared in order to predict the growth duration of photo period insensitive varieties under a given environment.

So far as the experimental studies go, temperature a affects the tillering rate and relative growth rate. Slightly at 3 to 5 week stage. During reproductive stage within a range of 22 to 31°C the spikelet number increases as the temperature drops. Thus the optimum temperature stage is noticed to shift from high to low as growth advances from vegetative to reproductive stage. Low temperature quickens the increase of number of spikelets per panicle.

The average optimum air temperature for the ripening of rice in temperate region has been found to be 20 to 22°C. However, in tropica climate daily mean temperature of 28° to 29°C is also observed to be equally favourable for Indica varieties. The Indica varieties are better adapted to high temperature. But Japonica varieties need low temperature for better ripening. Hence, low temperature is helpful in increasing the weight per grain owing to longer ripening period. It has been experimented that constant cloudy weather conditions is more detrimental to grain filling under high temperature due to shorter ripening period. Temperature greatly influences the growth rate right after germination. Growth rate increases with temperature.[10] Response of rice plants to varying temperatures at different growth stages has been presented in Appendix-I.

Solar radiation and Rice :

The amount of solar radiation at 26 sites in 15 rice growing countries ranges from 50 cal/cm^2 per day in December at Milan (Italy) 700 cal/cm^2 per day or higher in June or July at Lisbon (Portugal) and Davis in California (U.S.A) or from November through January at Griffith (Australia) or more during the rice ripening period.[10]

Solar radiation so to say is the only form of energy used in Photo-Synthesis by green plants. Its requirements for a rice crop differs from one growth stage to another. Shading during vegetative stage though insignificantly affects the yield and yield component, but during reproductive stage it considerably decreases the spikelet number and hence yield. Yield also gets decreased because of shading during ripening stage which is attributed to decrease in filled grain percentage.

In brief it can be said that the temperature and solar radiation are responsible for rice productivity when water supply is adequate. Its distinct that the influence of climate seems apparent only when a good variety is grown in good soil, with adequate spacing, timely supply and dësired amount of nutrients, and thorough control of pests and diseases. Weather conditions before and after flowering affect the yield in various ways. As for instance, it affects the yield capacity of a crop and the size of the Photo-synthetic survace for ripening just before flowering where as it increases the grain plumpness immediately after flowering. Therefore, solar radiation approximately 200 $cal/cm^2/day$ is essential during reproductive phase to obtain an yield of 4 ton per hectare.

In tropical countries it has been marked that a significant positive correlation exists between the grain yield and solar radiation from 15 days before flowering to harvest. According to Yoshida and Parao (1974) in IRRI, Solar radiation and temperature during reproductive stage have collectively the maximum influence on rice yield as they determine the number of spikelets per unit area. It is also observed that a combination of low daily mean temperature and high solar radiation during reproductive stage increases the grain yield.[12].

Moisture Requirement and Rice :

In most of the rice growing countries of the world paddy cultivation is entirely dependent on seasonal rainfall. The requirement of water for rice crop is affected by solar radiation temperature, win and speed, and air humidity.

So far as soil factors are concerned soil texture, depth of water table, and topography determine seepage, percolation and run off of water. The water requirements of irrigated rice crops at 43 sites in China, Japan, Korea, Philippines, Vietnam Thailand and Bangladesh are given below.[13](King 1971).

TABLE -

Water loss		Water requirements
Transpiration		1.5 - 9.8 mm/day
Evaporation		1.0 - 6.2 "
Percolation		0.2 -15.6 "
	Total	5.6 -20.4 "

Field operation		Water requirements
Seed nursery		40mm/ Crop
Land preparation		200 "
Field Irrigation		1000 "
	Total	1240 mm/crop

From the above data it is vivid that the daily water consumption for most places ranges from 6mm to 10mm and the total requirement touches about 1240 mm per rice crop. In order to estimate whether the rainfall is enough to meet the water requirement of a rainfed rice crop both gains and losses of water must be taken into consideration.

However, humid atmosphere stands erroneous for paddy crop. Its observed that in many countries where yield is satisfactory humidity in the atmosphere is very low. Irrigated paddy is cultivated in northern India and Pakistan where rainfall in annual average is even less than 280 mm. So paddy field has its own micro-climate raising the relative humidity within the crop much above the adjacent unirrigated areas.[14]

<u>Rice and Soiltype</u> :

According to Dudal (1958), Paddy soils are left unused for varying periods in temporarily flooded condition in order to allow the movement of iron and manganese compounds from the upper layers to reprecipitate at a lower depth with the help of net abolism of anaerobic bacteria. The surface soil starts getting oxidised because of oxygen obtained from irrigation water. On the other hand, iron and manganese compounds in the reduced zone are carried down get reprecipitated and from a layer 5 to 20 cm thick at depths ranging from 20 to 60cm. This is called 'plough pan' and occurs in the upper layers of paddy soils as a result of disintegration of the aggregates by ceaseless flooding. This plough pan is therefore not necessarily related to ploughing of the field. The process of paddy soil formation a further starts when substantial amount of silt is deposited in succession by floods or irrigation water.

This sort of formation of paddy soils has been noticed on alluvial soils, grumosols, latosols, andosols, regosols and to some extent on red yellow padosolic soils, grey hydromorphic soils, and planosols and grey brown podsolic soils.

Soils also vary even to a greater extent within relatively limited areas. Hence, adequate knowledge regarding soil is very necessary in relation to choice, quantity and timing of fertilizer application. The type of soils favourable for rice cultivation rely more on the surrounding conditions under which the plant is grown than upon the nature of the soil. Water is considered as the most important factor for paddy cultivation. So the soil water relationship largely determines the ability of the soil in order to develop fullest potentiality for better production. Rice, when cultivated under semiaquatic conditions needs a heavy soil through which the irrigation water does not percolate easily because the demand of the plant for water is felt more precise than on soil condition. Peddleton (1943) says that "Rice doubtless the most adaptable food crop man grows and if enough water remains in the soil until the maturing of the crop, it can produce at least a little grain on soils that are unbelievably poor in plant nutrients".[14] Paddy even, has been grown excellently in the poorest class of soil.

In Asia, extensive areas of paddy fields are found in the deltas of great river or along their banks. So the paddy cultivation is judged better from the point of view of water supply rather than from the nature of the soil. According to some authors, paddy does not have a special demand on soil, but still different types of paddy have been found suitable for certain specific types of soils. Evidences are found that, rice grows better on heavy clay soil than upon the lighter soils constituting of higher proportion of sand. Even satisfactory yields are obtained from sandy soils, if there is adequate supply of water through irrigation, with heavy dressings of organic matter and fertilizers. The 'muck' and peat soils are unfavourable for rice growth due to difficulties in draining and cultivating such soils. The heavier types of soils containing good amount of organic matter are most suitable for paddy cultivation. So dominantly paddy yielding areas are found to consist of their soils more than 70 percent of the finer particles and clay plus silt, Ramiah (1954) says that their are two important reasons for the wide disparity of rice yields. First the low water supply in certain areas and second, because of the variation in soil conditions.

CHAPTER - II

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CHAPTER-III

AGRO-CLIMATIC SET-UP

The area selected for study is the Lower Brahmaputra valley. The valley of Brahmaputra, situated between $25^{o}44$ to $27^{o}55$ N and $89^{o}41$ E to $96^{o}02$ E is an area of unique characteristics and a well defined physical unit as well. It is surrounded by the Eastern Himalayas, Patkai, Naga Hills in the east, the Garo-Khasi-Jayantia and the Mikir Hills in the South. The valley extends from the eastern most tip of the upper Assam to the west of Dhubri on the border of Bangladesh. It covers an area of about 56,274 sq.km and consists of the administrative districts of Lakhimpur, Dibrugarh, Sibsagar, Nowgong, Darrang, Kamrup and Goalpara. (Fig -7)

Physiography :

The Brahmaputra valley is made up of the aggradational work of the Brahmaputra and its numerous tributaries. The valley appears to have gentle slope from North-East at Sadiya to Dhubri in the west. The valley is separated from its surrounding physically, by 150M contour and its general level varies from 130 M in the east to 30 M in the west with a fall of 12cm per km. The valley is predominantly built up of alluvium of 1500 M thick upon a sag formed during the Himalayan uplift. On the other hand, it is very well defined by the boundary fault in the North and the Naga thrust[1] in the south. The slope of the valley seems to be steep in the Northern margin, having an immediate fall from the Arunachal Himalayas, but in the south, the valley has a gentle fall from southern hill ranges.

In the upper Assam the valley is substantially wide ranging between 80 to 100 km in an average. But in the middle part it has narrowed down to 55 km because of the projection of the granite-gueissic rocks of the Mikir Hills. It again goes on widening towards west and the plain of Kapili joins the main valley. However, it further narrows down to 65 km in an average while running between the Shillong Plateaue and Bhutan Himalaya. In Gauhati area, the river flows very close to the Shillong plateau and it has been noticed that a substantial part of the plateaue has been detached and granite hillocks projections have come up in its northern bank. From this point the valley starts widening till it merges with the plain of Bengal.

There is a spectacular difference between the Northern and Southern bank of the river. Numerous tributaries in the form of channels and streams are seen in its Northern back forming alluvial fans on the way. These alluvial fans obstruct the courses of the tributaries near the foot-hills. Hence a number of channels are formed until the tributaries have a permanent course. Meandering courses of these tributaries are also common on the way with bitts and oxbolakes. Extensive marshy tracts with wet soil have been formed by the alluvial debris of the tributaries giving rise to dense forest cover.

The southern section of the valley is less wide and the tributaries are very large in the south-east. Mikir and Rengma hills have been isolated from the Meghalaya plateau by the head ward erosion of the tributaries, Dhansiri and Kapili. The Western section of this part is very narrow with small tributaries. But the eastern part of the southern section of the valley is full of meanderings of the tributaries with bills and oxbotakes.

An important physical characteristic of the Brahmaputra is that the river is considerably braded only because of its low gradient resulting into numerous riverain islands.

Drainage :

The Brahmaputra and its hundreds of tributaries play vital role in the drainage system of the region. The prospect and importance of agriculture in the State lie in the fact that the fullest exploitation of the vast potentiality of the water resources of this valley drained by the mighty Brahmaputra reaches its peak.

The mighty Brahmaputra owes its origin to Kailash range at an attitude of about 5/50m. The upper course of the river lies in Tibet where it is called Tsangpo. While flowing through the Siang division of Arunachal Pradesh it is known as Dihang. Near Sadiya it joins with Dibang from North and Lohit from east and from this point the waters of these three rivers make the Brahmaputra. The river flows between sandy banks and it has got numerous divergent channels which afterwards rejoin the mainstream It carries heavy silt and sometimes with a little barrier, it creates almond shaped banks which may be washed away or left out to form big char. Most of the places in the valley are endangered by the erosional activity of the Brahmaputra during floods. Dibrugarh being situated on the sandy banks of the river is susceptible to erosion every year during floods. But Tejpur, Gauhati, Goalpara and Dhubri are less prone to erosion because they are situated on the outcrop of hard and resistant rocks.

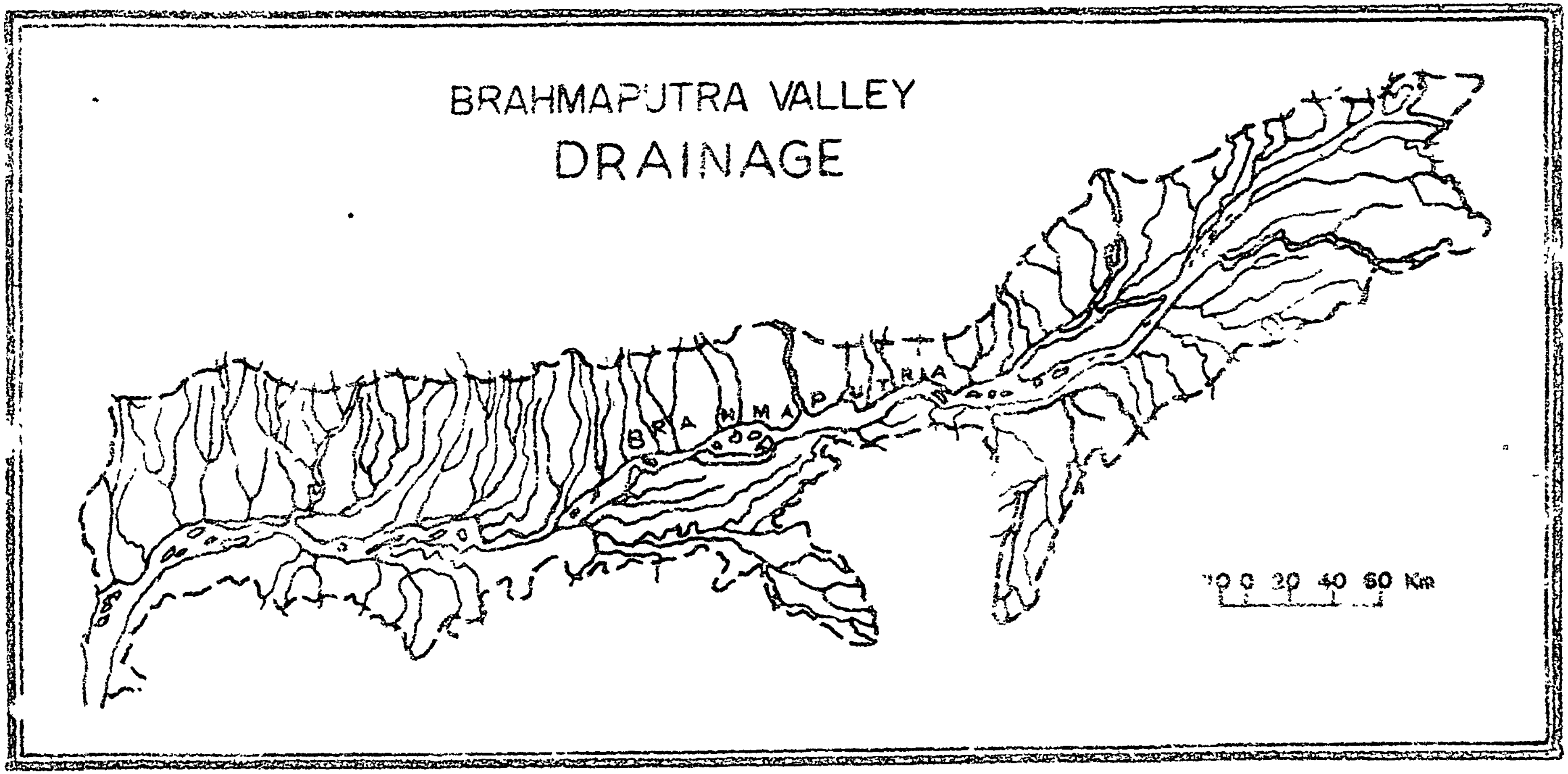


FIG-2

The rivers takes turn immediately after Dhubri round the spur of the Garo Hills. Then it flows through the plains of Bangladesh, gets confluenced with Padma, a branch of the Ganga and finally merges into the Bay of Bengal.

The important and major tributaries of the Brahmaputra include the Subansiri, Bhareli, Dhansiri, Barnadi, Pagladia and the Sarkosh on the right bank and the Lohit, Dihang, Noa-Dihing, Burhi-Dihing, Disang, Dikhow, Shanji, Dhansiri, Kapili, Digaru, Kulsi, Singra, Jiniram, Dudhnoi and the Krishnai on the left bank. A good number of these tributaries are rivers having substantial catchment areas. The following table presents the catchment areas and the discharge of water in Cusecs of some of the important tributaries of the Brahmaputra.[2]

TABLE-II

Tributary	Catchment area in km^2	Discharge of water in cusees
Manas	31,000	-
Sankosh	26,000	-
Lohit	21,000	33,800
Dihang	13,000	27,200
Subansiri	-	16,000

The rate of discharge of the river at Goalpara has been measured to be over half a million cusees of water. A few tributaries on the right bank appear to be changing their courses, thereby causing concern to the agricultural land and the human property some known tributaries of this type are the Bhareli, the Dhansiri, the Baruadi and the Manas.

Left bank tributaries such as the Lohit, the Dihang, the Burli-Dihing, the Dhansiri and the Kapili are seasonal mon-

monsoon streams and have less meandering course. But Dhansiri is quite meandering. Few of them are navigable also.

Floods, in the valley,during rainy season are considered as the most dangerous natural calamity resulting into heavy loss and damage to agriculture and settlement. This is because of the tremendous volume of water and silt discharge by the river. And the water due to heavy down poor of rain in the rainy season is supplemented by the snow melting water of the Himalayas. The river gets chocked up, active erosion starts on the bank, there by filling the river beds which loose the water holding capacity. This sort of conditions make the river swell, thus resulting into innndation. Earthquakes are also another danger to the valley, making the river change its course. Heavy water discharge of the Brahmaputra thus, influences its tributaries in their water profile. Hence floods have become common feature in the tributaries along with the main river almost every year which create flood and havoc conditions resulting into loss of crops and property.

Climate :

The climate of Assam, as well as the Brahmaputra valley is primarily monsronic. The valley's climate has a rythemic change in the wind direction, it is mainly governed by the following five factors :

i) the Orography

ii) the alternating pressure cells of North East India and the Bay of Bengal

iii) the predominance of maritime tropical airmass.

iv) the periodic western disturbances and

v) the local mountain and valley winds.

The high and lofty mountains in the North help to protect cold airmass blowing from Tibetan plateau to the valley as well as create favourable orographic condition for Orographic rainfall. These mountains also check warm moist southwest monsoon airmass. The east ward moving upper air troughs called the western disturbance and the local phenomena such as mountain and valley winds have considerable impact on the climate and weather of the valley.

The mountain and valley winds start moderating the temperature conditions so that heat waves in the valley are hardly experienced in summer. Fogs, thunderstorms and dust raising winds also come under the local weather conditions. Winter mornings are very foggy in the valley and prolongs for a period of 60 to 70 days in some places of southern part, 90 to 100 days. The existence of fogs is due to availability of moisture evaporated from river beds and from marshy and swampy areas of the valley.

Thunder storms in the valley are also very frequent with prepronsoonic rain exceeding 100 days a year in the north east part of the valley. These occur due to profused incursion of moisture both from monsoon winds and local sources (rivers-lakes and swamps) and addition of radiated heat from dry surface over Assam with adequate potential energy for the growth of storms.

Dust raising winds are seen in the valley in the beginning of the pre monsoon season i.e. in March. This phenomenon occurs because of the steep pressure gradient over the valley and subsides with showers of rain.

Seasons :

On the basis of temperature variation rainfall and winds the following four well defined seasons are observed in the valley:

1. Winter season - December to February
2. Premonsoon season or Summer - March to May
3. Monsoon season - June to September.
4. Retreating Monsoon - October and November.

The winter season starts from December and ends in February. The main characteristic phenomena of this season are cool weather, frequent morning fog, average monthly temperatime above 12.8°C, total rainfall amounting to an average 11.4cm. January is the coldest month. Cold spells occur with decrease in temperature.

The summer season begins from March and ends in May. The season is characterised by a rise in temperature, increase in amount and frequency of rainfall with the advance of the season, decrease in diurnal range of temperature. The total average rainfall during the season is recorded as 51.87 cm with an average temperature of 23°C and average diurnal range of about 6.1°C.

Monsoon season in the valley starts from June and ends in September. The low pressure trough created in the valley drawn in the monsoon currents. The seasonal characteristics include high humidity, weak surface winds, cloudy sky and very sultry weather due to high humidity. The mean temperature during the season increases to 27.17°C with a diurnal range of over 6°C. August seems to be the hottest month of the year and falls in this season. The total rainfall is very high with number of rainy days 18-20 in June, July and August and about 14 days in September.

The season of retreating monsoon covers the period of October and November. The season is characterised by a sudden retreat of monsoon when the monsoon weakens towards the end of September, fall of temperature, and appearance of morning mist and fog. The diurnal range of temperature starts increasing and varies from 2.8°C to 5.6°C Winds in this season blow from the north. The average rainfall in this season is about 15.2cm with rainy days varying between 7 to 9 in October and 1 to 3 days in November.

Summing up the whole climatic phenomena in the valley in general it could be concluded that though there prevails a homogenious climate in the valley, nevertheless there is considerable heterogenity in climatic conditions within and between different parts of the valley, in terms of variations in rainfall, range of temperature, and other phenomena like mist and fog. There is a spectacular difference between the eastern and western part of the valley so far as rainfall and temperature are concerned. The eastern part gets very high rainfall, and low range of temperature where as the western part experiences less rainfall and a higher range of temperature. At the same time the middle portion of the valley seems to be having a rain shadow position and many climatic phenomena different from east and west.

Since the present study is confined to the western part of the valley in the lower Brahmaputra valley in particular, a detailed account of the rain fall temperature and humidity distribution in the whole valley in general and the lower part in particular was presented below with a special emphasis on the period 1977-78 for which statistics of the High Yielding Varieties were collected. This discussion will more relate to the rainfall temperature and relative humidity distribution in the Lower Brahmaputra Valley during 1977-78 because these climatic elements are directly responsible for the yields of the High Yielding Varieties of rice obtained during this year. Therefore the climatic study has been related to the productivity of HYV rice in accordance with the time duration in which transplantation and harvest of HYV rice were finished.

Rainfall effectiveness :

(i) Total and Mean Monthly rainfall :

Much of the arable land available for agriculture lie on either side of the river Brahmaputra where though rain fall does not vary so much round the year, but gets concentrated only during the Kharif season with the arrival of monsoon, thereby causing water logging condition which occasionally causes serious damage to the crop. Therefore it is unpracticable to generalize the pattern of annual and monthly rainfall. The rainfall effectiveness is studied in terms of concentration or intensity of rainfall on the monthly or weekly basis.

At a glance to the 30 years normals of monthly rainfall total and annual mean for 6 major meteorological stations such as Dibrugarh, Sibsagar, Tezpur, Gauhati, Nowgong and Dhubri, plotted in Fig. it is distinct that the 30 years mean annual rainfall varies from east to west direction, between 2759.4mm and 1043.9 as the highest and lowest for Dibrugarh and Nowgong respectively. Nowgong being situated midway between Dibrugarh and Dhubri gets the least rainfall and from this point it starts increasing east ward again.

During the monsoon season i.e. from June to September in the valley, 60 to 70 percent rainfall occurs, Nowgong being an exception where above 90 percent of the total annual rainfall is recorded during June to September though the total monsoon rainfall is relatively lower than all other stations in the valley. In terms of percentage, Dhubri has the highest i.e. (68.46) during monsoon season where as Dibrugarh stands second. But Dibrugarh has the highest total rainfall during June to September So it all depends on the monthly distribution of rainfall during monsoon period rather than their percentage occurence.

Intensity :

The precipitation and the number of rainy days may be sufficient to meet the requirements of different crop production in general and HYV rice in particular, but successful harvest is noticed only when there is uniform and timely rainfall. So the concentration of rainfall over few months decreases its usefulness. In 1977 it so happened that the transplantation of HYV rice was carried on without rain because of the lat arrival of monsoon in many blocks of the lower Brahmaputra valley.

It would be worthwhile if the intensity of rainfall is studied for the selected station of the whole valley which explains the intensity per 24 hour period. The intensity of rain-

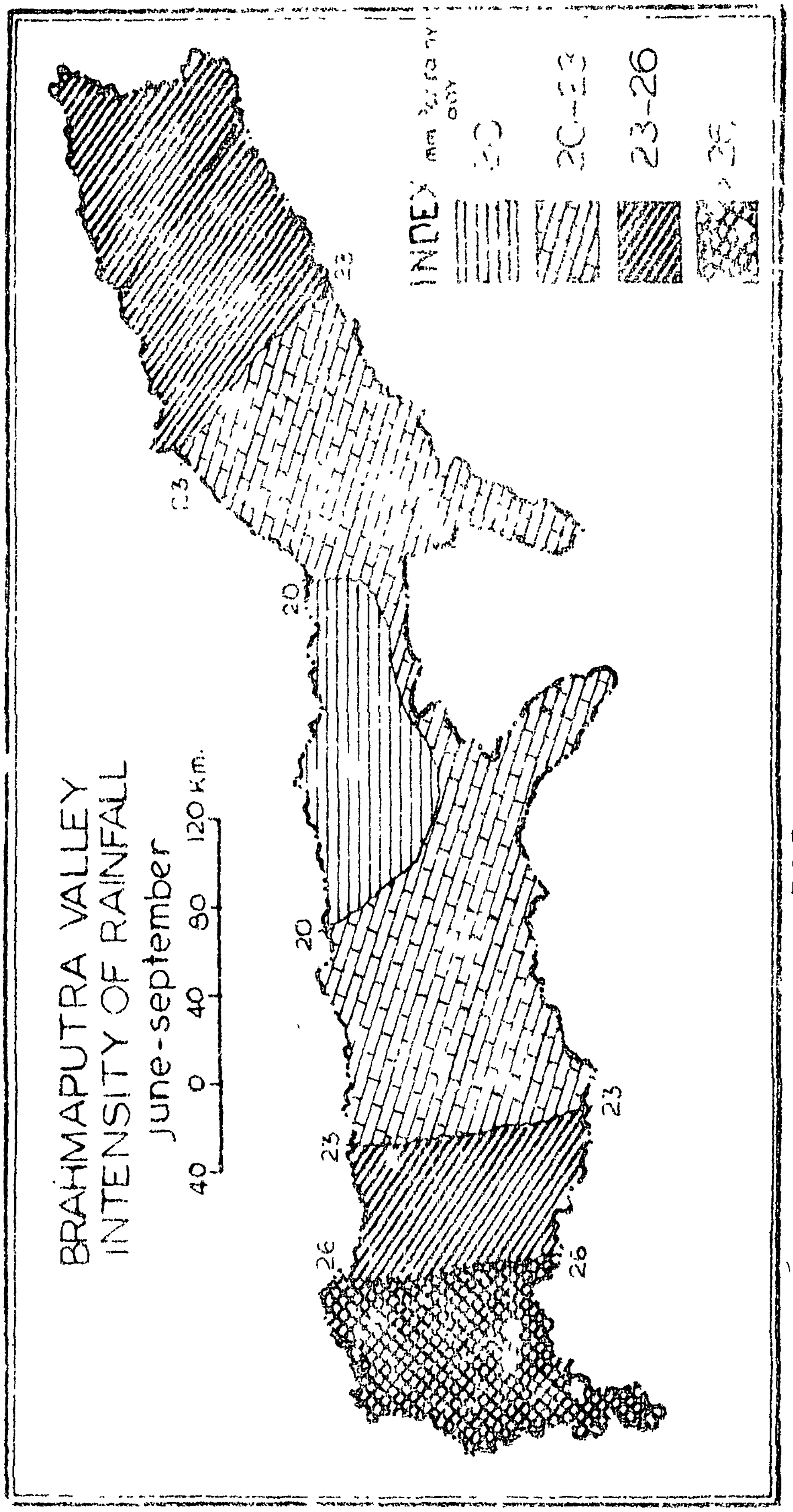

BRAHMAPUTRA VALLEY
INTENSITY OF RAINFALL
June-september
40 0 40 80 120 K.m.
INDEX
23-26
20
23
26

FIG-3

fall is calculated with the following formula. The table presented below shows the station-wise monthly intensity of rainfall.

$$I = \frac{\text{Total monthly rainfall}}{\text{No. of rainy days}}$$

TABLE -

Intensity of Rainfall (1931-60)

				M		O		N		T		H	S
Stations	Jan	Feb.	Mar	Apr.	May	June	July	Aug	Spt.	Oct.	Nov.	Dec.	Mean Annual
Dibrugarh	9.69	9.81	12.48	17.11	21.86	26.09	25.57	23.15	22.47	20.46	11.38	10.62	20.95
Sibsagar	9.28	9.49	11.97	24.24	21.75	21.12	24.06	21.63	20.53	15.57	12.54	12.19	19.91
Tezpur	9.44	9.78	11.52	14.44	18.22	17.46	20.63	20.03	19.36	18.97	12.58	9.2	17.99
Gauhati	9.5	10.17	12.71	19.17	18.12	20.1	21.23	23.07	20.00	18.77	7.67	10.00	18.84
Dhubri	14.00	12	16.18	19.52	25.52	35.21	28.18	21.69	29.07	25.02	16.88	12	26.47
Silchar	13.27	13.97	14.48	25.2	28.19	28.28	22.58	22.31	23.21	24.35	23.16	13.8	23.89
Nowgong	11.5	11.79	8.4	0.77	9.71	18.08	20.58	23.04	21.1	16.33	20.00	11.4	20.63

It will be seen from Table - that in Dibrugarh, June and January have the highest and lowest intensity of rainfall being and respectively. But in Sibsagar the highest intensity is observed in the month of April, lowest being the same. Tejpur experiences high intensity of rain in July and low in December. As evident from the Map - Gauhati shows highest intensity of rainfall in the month of August and lowest in January. Dhubri lying in the lowest part of the valley has the highest intensity of rain in June and lowest in February and December. So the highest rainfall intensity throughout the valley from east to west is observed in the months of June, April, July, August and June for the stations described above. Similarly lowest is seen mostly in the month of January and December for Tejpur and December and February for Dhubri.

So far as the intensity of rainfall in the monsoon reasons is concerned, Dhubri has the highest intensity during this season where as Tejpur has the lowest.

Rain factor :

Another meteorological quantification has been done with the help of the formula rain factor which is an index to express a relationship between precipitation and temperature to have an idea about the climatic aridity of the valley. On the other hand it also helps in delimiting the climatic region. Since the number of stations are less, a general discussion over this index could be given. Thus the index is calculated as.

$$\text{Rain factor} = \frac{\text{Annual precipitation in MM}}{\text{Mean annual temperature in }^{\circ}\text{C}}$$

The following table presents the station-wise rain-factor indices.

TABLE - IV

Stations	1973	1974	1975	1976	1977	Average
	YEARS					
Dhubri	90.5	80.22	59.67	90.49	135.48	91.27
Gauhati	65.52	82.61	62.19	67.33	106.06	76.74
Rangia	24.2	44.44	71.00	71.80	51.39	52.56
Tangla	58.88	90.02	61.17	82.0	91.15	76.64
Majbat	19.13	47.26	78.93	80.3	108.08	66.74
Tejpur	5.93	77.23	-	51.41	87.21	62.95
Gohpur	-	-	-	103.75	66.46	85.11
Chaparmukh	-	74.63	115.02	127.07	153.56	117.57
Lumding	-	40.06	61.85	56.87	62.58	50.34
Dibrugarh	99.77	124.7	105.08	82.94	140.91	110.68
Digboi	-	33.01	-	43.07	63.19	46.42
N.Lakhimpur	100.87	81.35	129.54	110.63	141.65	112.8
Silchar	114.98	98.14	89.82	151.66	133.71	117.66
Haflong	86.95	23.04	86.69	70.00	60.01	65.54

As evident from the Table IV the 5-years average rainfactor from 1973-77, varies between 46.42 to as high as 117.57 for Digboi and Chaparmukh respectively. The second and third highest indices are found out for North Lakhimpur and Dibrugarh. Such low index which shows high aridity in Digboi and its surrounding region may be attributed to high temperature range and low rainfall. Moreover Lumding is also having comparatively lower index i.e. 50.34 and is situated on in the south east of Nowgong and North of Mikir Hills which is otherwise interpreted as the rain shadow area having rainfall comparatively lower than all other stations in both lower and upper Brahmaputra valley. Hence, crop risk in this area is considerable. In order to raise successful crops irrigation is felt essential in this part of the valley.

In upper Brahmaputra, North Lakhimpur, Chaparmukh and Dibrugarh have fairly high indices which shows low aridity in these parts. So water surplus in these areas are more prominent than deficit. On the other hand these areas experience high amount of rain fall with low mean daily temperature range. A rational management of water resources in this part of the valley will help in bringing high productivity for all crops and particularly rice.

Switching over to the lower part of the valley, the indices appear to be relatively lower than the stations in upper Assam. In this area although rainfall, total, monsoonal and mean monthly are not very less, but the daily temperature range is very high, thereby causing considerable evaporation from water bodies. Though the mean annual rainfall of Dhubri, being situated in the western most tip of the valley, is more or less same as that of Dibrugarh, there is a substantial difference between the rain-factor index i.e. 91.27 for Dhubri and 110.68 for Dibrugarh. Its all because of the temperature variation between the upper and lower part of the valley. Rangia and Tejpur in Kamrup and Darrang districts respectively experience acute aridity the indices nearing 50.0. In the lower part of the valley comprising the districts of Goalpara, Kamrup, Nowgong and Darrang, the index ranges between 50.34 to 91.27 for Lumding and Dhubri respectively. Hence its district that as one proceeds towards the western part of the valley the index goes on increasing, indicating less and less aridity in the region. Gauhati, being situated midway experiences a moderate index which can be interpreted as not very arid and very wet climate.

In the year 1977, for which the highly weather sensitive varieties of High Yielding rice has been studied in the lower Brahmaputra valley region, it is observed that the rainfactor index has a tremendous variation between 51.39 to 135.48 for the stations Rangia and Dhubri respectively. Since higher is the index, lower is the aridity and vice versa, the same has a cast to west trend.

Air Humidity :

Apart from temperature and amount of rainfall the relative humidity has also a close bearing on the output of varieties of rice. The valley experiences a very humid climate, the mean annual relative air humidity exceeding 70 percent in each of the raingauge stations excepting Nowgong whose mean annual relative humidity comes out to be 55 percent only. The data relates to 30 years average for each month from 1931 to 1960. In the upper part of the valley, Dibrugarh and Sibsagar have more than 80 percent relative humidity in air. However, in the lower Assam valley the same has a range between 76 to 78 percent. So far as the relative humidity is concerned there appears not much variation between lower and upper Brahmaputra valley. But the slight variation in the lower valley is due to high temperature range in its air.

Coming over to the air humidity in monsoon season only, it is observed that more than 80 percent humidity is experienced in every part of the valley excepting Nowgong where even in June the air humidity is 49 percent. In August highest humidity is recorded i.e. 81 percent and June and September have more than

75 percent relative humidity. Dhubri being situated in the lowest tip of the valley has the highest relative humidity in its surrounding air. On the contrary it is the most humid part of the valley where percentage of humidity exceeds 85 percent and in June average air humidity is 87 percent.

Dibrugarh has a very uniform percentage of air relative humidity in wet monsoon months. An average 85 percent is observed in each month starting from June to September. Winter months in the valley also appear to be humid, the air humidity ranging between 60 to 80 percent. But Nowgong and its surrounding air seem to be very dry, the lowest humidity being 27 percent in April. Even February and March show 49 and 34 percent humidity in the air respectively.

Therefore, it has been observed in most places that rice gives satisfactory yield in the areas having less humid atmosphere. Either part of the valley seem to be having very humid surrounding which sometimes stands erronious for rice crop. However, Nowgong and its surrounding areas affect the crops favourably in winter because of its very low relative humidity which is rather conducive for crop growth. The variation of temperature, and rainfall and humidity has been shown in Fig. - 4

The following table presents the monthly average relative humidity in percentage for six raingauge stations in the valley. The data relates to 30 years average from 1931 to 1960.

TABLE - V

Relative humidity in Percentage

	MONTHS												Meal
Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Spt	Oct	Nov	Ded	Annual
Dibrugarh	83	78	71	74	81	85	85	85	85	82	80	84	81
Sibsagar	85	80	74	76	80	82	82	83	86	86	86	86	82
Tejpur	78	70	62	66	89	83	84	84	84	81	79	81	78
Gauhati	78	68	61	65	77	82	82	82	83	81	81	81	76
Dhubri	75	66	57	65	81	87	86	86	86	80	78	78	77
Nowgong	61	49	34	27	28	49	78	81	75	59	55	61	55

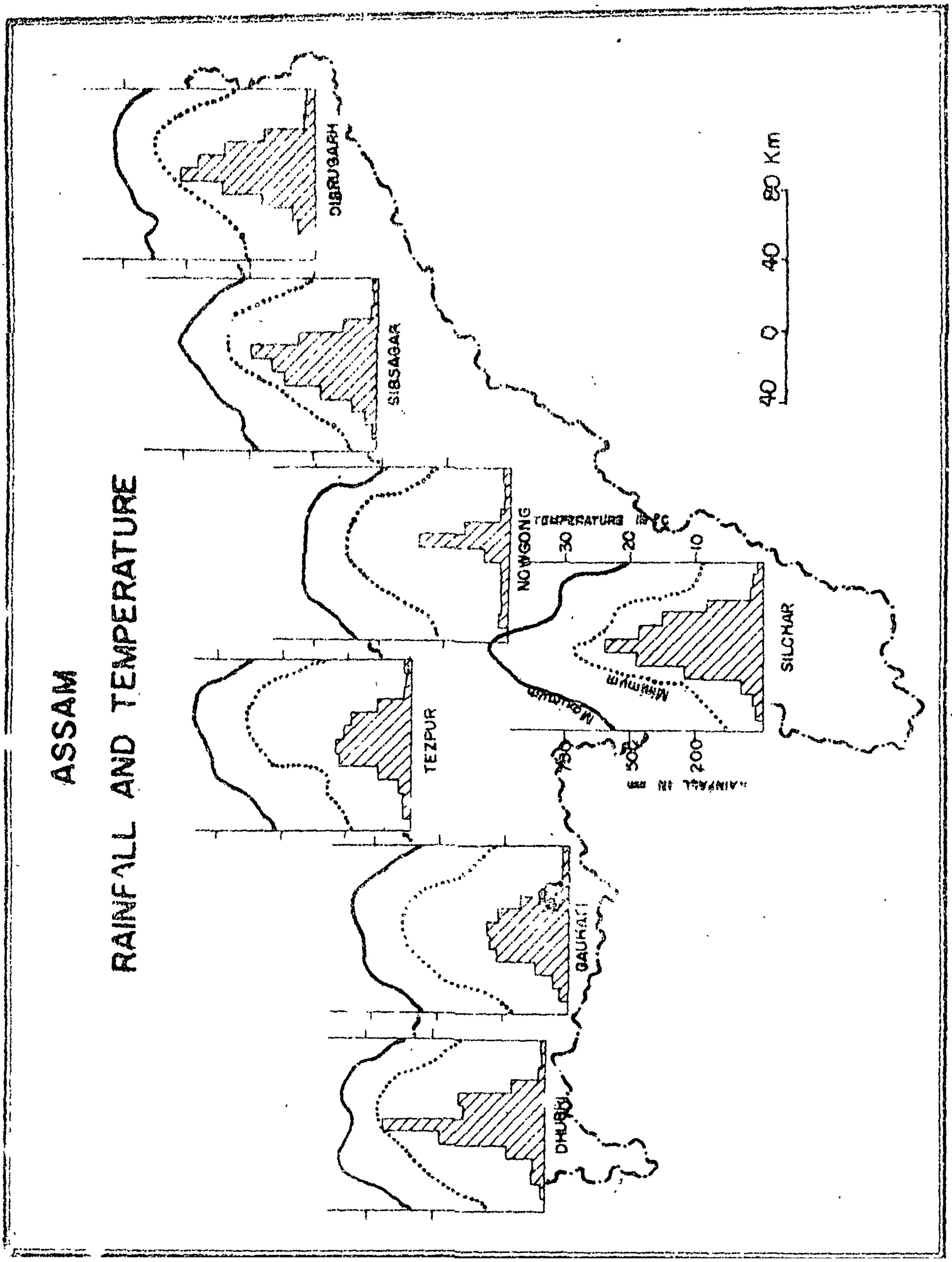

ASSAM
RAINFALL AND TEMPERATURE
DIBRUGARH
SIBSAGAR
NOWGONG
TEZPUR
GAUHATI
DHUBRI
SILCHAR
Maximum
Minimum
TEMPERATURE IN °C
30
20
10
RAINFALL IN mm
100
200
40 0 40 80 Km

FIG-4

Temperature :

As evident from the 30 years normals of the above said stations, the mean annual temperature varies between as low as 23.2 to as high as 25.35 for Dibrugarh and Nowgong respectively. There is a spectacular difference between the Kharif and rabi seasons of the year, so far as the temperature variation is concerned. Stations falling in the lower part of the valley show a higher range of temperature than the upper, normally more than 24°C. Hence the sensitive high yielding varieties of rice crops are more prone to failure and low yield.

The efficient index for temperature has been calculated with the help of the formula

$$I = \frac{T - 32}{4}$$ where T = mean monthly temperature in °F.

devised by C.W.Thorathwaite

The range of variation for each station was given below:

Dibrugarh	-	14.29	-	18.91	(December - August)
Sibsagar	-	13.75	-	19.40	(January - July)
Tejpur	-	14.29	-	19.31	(January - July)
Gauhati	-	14.27	-	19.45	(January - August)
Dhubri	-	14.20	-	19.15	(January - August)
Nowgong	-	13.60	-	21.94	(January - May)
Silchar	-	14.77	-	19.20	(January - July)

From the above table it is vivid that January is the coldes month in most of the places of the valley when the efficiency of temperature has a variation between 13.6 to 14.29°F for Nowgong and Tejpur respectively. But December seems to be coldest in Dibrugarh having less temperature efficiency.

So far as the hostest months are concerned when air temperature is recorded to be efficient, July and August are most common in most of the places excepting Nowgong where May records the most efficient air temperature.

CLIMOGRAPHS

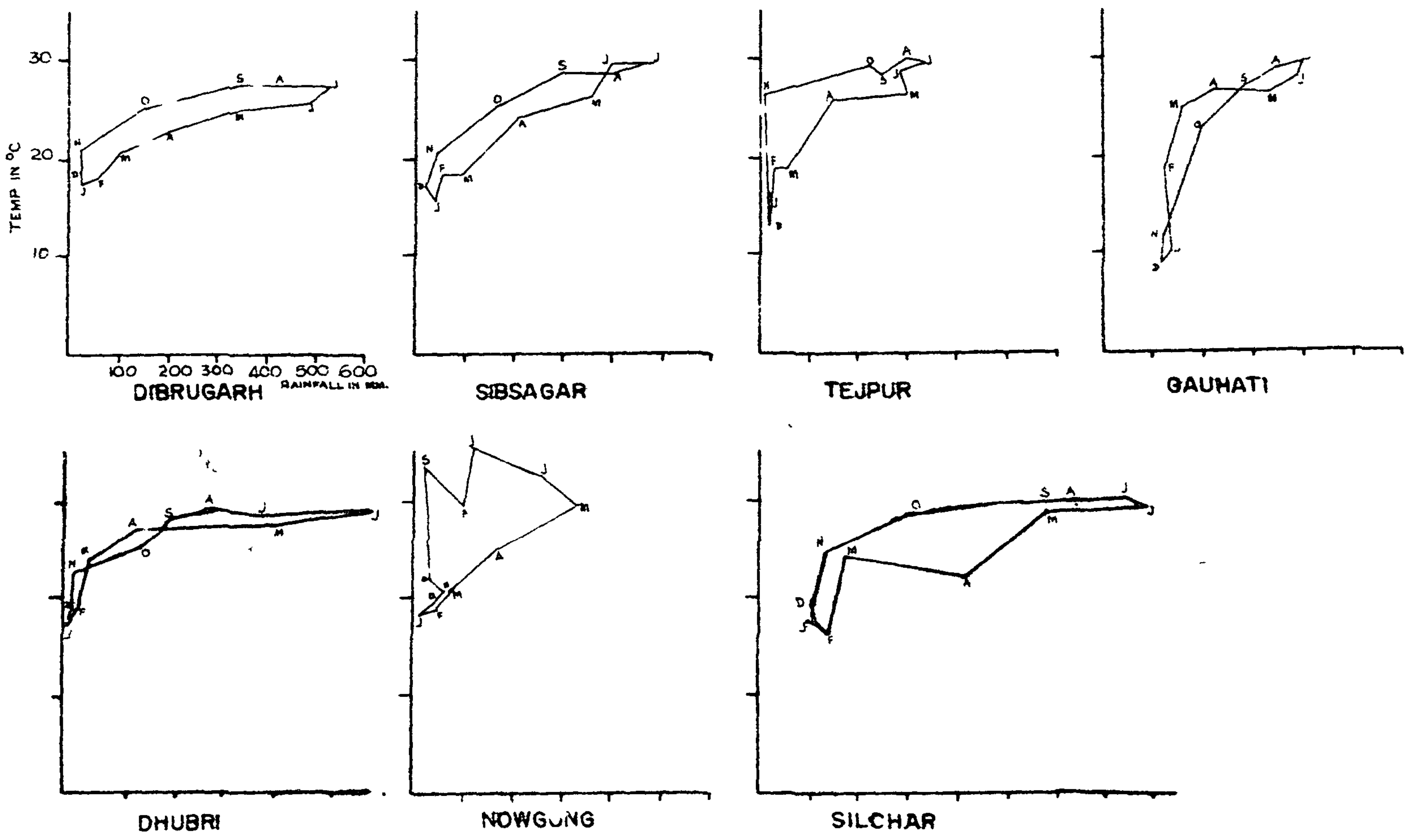


FIG-5

Since most of the agricultural crops need efficient air temperature and, solar radiation for their photosynthesis process within a certain range, temperature efficiency determines the productivity to a greater extend. So the favourable and unfavourable climatic regions are sorted out on the basis of precipitation and temperature efficiency indices which on the other hand more relate to humid character rather than thermal. Different patterns of climographs showing the characteristics of the climatic elements such as temperature and rainfall and humidity have also been prepared to know the general variation of weather and climate in different parts of the valley (Fig. 5) which directly influence the cropping patterns, their growth and productivity.

Variability of rainfall :

Since there is a close relationship between the timings and distribution of rainfall and the agricultural activities, production and productivity of various crops grown in the valley, it is very necessary to examine the variability* of rainfall of the valley for a certain appreciable time period.

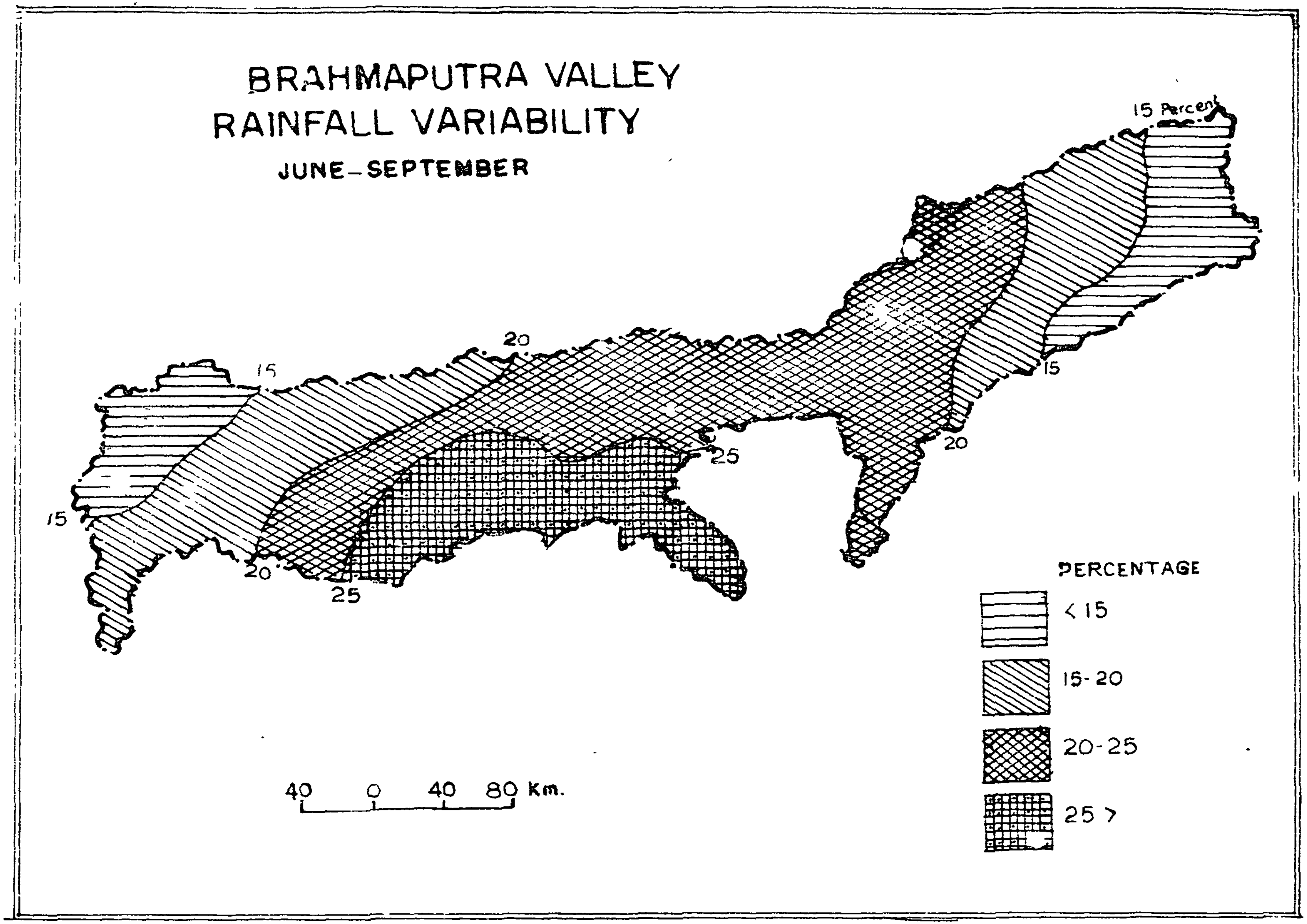
The mean monthly rainfall for the selected stations and the percentage variability have been plotted in Figures 4 and Fig. 6 A comparison of Figures 4 and 6 , indicates that the tendency of deviation from the average is proportionately higher in the

*The median value method by P.R. Crowe has been applied in working out the mean monthly variability of rainfall for as many as seven selected stations all of which fall within the valley of Brahmaputra. The figures have been computed on the basis of monthly rainfall statistics for 30 years i.e. (1931-60), collected from the India Meteorological station, Gauhati. The formula, with the help of which percentage variability of rainfall has been calculated is as follows.

$$V = \frac{VQ-LQ}{2} \times \frac{100}{M}$$

Where LQ = Lower Quartile
UQ = Upper Quartile
M = Median

In order to find out the percentage variability, first, the data is arranged in ascending order of magnitude and then the quartile values are calculated.



BRAHMAPUTRA VALLEY
RAINFALL VARIABILITY
JUNE-SEPTEMBER
15 Percent
15
20
25
PERCENTAGE
< 15
15-20
20-25
25 >
40 0 40 80 Km.

FIG-6

relatively drier parts of the valley than in the wetter parts, For instance Nowgong, Gauhati and Dhubri in the lower part of the valley have relatively greater variability in rainfall than that of the upper portion. Nowgong having the average monthly rainfall of less than 100 MM has relatively higher percentage of variability in monsoon months. Gauhati and Dhubri though have comparatively higher rainfall, nevertheless the percentage variability seems to be specfacular in monsoon months.

The following table shows the average annual rainfall in millimeter and mean annual variability in percent.

TABLE - VI

Station	Average annual rainfall in mm.	Mean annual variability in percent
Dhubri	2525.2	14.00
Gauhati	1673.2	13.56
Tejpur	1894.4	10.68
Nowgong	1043.9	11.21
Sibsagar	2504.3	8.63
Lakhimpur	2606.8	7.93
Dibrugarh	2759.4	6.14

Blandford* is of opinion that an annual variability of 12 percent or more makes an area susceptible to famine. Hence the whole Brahmaputra valley may be regarded as vulnerable in this respect. It is seen that while the precipitation steadily decreases from east to west till the middle part of the valley which has a transitional characteristics and from this point of again it starts increasing weast ward, the deviation from the average is proportionately large in the west rather than the east.

*Blandford H.F., 'Rainfall of India' Memoirs of the India Meteorological department, Vol.III, 1386-31, p.130.

This sort of considerably variable rainfall has a direct effect on the raising of many food crops. Its no meaning if there is a concentration of rainfall over few months only. From the monthly rainfall data of some of the important recording stations in the valley it is analysed that very meagre rainfall occurs during November to March. April and May, coming under the pre-monsoon period though have an appreciable average rainfall, the monsoon season from June to September experiences heavy down pour of rain, thereby causing water logging in the low lying areas followed by floods and natural calamities. Even if the rainfall gets intensified in monsoon season, and there is a possibility of late and early arrival of monsoon, successful crop production remains uncertain. Hence timely and uniform distribution of rainfall has a low variability areas under this pattern of rainfall are less prone to famine.

Coming over to the station-wise percentage variability of monsoon rainfall in the valley the following picture emerges out of the analysis. As it is said earlier that substantial rainfall occurs between June to September in almost every part of the valley, it will be more meaningful to examine the variability in these months rather than considering the average annual rainfall. From the point of view of agricultural operations, the variability of rainfall in the wet monsoon months is more significant than the annual variability for the total rainfall of the year is below or above the average but its distribution is timely, the crops are not much affected. As a matter of fact, timely distribution of rainfall is more important than the annual total. For instance insufficient or excessive amount of rainfall in the month of June delays the sowing of early Kharif crops and affects their outturns. The insufficiency of rainfall in July and August results in the failure of rice crop, especially in the unirrigated tracts, while in the irrigated parts the cultivator rushes towards the irrigation sources to protect the following rice crop at the critical time when labour is most needed for preparing the land for rabi sowing. The incidence and amount of rain in the last week of September or in the first week of October is even more important to the sowing of rabi crops as well as to the quality and yield of Kharif crops. Heavy falls in the end of wet monsoon may lead to water logging, while premature cessation of the rains may cause postponement or restriction of the sowing of rabi crops.

The following table shows the mean monthly variability of all the raingauge stations coming within the Brahmaputra valley region for each of the wet monsoon months.

TABLE - VII

Mean Monthly variability of rainfall in Percent

Stations	MONTHS			
	June	July	August	Sept.
Dhubri	25.67	18.12	11.56	13.36
Gauhati	24.15	31.25	7.45	52.35
Tejpur	19.38	30.61	14.95	25.86
Nowgong	17.42	29.13	31.73	35.44
Sibsagar	14.31	19.45	22.35	26.72
Lakhimpur	14.82	28.05	30.00	24.78
Dibrugarh	10.52	15.66	29.88	20.19

It will be seen from table - VII that the variability is least in the months of June and August but it is much higher in the months of July and September. The variability is below 32 percent for all the rainfall stations in case of the former and ranges between 7 to 32 percent (Table - VII) where as the same has a variation between 10.52 to 52.35 percent for all the stations and the lowest and highest being observed in the station Gauhati in August and September respectively.

To sum up, the variability of rainfall is highest in those stations which have the lowest seasonal precipitation and least in those which have the highest seasonal rainfall. Comparing the stations situated in upper and lower part of the valley one reaches the conclusion that the variability in general has an increasing trend in every wet monsoon month starting from Dibrugarh as least to Nowgong as highest. And again from Nowgong it has a decreasing trend till the lower most district of the valley.

Considering the districts of Goalpara, Kamrup, Darrang and Nowgong in the lower Brahmaputra valley which has been taken as the area for case study of the performance of HYV rice cultivation it can be noticed that every climatic phenomenon is reverse in one part as compared to the other in west to east direction. For the sake of comparison two stations each for the lower part of the valley in west and east direction may be taken into consideration. Dhubri and Nowgong in the lower part present the following variability pattern lying in the west and east direction.

TABLE - VIII

	Dhubri	Nowgong
June	25.67	17.42
July	18.12	29.13
August	11.56	31.70
Sept.	13.36	35.44

In July, August and September there is an increasing trend invariability from west to east direction whereas in June the same decreases from west to east.

Hence the variability figure of the wet monsoon months indicates an increase relationship between the average monthly rainfall and the meanvariability.

Precipitation Efficiency*

This is a quantitative index showing the efficiency of precipitation in each month for different meteorological stations. The indices help in distinguishing major climatic regions based on humidity rather than on thermal character. Therman efficiency 'I' index could be used to subdivide these macro regions. In case of Brahmaputra valley, the stations selected are Dibrugarh Sibsagar, Tejpur, Gauhati, Dhubri and Nowgong covering almost the entire valley from east to west.

At a glance to the monthly indices it is distinct that the efficiency index for drier months such as November, December, January, February and March is more than that for the wet monsoon and premonsoon months. The following tables present the twelve months indices for each station.

TABLE-IX

DIBRUGARH

MONTHS												
J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
1.3	1.3	1.3	1.16	1.16	1.04	1.04	1.04	1.04	1.16	1.3	1.3	1.16

* The index has been devised by C.W. Thornthwate for climatic classification based on humidity rather than on thermal character. Thermal Efficiency 'I' is applied to subdivide these. Hence

$$i = 11.5 \left(\frac{P}{T-10}\right)^{10/9}$$

P = Monthly mean pt. in inches

T = Monthly mean temperature.

SIBSAGAR

J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
1.3	1.16	1.1	1.04	1.0	.95	0.94	1.15	0.95	1.00	1.01	1.21	1.05

TEJPUR

J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
.88	.84	.78	.63	.72	.7	.69	.69	.70	.73	.8	.86	.75

GAUHATI

J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
.75	.72	.66	.63	.60	.59	.58	.58	.58	.61	.67	.73	.64

DHUBRI

J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
1.2	1.16	1.05	.98	1.1	.98	.97	.96	.97	1.0	1.1	1.19	1.04

NOWGONG

J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
.48	.45	.46	.44	.32	.32	.35	.36	.36	.38	.44	.48	.38

SILCHAR

J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
1.56	1.51	1.38	1.32	1.29	1.26	1.25	1.28	1.26	1.3	1.4	1.52	1.36

From the above tables, it will be seen that the indices start increasing from January to April, have decreasing trend till October, and then again go on increasing. Hence it could be inferred that, higher is the index lower is the precipitation efficiency for that month and vice versa.

In order to have a comparative study of the efficiency indices, the mean annual efficiency index could be taken into consideration starting from the upper Brahmaputra valley till lower, it is observed that the mean annual efficiency index is highest for Dibrugarh and lowest for Nowgong. So from generalization point of view, the stations recording higher rainfall, have higher indices than that of the stations recording lower rainfall.

However, the month to month change of the index shows that, the months in the monsoon period when the intensity of rainfall in high, have comparatively lower indices than the months in the winter season for a particular station.

Therefore Nowgong lying midway between the upper and lower portion of the valley could be taken as the driest part having higher variability of rainfall, low intensity and low precipitation efficiency. From this point again every climatic index shows positive trend towards the lowest part of the valley. Gauhati and Tejpur being situated on the either bank of the river have also relatively lower precipitation efficiency and the highest efficiency is observed in Dhubri lying at the western most tip of the valley.

Taking each and every point of the aforesaid discussion, it could be said that agriculturally the lower Brahmaputra valley is not very unfavourable from the rainfall point of view. The rainfall is fairly reliable especially in the month of July and August. The risk to crop however remains in the months of July and September in which the variability of rainfall is higher at all the rainfall recording stations. In fact it is the excessive rainfall which damages the crop in the rainy season.

Soil :

The Brahmaputra valley is formed by the alluvial deposits in which alluvial soils have been deposited by the Brahmaputra and its over fifty significant tributaries. Soils of Assam, can be classified into the following major categories among which the first three cover the entire valley of Brahmaputra and the last one is found only in the hill districts. The areal distribution of these soils is given in Fig. - 7

i. New alluvial soil
ii. Old alluvial soil
iii. Laterite soil and
iv. Red soil.

The new alluvial soils are confined in the low lying tracts of the flood plains of the river in which new silts are deposited almost every year. These soils are sandy loans or silt loams having less acidic contents and thus suitable for the cultivation of rice Jute, pulses, mustard potato and vegetables. These soils are enriched with available phosphate potash and exchangeable calcium.[1]

The old alluvial soils are found at relatively elevated tracts which are free from floods. These soils are more acidic in nature. The greater parts of the valley are covered by the old alluvial soils. These soils lack in available phosphate with low or medium potash content and texturally vary from sandy to claying loam with high to low content of nitrogen. These soils

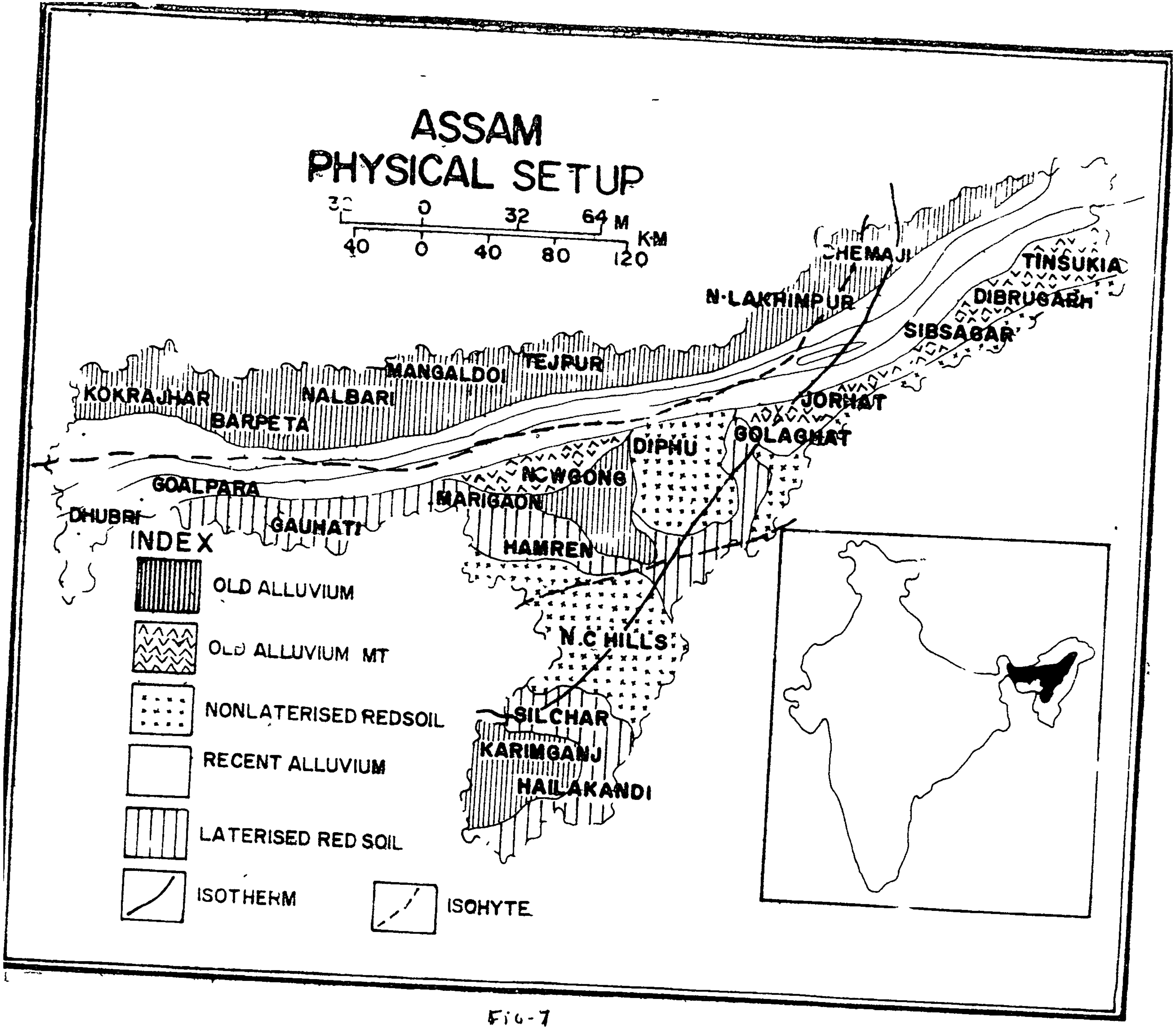

ASSAM
PHYSICAL SETUP
32 0 32 64 M
40 0 40 80 120 KM
CHEMAJI
N·LAKHIMPUR
TINSUKIA
DIBRUGARH
SIBSAGAR
JORHAT
GOLAGHAT
TEJPUR
MANGALDOI
NALBARI
KOKRAJHAR
BARPETA
DIPHU
NOWGONG
GOALPARA
MARIGAON
DHUBRI
GAUHATI
HAMREN
N.C HILLS
SILCHAR
KARIMGANJ
HAILAKANDI
INDEX
OLD ALLUVIUM
OLD ALLUVIUM MT
NONLATERISED REDSOIL
RECENT ALLUVIUM
LATERISED RED SOIL
ISOTHERM
ISOHYTE

FIG-7

are favourable for rice, sugar cane, fruits and vegetables but not conducive for the cultivation of pulses and mustard.

Laterite soils are found in limited areas in the valley. These are considerably leached poorly contained with plant nutrients, thus agriculturally less useful. An important feature of the soil types in the valley is that, the northern fringe in the lower part of the valley covering the district of Goalpara, Kamrup, and parts of Darrang constitutes of coarse alluvium formed by the debris which have been deposited by the streams in the tarain tracts. On the other hand red loan and extensive laterite soils are exclusively found in the hill districts soils of the Brahmaputra valley in general have higher ingradients of nitragen, phosphorous and pottassium content.[3]

Considering soil as one of the major agro-climatic factors for the growth and yield of any food or nonfood crop in general and for high yielding varieties of rice in particular, a thorough and detailed discussion on this parameter has been devoted for the lower Brahmaputra Valley where community development blocks have been taken as the unit area of study. The discussion relates to the major soil nutrients, soil texture and reaction whose impact in the coming chapter has been studied in relation to the productivity of the highly sensitive varieties of High Yielding rice.

Since adequate scientific data is not available for the soils of the valley, the present point of discussion is based mainly on the work done by the Regional Soil Survey Division of the Government of Assam. The informations about the texture, structure, p^H values, soil nutrients such as nitrogen, phosphorous and potassium were obtained from the Soil Testing Laboratory, Gauhati and Jorhat. The texture and soil nutrients have a close bearing on the growth, development and outturns of different crops therefore, in the present chapter, a systematic study of the soil texture, soil nutrients and climate parameters has been attempted, their relationships with the performance of rice, especially high yielding varieties have been established in Chapter-V.

Textural classification of Soils:

Soil texture refers to the size of soil particles and the arrangement of soil particles is called soil structure. The texture and structure of soil of a region has great significance as it influences the moisture, availability of plant nutrients, action of micro-organisms and plant growth. The soil texture, however, varies with the proportion of clay and sand particles. These particles are classified according to the international scale given below.[3]

TABLE - X

Name of soil particles	Diameter
1. Fire gravel	2.0 - 1.0
2. Coarse sand	1.0 - 0.5
3. Medium sand	0.5 - 0.25
4. Fire sand	0.25- 0.1
5. Very fine sand	0.1 - 0.05
6. Silt	0.05-0.002
7. Clay	$<$0.002

The structure and mechanical composition determine the character of soil texture which means its consistency, degree of compactness, and friability. According to the compactness the soil may be distinguished into three categories. The first category is of coarse textured soils which are usually dry and drought and to this category belong the gravel, the gravel loam, the sand and the sandy loam. The second category is of medium textured soil and to this category belong the loam and the silt loam. The third category is of finely textured soils, capable of reclaiming moisture and this category includes clayey-silt, loam, silty-clay loam, clayey-loam and clay. According to the dimensions of the pores and the character of the porosity, texture can be finely porous, spongy, spongy forminated alveolate and tabular.[4]

Sandy soils are open and porous and do not hold water which is adequately required, organic matter and plant food satisfactorily. Silt and clay loams in contrast are capable of holding water, organic matter and plant food in good measure.[5]

Significance of soil Nutrients for Plants:

The plants collect 13 out of 16 elements essential for their growth from the soil.[6] The rest three carbon, hydrogen and oxygen come from water and from carbon dioxide (CO_2) present in the air. The 13 elements are categorised in three groups given below, each further consisting of 3, 3 and 7 elements respectively.

1. Primary - Nitrogey (N)
   Phosphorous (P) and
   Potassium (K).

2. Secondary - Calcium (Ca)
   Magnesium (Mg) and
   Sulphur (S)

3. Micro nutrients-Boron (B), Copper(Cu)
   Iron(Fe) Manganese (mn)
   Molybdenum (Mo)
   Zn (Zn) and
   Chlorine.

Generally plants require primary and secondary elements in substantial quantities where as the micro nutrients are needed proportionately in negligible amount. The availability and proportion of plant nutrients affect favourably or adversely the germination, growth and development of crops. Their influence has been ascertained on the HYV rice in the area selected for study.

Nitrogen :

Nitrogen has been proved to be the most essential or the key element for better yield of any kind of plant and specially rice. Plants need nitrogen because it promotes rapid growth of the plant, gives dark green colour to the plants, increases yields of leaf, improves quality of leaf crops, increases protein content of food and feed crops, feeds soil micro-organism during decomposition and finally increases flowering and fruiting. *Specially the rice plants mainly rely on nitrogen for the decom-*position of organic materials under an aerobic conditions. At the early stages of growth, rice plants take up nitrogen in the form of ammonia.

Researchers and agricultural Scientists in India have drawn the conclusion on the basis of experiments that, rice under varied circumstances gives a sharp response to the application of nitrogen.[7] Sethi (1940)[8] finds no example concerning the failure of nitrogen in giving immediate response. On the contrary, an excessive amount of nitrogen results in undesired number of tiller formation for which the yield of grain is affected by mutual shading of the tillers. Excessive nitrogen also causes various kinds of cryptogamic diseases, lodging and unfavourable effect on milling quality and quantity. It has been further noticed that, at the early stage of growth, a paddy plant gives a positive response to ammoniacal nitrate, rather than nitrate nitrogen.[9] But in the late stages of growth nitrate nitrogen has been found to be very effective.

Phosphorous :

Since the plant receives considerable amount of phosphates from the soil, there is no way to increase phosphate in the soil excepting the practical application of it which when applied responses readily. Insufficient amount of phosphate is available in solution, or suspension state in irrigation water. Phosphate manuring in the paddy field helps increase the grain yield rather than straw.[10] Sircar and Sen (1941)[11] conclude that phosphorous deficiency leads to reduced height and less number of tillering. They are also of opinion that the nitrogen intake of rice plants heavily depends on the concentration of phosphates. Hence, phosphorous is not only helpful in early stages of growth but also helps in the later stages of development. Phosphate and Potash help grow the plant roots in relation to tops while nitrogen increases the growth of tops (Sato, 1938)[12]. The following are the five main functions[13] of the phosphate.

i - It stimulates early root function and growth.

ii - It gives rapid or vigorous start to plants.

iii - It hastens maturity.

iv - It stimulates flowering and seedling.

v - It gives resistance to seed and hay crops.

Potassium :

The soils of predominantly rice grown areas are supposed to have potassium adequately because of their heavy nature. In general it does not affect the yield, but in light soils, if it is applied gives a sharp response.[14] On the other hand, when potash is used along with nitrogen and phosphate, gives higher yields. Pottassium is available in less quantity in soil than phosphorous, nevertheless soil retains it to a greater extent.

Coming over to the secondary elements without which the plant nutrition remains incomplete, it could be said that calcium, magnesium and sulphur are in no way unimportant for plant growth.

Moreover, excess of these elements also gives adverse effect on growth, thereby causing less yield especially of the grain crops.

The prevailing agro-climatic conditions prevailing in the Lower Brahmaputra Valley consisting of Kamrup, Goalpara, Darrang and Nowgong districts under study show significant variations at a micro level analysis. Agricultural as well as Community Development Blocks as the component areal units in the present study could be sorted out on the basis of the quality of the soil and atmospheric parameters favourable for boosting up the crop productivity. A picture of organic carbon, phopherous and potassium in the soils of the area have been plotted in Figs.

At a glance to the figure No. 8 presenting the soil fertility status of various community development blocks, in terms of organic carbon, available phosphorous and potassium content it is vivid that the nutrient index* for Nitrogen or organic carbon varies from 1.7 to as high as 2.95 in the block Manikpur and

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*The index for every individual nutrient such as organic carbon or nitrogen, phosphorous and potassium in the soil is calculated in accordance with the following statistical formula.

$$N1 = \frac{\begin{array}{l}\text{Percentage of soil}\\ \text{samples coming}\\ \text{under low category}\end{array} X1 + \begin{array}{l}\text{Percentage of soil}\\ \text{samples coming un-}\\ \text{der medium category}\end{array} X2 + \begin{array}{l}\text{Percentage of}\\ \text{soil samples}\\ \text{coming under}\\ \text{high category}\end{array} X3}{100}$$

The laboratory formula determining the low, medium and high content of each of the above said soil nutrients have been presented in the foot note pp.

After having calculated the indices for each nutrient, the same are categorised with the help of the following standard class groups with a view to identifying the low, medium and high proportion of nutrients in the soil.

<u>Class group</u>

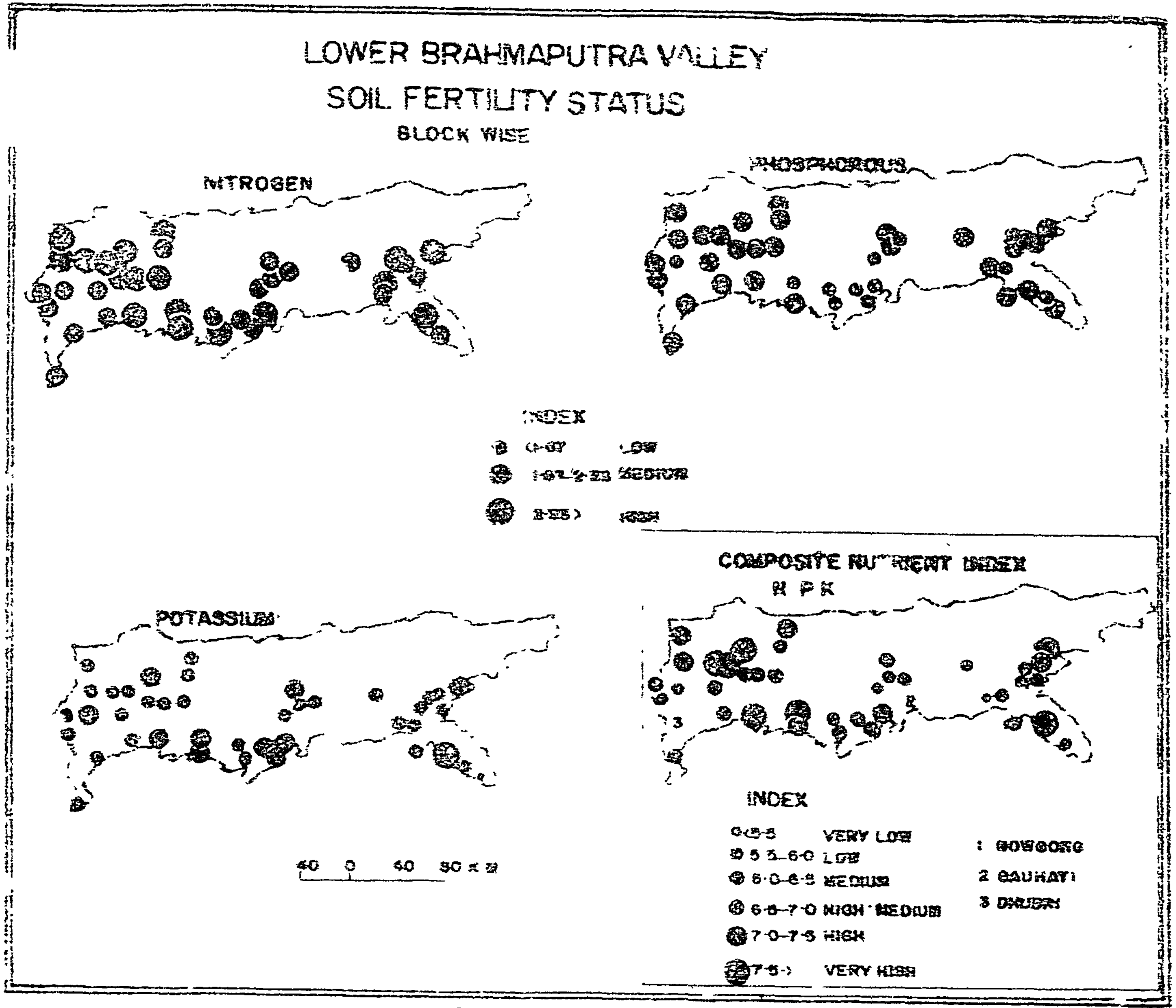
Less than 1.67	- low
1.67 to 2.33	- medium
2.33 and above	- High.

Kokrajhar respectively. Out of 43 sample blocks under investigation only 19 blocks fall under the higher nitrogen content group and the rest 24 come under Medium category. Switching over to available Pottassium (K2O) content in the soils of the said number of blocks it is noticed that only one block has higher proportion of pottasium available in the soil. As per the laboratory analysis of the soil samples, the soils of 12 blocks show a medium level of pottassium nutrient index and as many as 30 blocks are poorly contained with pottassium which is an essential inherent element of the soil for any kind of plant nutrition in its vegetative and growth period.

So far as the content of available phospherous in the soil is concerned, one could notice a spectacular variation between blocks. The nutrient index for phosphorous content of the soil ranges between 1.08 to 2.69 in the blocks of Gauripur and Khagarijan respectively as the lowest and highest share in content. It is interesting to note that not even a single block has higher phosphorous content as evident from the Map showing soil fertility and that too, 33 blocks come under the Medium category* of phosphorous nutrient and the rest 10 blocks do have low phosphorous content.

* Different categories of nutrient content in the soil after chemical Analysis.

<u>Potassium</u>	∠125 - Low 125 - 300 - Medium 300 + High
<u>Phosphorous</u>	∠20 - Low 20 - 50 - Medium 50 + High
<u>O/C</u>	∠.5 - Low .5 - ..75 Medium .75 + High


LOWER BRAHMAPUTRA VALLEY
SOIL FERTILITY STATUS
BLOCK WISE
NITROGEN
PHOSPHOROUS
POTASSIUM
COMPOSITE NUTRIENT INDEX
N P K
INDEX
VERY LOW
LOW
MEDIUM
HIGH MEDIUM
HIGH
VERY HIGH
1 NOWGONG
2 GAUHATI
3 DHUBRI
40 0 40 80

FIG·8

The overall nutrient index taken organic carbon (N), Phosphorous (P_2O5) and Potassium together, reveals that the spatial variation of the indices is not that significant. According to the importance or significance of the above said nutrients different weightages such as 1.5 , 1 and 1 have been given to nitrogen, phosphorous and potassium respectively. After having the composite indices of these three, it is noticed that the same varies between as loww as 5.335 to as high as 7.87 in the blocks of Bhurbandha and South Salmora respectively. A vivid picture emerges out of the following frequency table concerning the fertility status of the 43 selected blocks.

TABLE - XI

Class group (N1)	Freq.	Cum. frequency	Categories
$\angle$5.5	1	1	Very low
5.5 to 6.0	6	7	Low
6.0 to 6.5	8	15	Medium
6.5 to 7	12	27	High medium
7.0 to 7.5	7	34	High
7.5 +	9	43	Very high

Having a look at the frequency table prepared for the overall soil nutrient index it is observed that only one block comes under the very low category soil so far as the nitrogen, Phosphorous and Potassium ingradients are concerned. The block is Bhurbandha of the Mangaldoi subdivision in Darrang District. As many as 6 blocks are having poorly fertile soil the index of which varies between 5.5 to 6.0. The blocks are Hazo, Gauripur, Golakgunge, Lanka, Juria, and Loharighat amongst of which Golakgunge ranks first the index being 5.92 and Lanka has the lowest index value i.e. 5.615 particularly in this group.

Coming over to the medium fertility group of the soil, one could see that 8 blocks are falling under this category. The blocks are Chamoria, Karara, Kamalpur, Manikpur, Rupahi, Kathiatoli, Kapili and Lawkhowa. Chamoria and Kapili having the indices 6.06 and 6.455 as the lowest and highest respectively. Haringa-look at the high medium fertility group of the soil, the index of which come under the class group 6.5 to 7.0, it is clear that maximum number of blocks i.e. 12 namely Chhaygaon, Rampur, Rangia, Boko, Lakhipur, Srijargram, Boitamari, Bilasipara, Chapar, Mankachar, Agomoni and Mayanga are in this group. Out of these Agomoni and Rampur have the indices of 6.585 and 6.97 as the lowest and highest respectively in this category.

So far as the high nutrient index group is concerned, 7 blocks are falling in this group; the blocks being Rani, Dimoria, Dudhudi, Kachhugaon, Gossaingaon, Borobazar and Khagarijan of which Rani has the lowest index i.e. 7.03 and Dudhnoi has the highest i.e. 7.26.

Switching over to the last class group of the nutrient index within which the soils of as many as 9 blocks having very high nutrient and fertility fall. The blocks are Balijana, Matia, Dotoma, Sidlichirang, South Salmora, Batadraba, Kaliabar, Kokrajhar and Jugijan. Amongst these Dosoma and south Salmora are having indices 7.505 and 7.87 respectively as the lowest and highest. Taking all the blocks together into consideration south Salmora also ranks first in soil fertility index in terms of organic carbon available phosphorous and potassium.

Soil texture is of prime importance for rice crop. From the information collected regarding the quality of soil in terms of its texture it is noticed in each and every block of Kamrup and Goalpara that the texture of a substantial percentage of samples collected by the Soil Survey Unit, Government of Assam. is of medium category. However, the percentage of sample in this category invariably exceeds 90 percent for all the blocks. And the percentage of light or heavy soils is very insignificant if not, sometimes nil also.

The texture of soils of Lower Assam has been categorised as per the following gradation.

TABLE-XII

Texture	Gradation
Sandy, Sandy Loam	Light
Loam, Loamy sandy	Medium
Clay	Heavy

But there are few blocks which need special mention such as Rampur, Dimoria, Chamoria, Hajo, Balijara, Dudkandi, Doloma, Kokrajhar and Manikpur where the soils are predominantly loam and loamy sandy in nature for which the percentage exceeds 99 percent. In case of Rampur, Dimoria and Dudkndi as per the soil analysis data hundred percent of the samples falls in the mediam category of the textural classification. On the otherhand, there is hardly any variation of soil texture of these particular blocks.

Coming over to the blocks of Nowgong and Darrang the soil texture variation appears to be significant as compared to that of Kamrup and Goalpara. As per the laboratory analysis report[9] it is seen at the first sight that the soils in these blocks are found in different types such as sandy, sandyloam, loamy, loamy sandy and clayie silt. But soils of most of the blocks constitute of sandy and sandy loam in a higher proportion which come in light textural classfication than loamy, loamy sandy and clayey. The percentages of sandy and sandy loamy soils vary between 14.0 as the lowest and 88 as the highest percent for the blocks of Jugijan and Lawkhdwa respectively.

In order to have a better understanding about the percentage variation of the light soils of all the blocks taking together into consideration the following frequency table has been attempted.

TABLE - XIII

Percentage/Class group of samples	Frequency	Cum. frequency
$\angle$5	25	25
5 - 20	1	26
20 - 35	0	26
35 - 50	1	27
50 - 65	2	29
65 +	14	43
Total	43	

The above frequency Table shows that the percentage of sandy and sandy loam soil sample being categorised as the light textured soil is less than 5 percent in maximum number of the blocks i.e. 25 coming under the western most tip of the Brahmaputra valley constituting of Kamrup and Goalpara districts. Only one block has percentage of light soil between 5 to 20 percent. The block is Lawkhowa of Nowgong district and 14 percent of its soil is of sandy loam texture.

In the 20 to 35 percent group not a single block is observed. Between 35 to 50 percent only one block namely Rupahi has 46 percent of its soils sandy and sandy loamy. In two blocks namely Mayang and Loharighat the soil is sandy loam. This soil covers about 50 to 60 percent of their total area. It may also be noticed from the frequency Table -XIII that in 16 blocks the soil is light sandy.

Hence from the above analytical discussion of the light textured soil of different blocks, it is very distinct that the texture keeps on changing in a west to east direction of the lower Brahmaputra valley. The soil being clayey in the west and sandy loam to sandy in the east.

It would also be worthwhile if the space variation of the medium and heavy textured soils are discussed in a similar analytical framework. The following frequency table reveals the comprehensive picture of the loam and sandy loam soils of the 43 sample blocks.

TABLE - XIV

Percentage class group of samples	Frequency	Cum. Frequency
∠20	6	6
20 - 40	6	12
40 - 60	1	13
60 - 80	0	13
80 +	30	43
Total	43	

The frequency distribution table reveals that the percentage of soil sample goes on increasing with an increasing number of blocks so far as loam and loamy sandy textured soils are concerned. As many as 6 blocks show percentage less than 20. These blocks are situated in Nowgong and Mangaldoi subdivisions.

Between 20 to 40 percent category of the percentage of soil samples having a medium category, another 6 blocks are coming and they are from Nowgong and Mangaldoi subdivisions. The blocks are Loharighat, Kapili, Kaliabar, Lanka, Mayang and Khagaryan. But the soils of only one block are having an appreciable proportion of loam and loamy sandy texture. The block is Jugijan which has 48 percent of its soils loamy and loamy sandy. No block comes under the percentage class group of soils between 60 to 80. But it is interesting to note that as many as 30 blocks have a higher percentage between 80 percent and above, of their soil loam and loamy sandy in texture.

Clayey or clay silt soils are found in a good number of blocks in Nowgong subdivision. The percentages vary between 45 to 35 as the lowest and highest respectively for the blocks of Rangia and (Rupahitkapili) respectively. Since there is a sharp textural difference between the blocks of Kamrup and Goalpara taken together and that of Nowgong and Darrang it is needless to discuss every soil type in detail.

The textural variation of soils between blocks it could be infered that while that blocks coming under Goalpara and Kamrup districts are predominantly loam and sandy loam, a substantial number of blocks of Nowgong and Darrang districts are of sandy and sandy loamy. But Clayey or heavy soils are so to say absent in Kamrup and Goalpara but in Nowgong and Darrang this sort of soils are found in many blocks although not predominantly. Soils keep on getting changed from west to east in texture from predominantly loamy and loamy sandy to sandy and sandy loamy and also clayey and clay silt.

The texture index prepared for the three categories of soil also indicate a remarkable variation between blocks. As per the importance of these categories for crop growth and productivity and specially for rice plant clayey or heavy soil has been given more weightage than sandy, sandy loamy, loam and loamy sandy. After giving weightages such as 3, 2 and 1 to Heavy, Medium and light soils respectively a weighted sum of the percentages of samples in different categories has been prepared and divided by 100 in order to find out texture index for each block.

Having a look at the different indices prepared and shown in Fig. 9 for different blocks, it is noticed that the indices range between 1.05 to 3.00 for the blocks of Jugijan and Chaparmukh respectively. More the index better is the soil texture. The following frequency table reveals the composite picture of the quality of soil in terms of light, medium and heavy texture.

TABLE - XV

Class	Frequency	Cum. frequency
$\angle$ 1.5	11	11
1.5 - 2.0	15	26
2.0 - 2.5	8	34
2.5 +	9	43

There are 11 blocks in which the indices are less than 1.5 and all these blocks lie in Nowgong and Mangaldoi subdivisions. Hence, the soils are the poorest in terms of texture which is unfavourable for rice crop, because it has low moisture retaining capacity. As many as 15s blocks are coming between 1.5 to 2.0

LOWER BRAHMAPUTRA VALLEY

SOIL TEXTURE INDEX

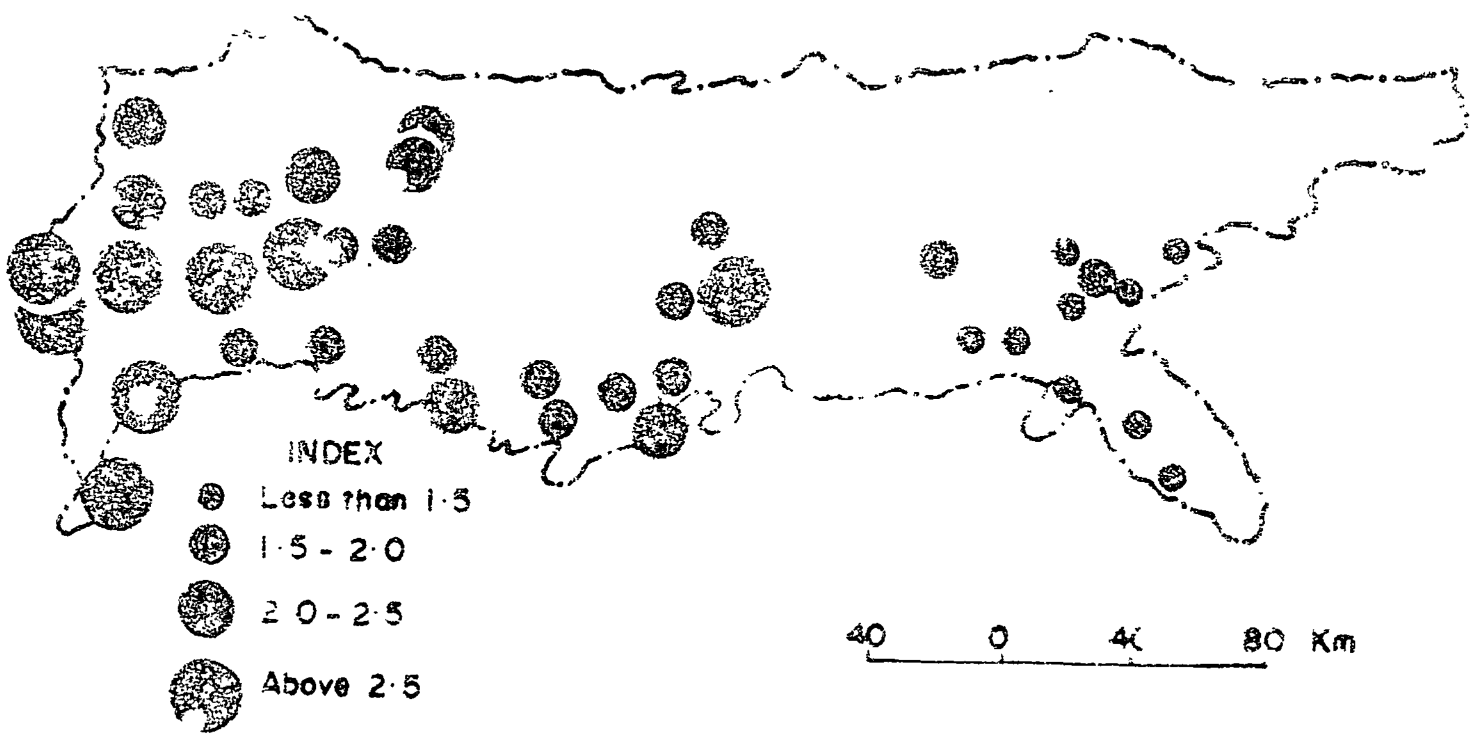


FIG-9

index class and the blocks are exclusively from Goalpara and Kamrup districts. In comparison to Nowgong these blocks are better in soil texture. Between 2.0 to 2.5 index class group 8 blocks are falling and the blocks are Dimoria, Rampur, Dudhndi Sidlichirang, Manikpur, Kachugaon, Gossaigaon and Borobazar. There are 9 blocks, the soils of which are considered to be the best in terms of their texture. The indices exceed 2.5. The blocks are Karora, Kamalpur, Gauripur, Bilasipara, Chapar, S. Salmora, Agomoni and Golokgunge, Chapar has the highest index i.e. 3.00.

Soil Reaction pH Value :

The presence of water in the soil is a significant determinant of soil aeration its fertility and suitability for different crops. Various forms of water are present in the soil that exhibit a complex relationship. The proportion of exchangeable bases in the soil in a soil is obtained by the process of measuring concentration of hydrogen ions. It is assumed that the proportion of other ions which can be held by the clay humns complex depends on the space left by hydrogen ions. The proportion of fre hydrogen ion in the soil solution is measured and stated pH values.

Soils vary in pH from about 4, for strongly acid soils to about 10 for alkaline soils that contain free sodium carbonate. The pH range for most agricultural soils is 5 to 8.5 pH. 7 is the neutral value.[15] Value below pH 7 indicate an acidic soil and value above pH 7 indices an alkalinity.

TABLE - XVI

pH Value Index

Under pH 4.5	Very high acidity
4.5 - 5.0	High acidity
5.0 - 5.5	Moderate to high acidity
5.5 - 6.0	Moderate acidity
6.0 - 7.0	Slightly acidity
7.0	Neutrality
7.0 - 7.5	Slight alkalinity
7.5 +	Strong alkalinity

The information collected on the soil reaction in terms of pH values, shows that the variation is not that remarkable. According to the percentages of soil sample in acidic, neutral and lakalinity range a pH index has been prepared giving different weightages to different range. The weightages are 3, 2, 1 for acidic, neutral and alkalinity respectively as per the favourability for rice crop.

The indices vary from as low as 1.988 to as high as 3 for the blocks of South Salmora and (Kokrajhar, Sidlichirag and Chamoria 3 for each) respectively. Hence, higher is the index better the growth and productivity of crops. The following frequency table shows the index wise group of blocks.

TABLE - XVII

Class group	Frequency	Cum.Freq.
∠2.0	2	2
2.0 - 2.25	8	10
2.25 - 2.50	0	10
2.50 - 2.75	2	12
2.75 +	31	43

The above Frequency Table shows that there are maximum number of blocks i.e. 31 whose index values exceed 2.75. Only two blocks have their index values less than 2.0. The blocks are Batadraba and south Salmora one each in Nowgong and Dhubri subdivision respectively. 8 blocks show their index between 2.0 to 2.25. The blocks are Kurara, Kamalpur, Gauripur, Bilasipara, Chapar, Mankalhar, Agomoni and Golakgunge. Between 2.5 to 2.75 there are another two blocks such as Baligana and Boitamari. Hence soil reaction does not show a significant vâriation. But it is observed that the blocks which come under Nowgong subdivision have poor nutrient index poor texture index though pH index does not show unfavourability.

The mean, standard deviation and co-efficient of variation gives the following explanation for Nutrient index, Texture index and pH index. The standard deviation mean and co-efficient of variation for nutrient index are .672, 6.76 and 9.94 respectively. The coefficient of variation shows that the nutrient indices do not vary significantly the variation being 9.94 percent.

Similarly the standard deviation and mean co-efficient of variation for Texture are 0.578, 1.995 and 28.998 respectively. The coefficient of variation of texture as compared to Nl is significant. So there is a significant variation of the textural quality of soils between blocks.

Coming over the pH index it is observed that the variation is less as compared to Texture but more as compared to nutrient index. The coefficient of variation for pH index is 14.1078 percent and mean and standard deviation are 2.685 and 0.378 respectively.

As a whole it could be concluded that the variation in soil properties in general is not very remarkable excepting soil texture which needs special mention for its west to east change.

CHAPTER - III

REFERENCE

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4. Ibid, p.38
5. Ibid, p. 39
6. Agricultural Gude Book, Department of Agriculture Assam, 1975-76, p.118
7. Grist, p. 247
8. Ibid.
9. Ibid.
10. Ibid, p. 248
11. Ibid
12. Ibid.
13. Agricultural Guide Book, Department of Agriculture, Assam, 1975-76, p.119
14. Grist, p. 249
15. Hussain, p. 39.

CHAPTER - IV

CROPPING PATTERN AND PRODUCTIVITY OF RICE

Areal Concentration:

Agricultural landscape of a region is well conceived of when its areal dominance of different crops are identified with the help of some standard statistical techniques. The simple delineation of an area into a wheat or cotton region may be useful in knowing the areas of wheat and cotton cultivation but it does identify the degree of their density of cultivation in a given space and time. The study of concentration of crops therefore has great relevance in understanding the agricultural mosaic of a region and finally in the agricultural landuse planning of a macro or micro level. The main objective of such attempts is to study and analyse the cropping patterns of an area on a regional basis with a view to bring out their areal concentration. For the delineation of crop concentration and crop diversification, many techniques have been used at different levels by the geographers. One of such approaches was developed by Bhatia with the help of which, the regional character of crop distribution in India was investigated and the dominance of crops in each region was determined.

The present Chapter is an attempt first to analyse the distributional pattern of the area under rice in Assam in order to find out its areal concentration and second to have a general discussion over the cropping pattern and productivity of rice including HYV exclusively in the valley of Brahmaputra. The regional dominance of rice has been determined first by comparing the sown area in proportion, and secondly by relating the crop density in each of the component areal units of the province to the corresponding density of the province as a whole. The latter approach helps in measuring the regional concentration of rice culture objectively and differentiate areas that have some significance with regard to its distribution within the region. The discussion on the cropping pattern and productivity of rice is primarily based on the informations and statistics collected from the Directorate of Agriculture, Government of Assam and the Agro-Economic research centre for North East India, Jorhat.

Data particularly to study the areal concentration of rice which has got to be highlighted was obtained from the Basic Agricultural Statistics for the years 1974-75 to 1976-77 published by the Directorate of Agriculture, Government of Assam and relate to the Sub-division level which are twenty two in numbers.

In order to have an average picture of the area devoted to rice in Assam, three years data i.e. 1974 to 1977 have been taken into account with the intention that the three years average would minimize the impact of vagaries of weather on the area of rice cultivation. In order to ascertain the spatial pattern of rice concentration, the cumulative frequency, the co-efficient of variation, standard deviation and the location quotient techniques have been applied.

Fig 10 reveals that rice is the dominant crop in all the component areal units of the area under study and irrespective

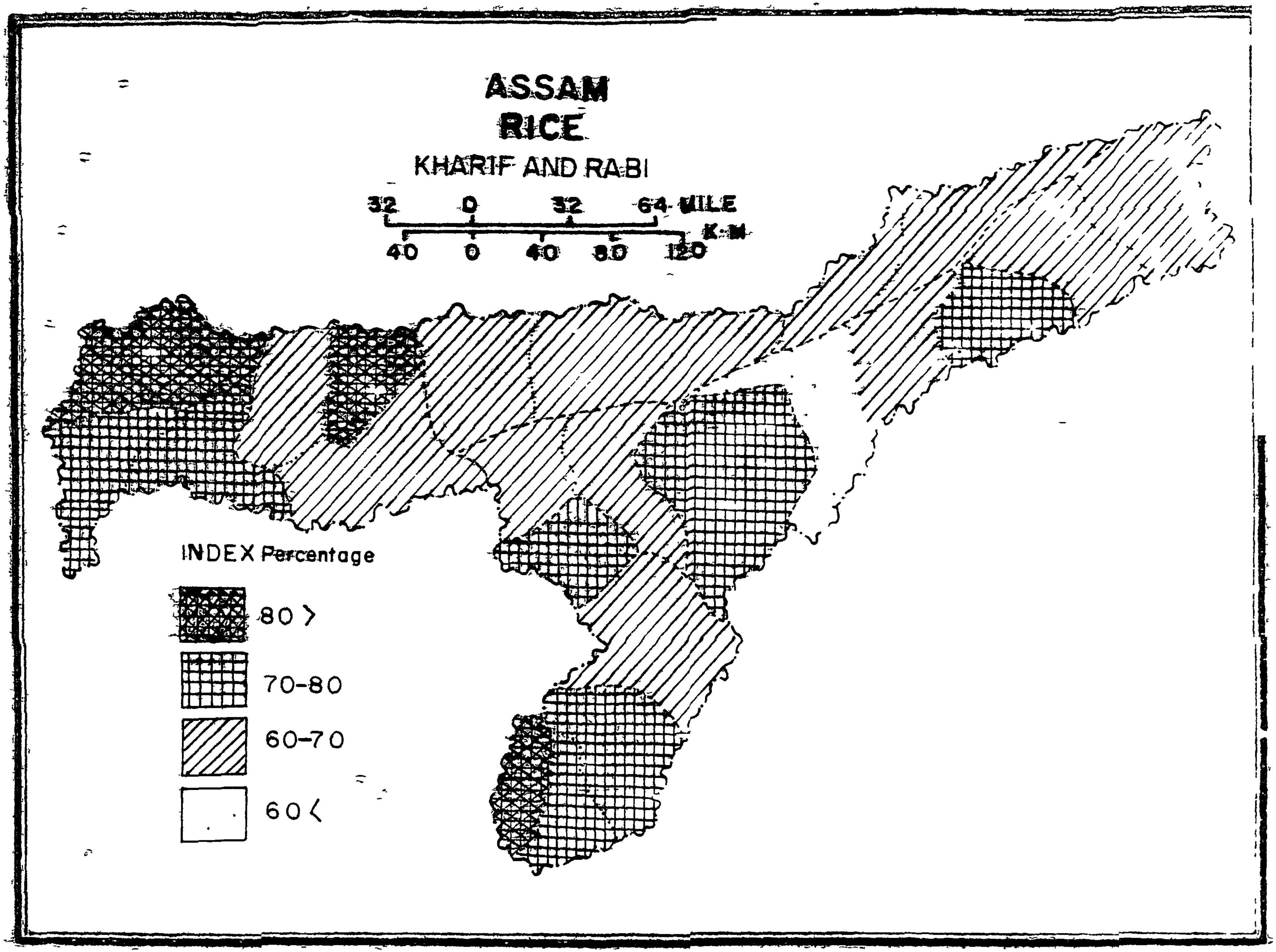
ASSAM
RICE
KHARIF AND RABI
32 0 32 64 MILE
K.M
40 0 40 80 120
INDEX Percentage
80 >
70-80
60-70
60 <

FIG.20

of subdivision, district and state, it has a substantial percentage share which invariably exceeds more than fifty percent in each unit. Hence rice ranks first in every areal unit of the area. The percentage of area under rice being significantly high, the whole of Assam would be delineated as an area of mono-culture. The minimum and maximum percentage of rice in the area varies between 52 and 85 in the subdivisions of Golaghat and Karimganj respectively.

Coming over to the frequency distribution pattern of the average percentage share of area under rice during 1974-35 to 1976-77 in Assam, the following picture emerges.

TABLE - XVIII

Class group of percentage of area under rice	Frequency	Cumulative frequency
60	1	1
60 - 70	12	13
70 - 80	6	19
80 +	3	22

It will be seen from the frequency table that as many as 12 sub-divisions out of the twenty two possess area under rice between 60 and 70 percent which is about 55 percent of the total rice area in the state as a whole. These 12 sub-divisions are Gauhati, Barpeta, Mangaldoi, Tejpur, Marigaon, Nowgong, Jorhat, North Lakhimpur, Dhemaji, Tinsukia, Dibrugarh and North Cachar Hills. Excepting the North Cachar Hills rest of the subdivisions fall within the plain area of the state. In the plain, however, the sub-division of Golaghat in Sibsagar has the lowest area under rice which is 55.2 percent.

As many as 3 sub-divisions namely Kokrajhar, Nalbari and Karimganj have over 80 percent of the cropped area under rice cultivation which is significantly high.

In the subdivisions of Goalpara, Dhubri, Sibsagar, Silchar, Hailakandi and Karbi-Anglong 70 to 80 percent of the cropped land is devoted to rice which is a fairly high percentage. The sub-divisbn of Golaghat has the least area i.e. 55.2 percent under rice cultivation.

Switching over to the seasonal break-up of the rice cultivation in Assam, Kharif is the main season of its cultivation. In the rabi season at the most upto 21 percent of the gross cropped area is devoted to rice in some of the areal units of the area.

Viewed at the district average figures of the percentage of area under rice, districts Cachar and Darrang have the highest and the lowest percentages i.e. 81.79 and 63.53 per cent respectively. Except the district Goalpara, Kamrup, Cachar and Karbi-Anglong which possess more than 70 percent of the area under rice, all the other districts have 60 to 70 percent of area under rice. Taking into account the districts falling in the plains of the state, it is interesting to note that at least 70 percent of the gross cropped area is devoted to rice which accounts for more or less the same in the hill division also 69.86 per cent as compared to the state average of 70 percent.

In order to have an idea about the consistency in the distributional pattern of percentages of area under rice in various

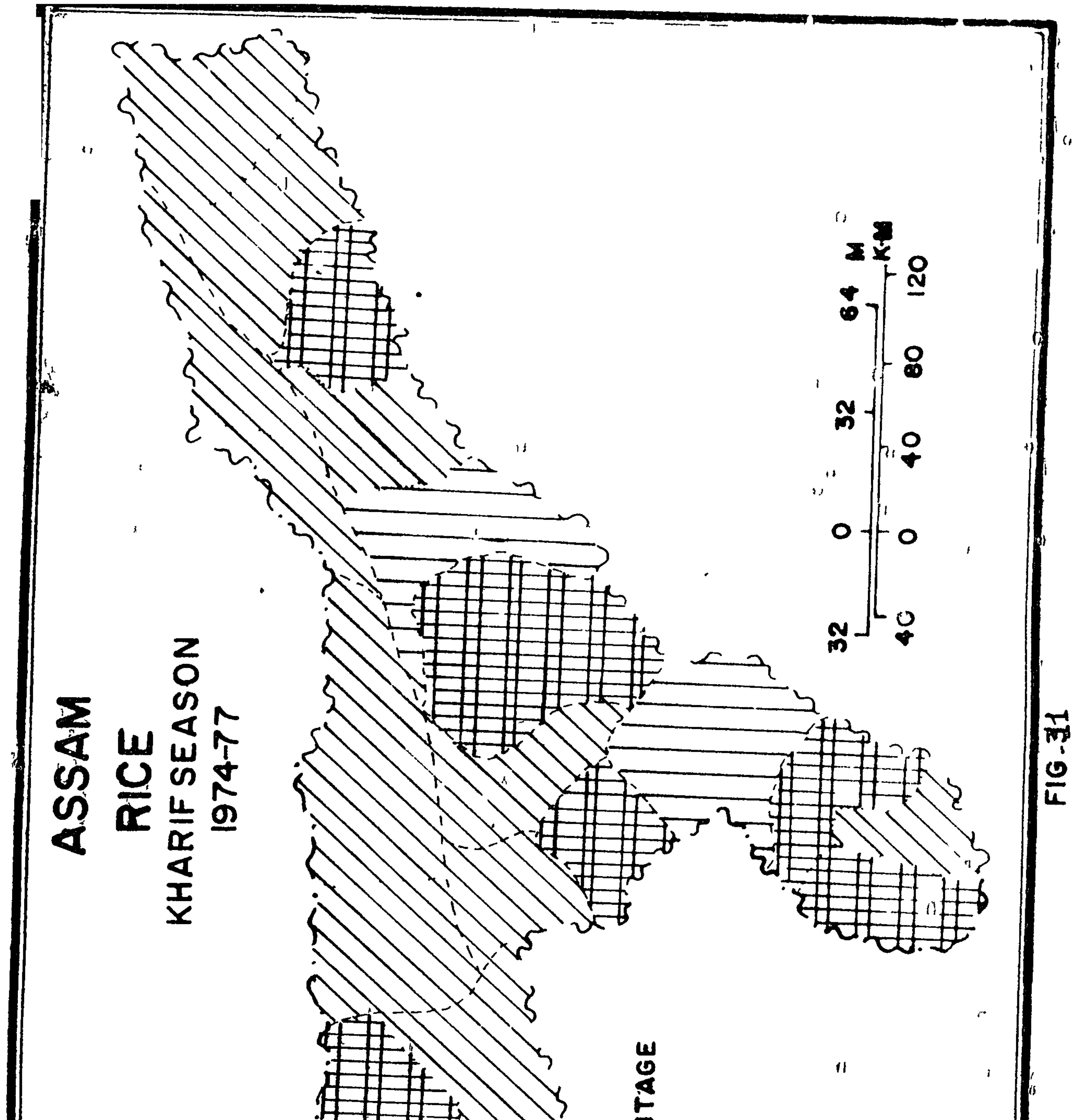
ASSAM
RICE
KHARIF SEASON
1974-77
INDEX PERCENTAGE
80 >
70-80
60-70
< 60
32 0 32 64 M
40 0 40 80 120 KM

FIG. 31

sub-divisions, it is worthwhile to analyse the measures of dispersion of the data in terms of their standard deviation. Mean and co-efficient of variation. Here the variability of the data could be meaningful if measured in relation to the mean of the variable. Thus the most commonly used measure of such relative variability is the co-efficient of variation defined as :

$$= \frac{SD \times 100}{Mean}$$

Coming over to the comparative picture of the co-efficient of variation of the average percentages of area under rice during 1974-75 to 1976-77, the average percentages in Kharif and rabi in separate and the distributions of percentages of area under rice in different component areal units, it is distinct that the co-efficient of variation in Kharif i.e. 12.632 is considerably less than that of rabi which 218.413. Hence we could reach the following inferences out of the analysis of the co-efficients of variations.

a - Since the co-efficient of variation is small in case of the three years average, it can be said that the percentage of area under rice in relation to the total cropped area in different in the subdivisions are more consistent in the Kharif season only.

b - Since the absolute values of the co-efficients variation between the three years average and the same of the Kharif season do not have a greater difference, the inconsistency between them is not very striking.

c - The co-efficients variation of either of the three years average or the kharif season only as compared to the rabi

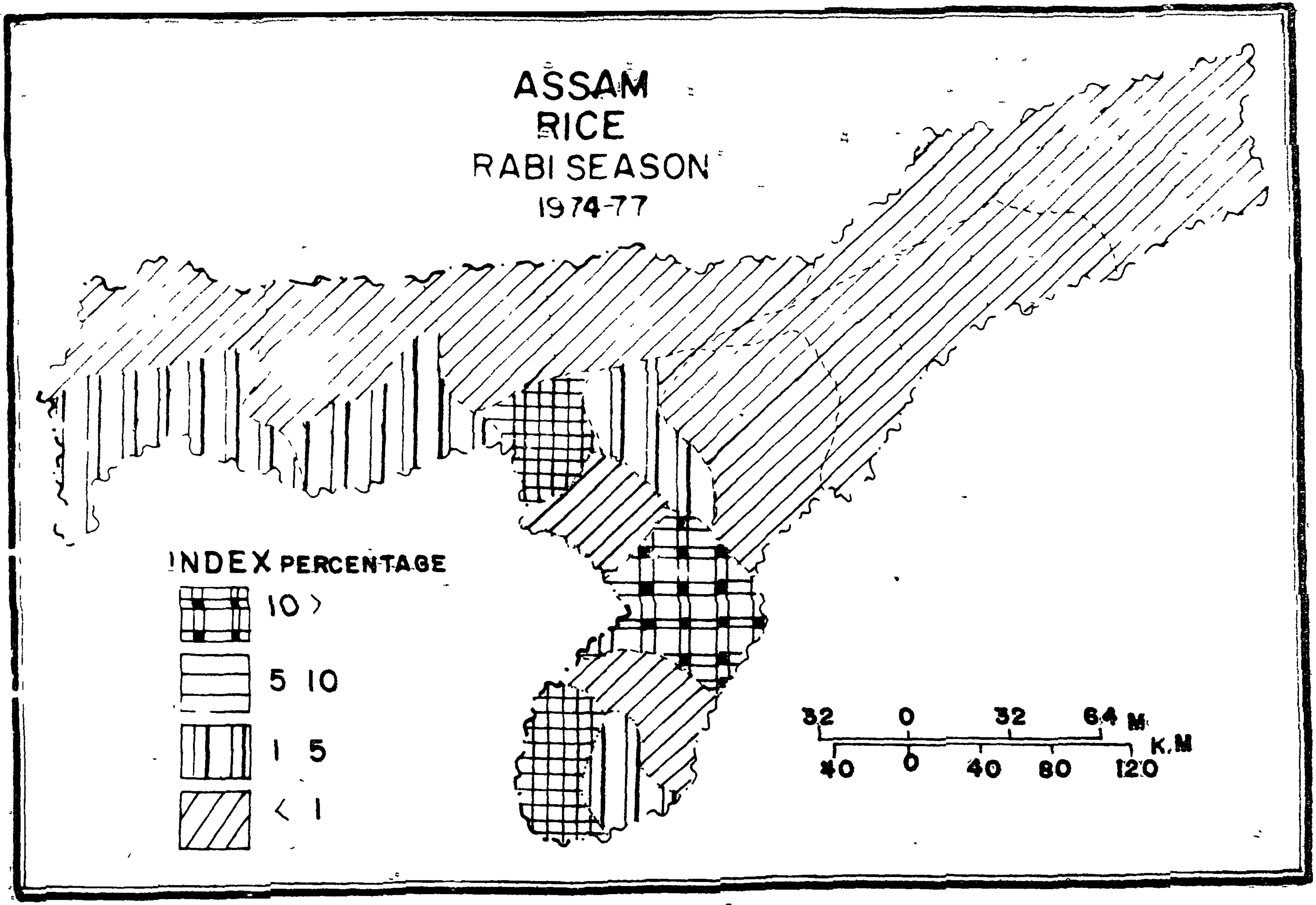
ASSAM
RICE
RABI SEASON
1974-77
INDEX PERCENTAGE
10 >
5 10
1 5
< 1
32 0 32 64 M
K.M
40 0 40 80 120

FIG-12

season however shows that the percentage of area under rice in Rabi is strikingly inconsistent for which the standard deviation exceeds the Mean. The co-efficient of variation is 218.413. It is mainly because of the greater inconsistency of the percentage distribution of area under rice in various sub-divisions.

In order to know the areal concentration of rice over space in different subdivisions the location quotient has been applied.

$$I = \text{Index for the concentration of crop} = \frac{\text{Area of crop x in a component areal unit}}{\text{Area of all crops in the component areal unit}} \div \frac{\text{Area of crop x in the entire unit}}{\text{Area of all crops in the entire region}}$$

If the index value is greater than unity the component areal unit accounts for a share greater than it would have had if the distribution were uniform in the entire region. Therefore the areal unit has a concentration of the particular crop under study. Since rice possesses a major share of area under cultivation in each areal unit, it ranks second to now of the agricultural field crops in the whole of Assam. Hence the percentage share in gross cropped area of the different crops other than rice is below 50 percent in each areal unit. The percentage values for the density of area under rice in all the component areal units that shoe concentration have been put in descending order. The index has been made by dividing the descending array into five equal parts to distinguish the very high, high, medium, low and very low concentration with the help of index scale, the concentration of rice as the first ranking crop in every unit has been plotted in figure - 13

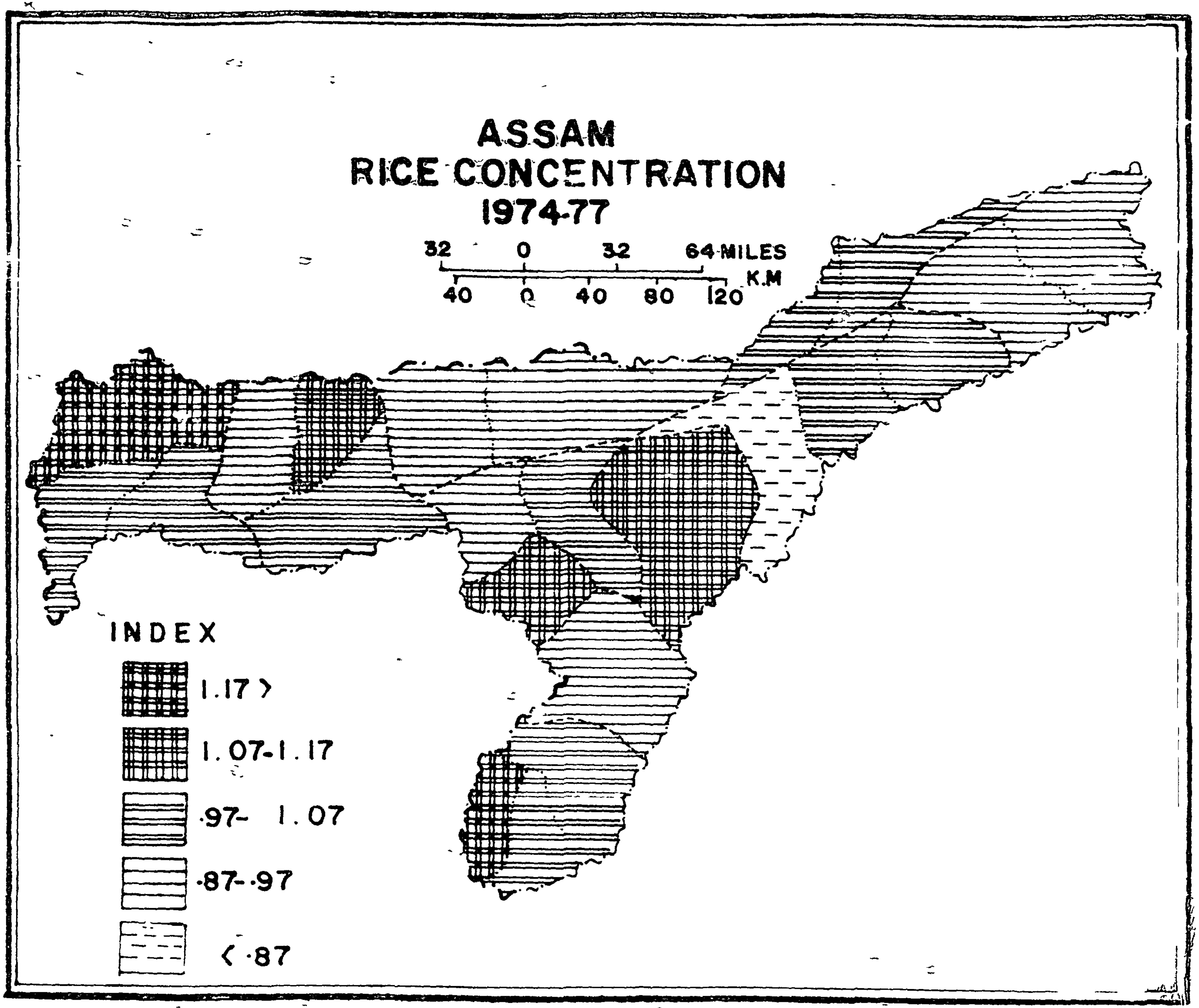
ASSAM
RICE CONCENTRATION
1974-77
32 0 32 64 MILES
40 0 40 80 120 K.M
INDEX
1.17 >
1.07-1.17
·97- 1.07
·87-·97
< ·87

FIG. 93

The following table shows the frequency distribution of the indices of concentration of area under rice.

TABLE - XIX

Class group of the indices of concentration	Degree of concentration	Frequency	cumulative frequency
0.87	Very low	1	1
0.87 - 0.97	Low	7	8
0.97 - 0.07	Medium	10	18
1.07 - 1.17	High	2	20
1.17 +	Very high	2	22

Having a look at the indices of concentration it is clear that the indices vary between as low as 0.77 to as high as 1.20 for the subdivisions of Golaghat and Karimganj respectively.

As per the arrangement of the index values in a descending order of magnitude and the different distinguishing parts of the array maximum number of subdivisions are coming under the medium degree of concentration. The subdivisions are Goalpara, Dhubri, Gauhati, Nowgong, Jorhat, Sibsagar, North Lakhimpur, Dhemaji, Silchar and Hailakandi. The concentration index values in these areas vary between 0.97 to 1.07.

But very high concentration of area under rice is noticed in the subdivisions of Kokrajhar and Karimganj, the index values exceeding 1.17. Similarly high areal concentration of rice under cultivation is observed in subdivisions of Karbi-Anglong and Nalbari, the index values varying between 1.07 to 1.17.

As many as seven subdivisions show low concentration having index values between 0.87 to 0.97. The subdivisions are Barpeta, Tejpur, Mangaldoi, Marigaon, Tinsukia, Dibrugarh and North Cachar. But Golaghat is the only subdivision which shows the least concentration of this crop.

The study made about the rice cultivation in Assam reveals significant varietions in the density pattern in different areal units. In the state of Assam rice is most extensively grown in the proximal or the peripheral subdivisions of the Brahmaputra valley. It is predominantly grown in the Kharif season when the agro-climatic conditions are more conducive for its cultivation. The frequency distribution of the percentage share under rice in Kharif, more or less tends to reveal the average picture of both the kharif and rabi seasons. In many of the subdivisions rice is not cultivated in the rabi season and in the rest only 5.91 percent of the total cultivated land is given to this crop. North Cachar hills are however, exception to this in which 21.67 percent of the gross cropped area is devoted to rice in the winter season.

Though rice in general is the dominant crop but its cultivation in the subdivisions of Kokrajhar and Karimganj is exceptionally extensive in which over 80 percent of the gross cropped area is under its cultivation. In seven subdivisions namely North Cachar, Tinsukia, Dibrugarh, Marigáon, Barpeta, Mangaldoi and Tejpur rice though a leading crop but its percentage share in the total cultivabed land is less than 60 percent

<u>Cultivation techniques</u> :

The methods of cultivation of different crops vary from each other. Rice - the staple crop is grown in different season with varying agricultural practices in the different parts of the country. Its sowing, growth and harvest, however, can be seen throughout the year. In the Brahmaputra valley three crops of rice in a year are grown. They are known by different names. The seasons of rice are (1) winter paddy (Sali and Bao) along with capsularies jute grown in low lands, transplanted winter sali paddy in puddled condition with standing water during July and August i.e. the growth period. Bao is a broad cast and deep water paddy cultivated in the flooded land. (2) Ahu (Autumn paddy) broad-cast or transplanted. (3) Boro (Summer rice) grown in marshy lands in Rabi season.

SALI : This is usually transplanted in the rainy season, in the months of July and August. Seedlings are raised in highly manured nurseries. Before transplantation takes place the field is ploughed and puddled 4 to 6 times depending on the nature of the soil and the labour and the cattle energy available. After ploughing, the field is pulverised with bamboo ladder. Paddy seed-lings are transplanted in bunches with standing water in the fields. Transplantation is mostly done by female labour and the whole operation is labour intensive. After transplantation the farmer pays cursery attention and applies the available quantity of fertilizer mostly after one and half months from the date of transplantation. Sali crop flourishes during the rainy season and is harvested in the months of November and December. Bao is grown with the help of broadcast method in the low lying areas in March and April, after having ploughed the dried fields atleast 4 to 5 times. Extensive weeding operations become essential for Bao paddy before the land gets flooded. It grows with water level even upto 4 to 5 inches. After the recession of the flood water the plants settle on the land and begin tillering. This is harvested in December and January. Asra, another shallow water paddy is cultivated just like the Bao and is harvested in November and December. Sali and Bao are considered as the principal crops in Assam in winter and these two occupy 57 percent of the total cropped area and 72 percent of the total area under rice in the state.

AHU - Ahu or the autumn rice broadcast varieties are sown in a well prepared field in March - April only. Weeding is necessary for the broadcast rice. It is harvested in July and June. Transplanted Ahu is grown in irrigated field. Seeds are sown in nurseries in March-April and 4 to 5 weeks seedlings are transplanted in puddled fields.

The writer has been told by the farmer during the curse of his field work that Ahu if transplanted gives higher yields than if broadcast. This fact is proved by the secondary data also. Ahu is followed by Sali rice and is grown in particular types of lands. Importance of this crop h-s been felt over years after the HYV has been in operation.

BORO - The summer season rice crop is called Boro. It is grown in marshy land during rabi season. Boro rice being a summer season crop requires adequate and timely irrigation. For this crop seeds are grown in nurseries in the month of November and December followed by the transplanatation of seedlings in well puddled fields in December and January. Boro rice is harvested from April to May and widely cultivated in Goalpara, Nowgong districts of the Brahmaputra valley.

Productivity :

So far as the level of output of rice in Assam is concerned it can be observed from table - given in the appendix - that the output has shown an increasing trend. From about 12.76 lakh tonnes in 1950-51 the production has gone up to about 22.5 lakh tonnes in 1975-76. Thus there has been a net increase of 9.7 lakh tonnes during the last 25 years. The simple annual growth rate, linear growth rate and compound growth rates[1] are 3 percent, 1.58 percent and 2.3 percent respectively.

Fluctuations in the out turn from year to year in terms of percentage rate of change in index numbers (presented in a table in appendix -) in Assam shows that the same has fluctuated between 18.85 percent to - 10.44 percent. The average rate of change during the period 1950-51 to 1975-76 is found to be 1.83 percent per annum. The annual rate of increase in Index Number is noticed high during the period 1966-67 to 1968-69. The index of area has gone up to 105.28 in 1968-69 from 96.91 in 1965-66. The yield rate also seems to have changed from year to year.

The average yield rate is about 964 kg/ha. The linear growth rate of productivity is found to be only 0.61 percent. The yield rate of rice is dependent on multiple physical as well as socio-economic factors and that too, weather conditions are primary determinants of yield. Absence of floods and timely rains stand favourable for growth of rice productivity. The average production of rice during 8 years out of 26 years was 1000 kg/ha.

In 1966-67 the yield rate dropped below 900 kg.

HYV Introduction in Assam :

The introduction of short duration HYV of rice which are less photosensitive has created such types of situations that three rice crops in a year can be successfully grown in a field provided proper irrigation facilities are available. In certain areas, two rice crops are found to be grown particularly where irrigation is provided.

The introduction of HYV began in Assam in 1966-67 at a smaller scale, but consequently started getting momentum. Only 13.1 percent of the area is reported to have been covered by this rice by the end of 1972-73. The main cònstraints of adoption of HYV of rice by the farmers are availability of timely irrigation seeds, fertilizers and insectisides. During the IV five year plan, the strategy of agricultural development in the state was based on the programme of High Yielding Varieties with package practices, thereby getting all possible supports from rapid development of irrigation, efficient supply of inputs through agro-industries corporation, and speeding up the proper educational programmes along with research and extension. There was also high level consensus over multiple cropping keeping the intention of increasing the intensity of cropping special programmes in Rabi season were organised.[2]

Area occupied by HYV rice :

Informations available on the area under HYV from 1969-70 to 1975-76 for the districts of Assam show that only 13 percent of the total area under rice have been covered by HYV by 1972-73 end. This coverage continued till 1975-76. On the contrary, the area under HYV has increased more than two times from 1969-70 to 1971-72. The districts of Cachar, Lakhimpur and Sibsagar have achieved partial success as compared to all other districts. District-wise acreage under HYV is presented below for the period of 1969-70, 1972-73 and 1975-76.

TABLE - XX

Area under HYV of Rice

Districts	1969-70	1970-71	1971-72	1972-73	1975-76
	Area	in	000 ha		
Goalpara	10.68(3.1)	11.57(3.5)	14.74(4.3)	24.96(7.1)	39.08(10.77)
Kamrup	16.00(3.7)	18.32(4.2)	27.73(5.5)	41.01(8.9)	44.42(9.48)
Darrang	8.7 (8.6)	10.49(5.9)	15.02(6.2)	14.68(5.9)	32.98(11.47)
Nowgong	8.8 (4.1)	10.86(4.8)	14.02(6.9)	18.27(8.1)	35.28(13.54)
Sibsagar	29.41(1.2)	31.49(12.5)	33.54(13.8)	45.46(19.7)	46.91(19.09)
Lakhimpur	11.83(5.2)	16.01(16.9)	24.03(13.8)	27.39(24.2)	14.68(12.13)
Dibrugarh	-	-	09.46 -	14.7(10.9)	25.74(19.95)
Cachar	18.84(5.8)	28.62(14.1)	39.41(20)	45.28(23.2)	41.39(18.57)
Mikir Hills	2.59(4.4)	35(5.7)	39.51(63)	40.00(37.1)	7.0(0.08)
N.C.Hills	-	-	-	-	12.0(0.01)
Total	99.85 (5.1)	108.63 (6.3)	271.75 (13.1)	213.46 (10.8)	287.60 (13.08)

It will be seen from table -XX that in 1969-70 about 3 to 12 percent of the rice cropped area was under HYV. Since then it has shown a continuous upward trend. In 1975-76 in the four districts under study 9.48 to 13.54 area was covered by the HYV. Nowgong with 13.54 percent has the highest area under HYV, followed by Darrang 11.47, Goalpara 10.77 and Kamrup 9.48 percent. In other districts of Assam, specially in Sibsagar and Cachar it has been appreciably diffused covering 19.09, 19.96 and 18.57 percent of the rice cropped area respectively. Thus the HYV have greatly replaced the indigenous varieties within a short span of period i.e. about 10 years.

Performance of HYV of Rice:

According to a report on performance[5] of HYV rice in Assam for which trials were conducted in Titabar Rice Research Station, the recommended varieties such as Jaya, Pusa 2-21, Pusa 2-103, Jagannath and Monohar Sali cultivated in Kharif and rabi seasons gave the following results.

TABLE - XXI

Variety	Average yield in kg/ha	Season of the trial	
Jaya	8111	Rabi)	
Pusa 2-21	6427	Rabi)	1971
Pusa 2-103	7023	Rabi)	
Jagannath	3385	Kharif)	1972
Monohar Sali	3141	Kharif)	

It will be seen from table-XXI that Jaya variety sown during the winter season gave the highest yield i.e. 8111 kg per hectare followed by Pusa 2-103 resulting into 7023 kg. per hectuare. From the agro-climatic point of view, it is interesting to note that rice sown in Rabi and grown with controlled irrigation gave higher returns than that of the Kharif rice. A comparison of the Kharif and rabi rice shows that the per hectare yield of rice in the rabi season is more than double in all three varieties mentioned. Thus inspite of providing NPK festilizers at the rate of 50-25 and 100.50-50 kg per hectare, the Kharif productivity is very low. As a matter of fact the HYVs perform more bettern when water supply is controlled and given in the right quantity at the right time.

The Assam Agricultural University, Jorhat is doing commendable work to educate the ruralities about the HYV by providing them them the extension service. The University selected three intensive districts for the demonstration and extension purpose. In the following table the yields of HYV in the districts of Kamrup, Sibsagar lying in the lower and upper Brahmaputra valley and Cachar a hill district of Assam, has been shown.

TABLE - XXII

Districts	Year	Crops	Maximum yields in kg/ha
Sibsagar	1972-73	Jaya(Paddy)	8989
	1973-74	"	6323
Kamrup	1972-73	"	7333
	1973-74	Pusa 2-21(Paddy)	7076
Cachar	1972-73	IR-8(Paddy)	9345
	1973-74	IR-8(")	7092

Source - Reports of the A.A.U 1972-74 and 1974-75.

Productivity of HYV :

The average yields of rice for the years 1950-51, 1960-61, 1970-71 and 1973-74 are 855, 968, 1022 and 994 kg. per hectare respectively. In a sample farm study in Nowgong district from 1969-70 to 1971-72 on 100 samples the following average yields of local and HYV rice have been obtained.

TABLE - XXIII

Crops	Average yield in kg/ha (local)	Average yield in kg/ha (HYV)
Sali paddy	1658	3105
Ahu paddy	1227	2398
Bao	1584	-

The above table shows that the performance of HYV as compared to local varieties is highly satisfactory because the average yield of HYV is about the double of the local varieties.

The report from the HYV rice cultivation in Sibsagar district shows that the average yield of HYV paddy is more than double the local paddy. The data for 1968-69 is presented below:

TABLE - XXIV

Seasons	Average yield in quintal/ha
HYV paddy	
(i) Sali	19.1
(ii) Ahu	14.05
(iii) Boro	23.42
Local Paddy	
(i) Sali	9.16
(ii) Ahu	6.52

Yield estimation survey in the Mayang Irrigation Scheme also shows that even the local varieties of paddy give appreciably. higher yield because of controlled water supply. The following table presents the output of HYV and local paddies in the Mayong command area in 1968-69. The table is based on the data and information collected from Agro-Economic Research Centre for N.E. India, Jorhat.

TABLE - XXV

Average yield of Paddy in sample House-holds, 1968-69

N = 100

Variety and season	Average yield quintal/ha
1 - Local Paddy	
a - Sali (Winter transplanted)	20.8
b - Ahu (Autumn)	14.1
c - Boro (Summer)	23.0
d - Bao (Broadcast deepwater)	6.9
2 - HYV paddy	
a - Sali (Winter transplanted)	37.8
b - Ahu (Autumn)	25.7
c - Boro (Summer)	33.4

The author was informed by the farmers of the area and the AERC Jorhat that the short duration HYV Paddy is grown in the areas having irrigation facilities in the Ahu season and the traditional indigenous varieties are grown mainly in the Sali season in the low lying and flood prone areas. Hence two crops a year could easily be grown without much difficulty.

From the above information available on HYV rice cultivation, it is infered that the comparative advantage or gain out of HYV rice cultivation has attracted the farmers for the new crop. Unless the HYV cultivation is adequately taken care of by the concerned, the difficulties for better yield will remain as it is. Therefore for the achievement of better and higher output, input should also be supplied parallely in cheaper rates to all the farmers especially to the marginal farmers who cannot afford to buy the costly inputs for the package programme.

Package and Non-Package Programme in HYV Rice cultivation :

In order to achieve better and higher yields out of the cultivation of high yielding varieties of rice, the package programme plays vital role in both farmers field and farm level management. Package means a systematic and Scientific cultivation of any crop with the help of sophisticated agricultural inputs such as chemical fertilizers, pesticides, Insecticides, adequate Irrigation facilities, advanced farm machineries and so on. Therefore the impact of package, non-package and partial package, so far as the cultivation of HYV rice is concerned, has been observed very significant in farm level as well as in the fields of the farmers. The following discussion is devoted to the Assessment Survey of the Ahu and Sali (HYV) rice production programme in 1977-78 taken up by the Directorate of Agriculture, Government of Assam. The results obtained out of the survey reveals the influence of package, non-package and partial package programme on the production of HYV rice in the districts of Goalpara, Kamrup, Nowgong of the lower Brahmaputra valley and Karbi-Anglong a hill district of the state of Assam. The whole survey was based on results obtained from the sample villages of every community development blocks.

Ahy (HYV) :

The estimate of average yield rates of early and regular Ahu shows significant difference in per hectare yield with various package programmes such as full package, partial package and non-package. The tables presenting yield rates have been given in Appendix -

A glance at Appendix - Reveals that the average yield rate of regular Ahu rice with full package of practice is better than that of early Ahu rice. So far as the two most important inputs such as fertilizer and irrigation are concerned, it is observed that the effect of fertilizer alone is more prominent in early Ahu where as the effect of irrigation appears to be the same in regular Ahu. It is concluded that the application of fertilizer in paddy is effective only under ideal weather condition and proper water management in dry weather.

The yield rate of early Ahu with full package programme varies between as low as 1385 to as high as 3528 kg per hectuare for the subdivisions of Dhubri and Mangaldoi respectively in the lower Brahmaputra valley. There appears to be an increasing trend in yield rate from west to east direction for both early and regular Ahu (HYV) rice cultivationp programme. In regular Ahu with full package, Dhubri has the lowest yield in kg. per hectare i.e. 1691 kg/ha where as the highest yield has been obtained from Nalbari subdivision i.e. 3329 kg per hectare.

Comparing the yields rates of full, partial and non-package programmes, the variation has come out to be very striking in either case of Ahu (HYV). In early Ahu with partial package the yield rate ranges between 1421 to 2203 kg per hectare for Dhubri and Nalbari respectively. The variation between the full and partial package is not that spectacular because of the average performance of partial package programme which has been found out taking the yield response of every single agricultural input. But the variation between the yield responses due to full package and partial package where a single agricultural input operates, seems to be significant for both early and regular Ahu (HYV) cultivation programme in lower Brahmaputra valley.

But the variation in yield between full package and non-package appears to be very significant in both the cases of Ahu (HYV) cultivation. For instance, in the early Ahu (HYV), the yield rate with non-package programme varies between 1303 kg to 1974 kg per hectare as the lowest and highest for the subdivisions of Dhubri and Nalbari respectively. The same characteristics are also observed in case of regular Ahu (HYV). However Dhubri, with non-package programme has given the poorest response in yield rate of regular Ahu (HYV) which is 785 kg. per hectare. Such poor performance of HYV in lower Brahmaputra valley in general and the subdivision of Dhubri in particular could be attributed to heavy rainfall and many other climatic factors which are yet to be investigated. The Sali (HYV) rice production programme also indicates the similar impact of different package systems with the same geographical variation in yield rate from west to direction of the lower Brahmaputra valley. But a comparative study between the yield rates of Sali and Ahu (HYV) rice shows that the yield in Sali season is more in kg per hectare than that of the Ahu season.

Summing up the whole situation on the performance and productivity of HYV rice in Assam in general and the Brahmaputra valley in particular, it could be concluded that the average productivity of HYV rice has not appreciably gone up, though the per hectare yield average has grown considerably during the last twenty five years. The average productivity of HYV rice has been observed to be the highest at farm level only. The low productivity in the farmers field therefore, could be attributed to numerous socio-economic and environmental factors such as the old and traditional farm technology, recurrent floods and occasional droughts and the typical agro-climate and so on.

CHAPTER - IV

REFERENCE

1. Ad-hoc study No. 38, Agricultural Development in Assam (1950-51 - 1975-76), p.26.

2. Ibid, p.156.

CHAPTER - V

FERTILIZERS AND HIGH YIELDING VARIETIES OF RICE

Apart from the physical variables, the various High Yielding Varieties of rice responded differently to the application and doses of fertilizers. Under the similar agro-climatic conditions a change in the quantity and quality of fertilizers and the timings of their application affect the quantity of crop and its production. In this regard the Indian Council of Agricultural Research and the Agricultural Department of Assam have conducted researches in the region with a set objective of determining the impact of application of chemical nutrients on the High Yielding Varieties of rice. The anthor collected data at the sub-division level on average yields of HYV rice grown in the whole Brahmaputra Valley under different doses of fertilizers. The collected data was processed with the help of analysis of variance to know the impact of fertilizer dozes on the output of HYV rice. Hence, in the present chapter,an analysis of variance of the yield rates of different varieties under different fertilizers doses has been made. The analysis of the following adaptive trial report of the Kharif (Sali) HYV rice published by the Directorate of Agriculture, Government of Assam 1977-78.

An adaptive trial on Sali (HYV) rice was conducted under rainfed condition in the plain districts of Assam during the year 1977-78. The objective of this trial was to study the adaptability of the strategy, enhancing the normal sali rice season by one month with short duration high yielding dwarf varieties of rice under rainfed condition so that the rice field remain free for rabi crops. According to this programme the transplanting was completed by 30th June and the harvesting by the 1st week of October. The trial was followed by seven varieties of rice with four different doses of fertilizers. Each of the 28 different types of trials was conducted in an one acre plot without replecation. The trials cover almost all the subdivisions of the plain districts except Marigaon sub-division. The varieties and fertilizer doses applied in the trials are furnished below:

Table - XXVI

High Yielding Varieties of rice	Fertilizer doses		
	N	P	K
1. Pusa 2-21	20	10	10
2. Pusa 33	40	20	20
3. Jaya	60	40	40
4. IR - 8	80	40	40
5. TTB - 417			
6. TTB - 1-121			
7. Kalinga - 1			

The total number of trials was 532 out of which 492 were alloted to cultivatory field and that of the remaining 40 to departmental farm. The difficulty was that only 88 trials were completed by the scheduled time i.e. 30th June and another 231 trials were completed after 30th June. The total achievement was 319 (60%) but the real achievement came down to only 16.5%. The reasons behind such poor achievement have been reported as (i) Non-Availability of Seed, (ii) Late Supply of fertilizer, and (iii) Late monsoon.

As per the guidelines, though it was indicated that the transplantation must complete by 30th June even if the trial plots are totally dry, the experiments did not follow it in spirit. Some experiments also refused demonstration trial and irrigated the plot apprehending that the crop might fail.

Results of the trials which were completed before 30th June were obtained in terms of total produce. The total produce was calculated with the help of random sample technique and cultivators own report. The total produce has again been converted into yield in kg. per hectare. Thus yield rate for every trial plot was estimated. Finally the yield rates of particular type of trial conducted in different trial-plots have been pooled together and the average yield rate for that type of trial was calculated. The following table presenting the yield rates of different varieties under different fertilizer doses could be taken as an example.

TABLE - XXVII

Yield rate obtained from trials conducted before 30th June

Varieties	Average yield of clean rice/ha				
	20:10:10	40:20:20	60:40:40	80:40:40	Pooled
Pusa 2-21	2622	2894	2875	2468	2685
Pusa - 33	1408	2171	1598	2119	1886
IR - 8	1886	1972	1786	2561	2051
Jaya	3907	3152	1863	3644	3067
T.T.B 4/7	2032	2233	2949	2680	2422
T.T.B.1-12-1	2027	2086	1669	1668	1887

As per the informations available in the above table it is observed that each variety of high yielding rice responded to fertilizer doses differently.

Similarly for the purpose of the study the original data on variety-wise subdivision wise has been split into individual variety response to different fertilizer doses as well as to to different subdivisions with a view to suggesting the areal adaptibility of a particular kind of variety with definite fertilizer doses.

Explanation of the technique of Analysis of Variance :

For a general understanding of the technique of Analysis of Variance of any kind of statistical data where a number of means are involved the mathematical steps could be explained in the following fashion. Since in the present case, the data relate to the average yields of different varieties of high yielding rice under different fertilizer doses, the hypothesis that the mean yields are homogenious or they do not differ significantly, could be tested with the help of the technique called Analysis of Variance developed by Fisher.

If the N observations of the variate X i.e. yield are arranged into h rows and R columns then X_{ij} represents the value of the member belonging to ith row and jth column, $\bar{x}_{.j}$ represents the mean of the jth column and $x_{i.}$ represents the mean of the ith row. The data is arranged as follows.

TABLE - XXVIII

	1st Col.	2nd Col.	j^{th} Col	k^{th} Col	Row Totals	Row Means
1st row	x_{11}	x_{12}	x_{1j}	x_{1k}	$T_{1.}$	$x_{1.}$
2nd row	x_{21}	x_{22}	x_{2j}	x_{2k}	$T_{2.}$	$x_{2.}$
i^{th} row	x_{i1}	x_{i2}	x_{ij}	x_{kk}	T_{i}	$x_{i.}$
h^{th} row	x_{h1}	x_{h2}	x_{hj}	x_{hk}	$T_{h.}$	$x_{h.}$
Column Totals	$T_{.1}$	$T_{.2}$	$T_{.j}$	$T_{.k}$	T	$x_{..}$
Column Means	$x_{.1}$	$x_{.2}$	$x_{.j}$	$x_{.k}$	$x_{..}$	

As per the above classification of the data into h classes, each row corresponds to some factors of classification. Hence, each row here represents the average yield of HYV rice in Kg. per hectare obtained from the application of R different doses of fertilizers. The various values X_{ij} or the mean yields differ among themselves and this variability may be due to

(i) Variation within classes or groups
(ii) Variation from class to class.

The main objective of the analysis of variance would be to break-up the total variation into components due to each of the factors and then compare them by the F test. If it is assumed that each group is homogenious within itself, then the variation within itself is due to chance or random causes. If the data is found homogenious in relation to the factor of classification or there is no effect due to this fadtor, then the variation between classes would be attributed to the random causes and the two variations will be of same order.

The hypothesis is built up that all X_{ij}'s (i=2, 2....,h; j=1.2,....., k) are drawn from a normal population with mean M and variance 6^2 and there is no difference between classes as such. According to the above table we have,

$$\sum\sum Xij = \sum Ti = T = \sum T.j = \sum\sum Xij$$

Where T = Grand total

$$\bar{X}i. = \frac{Ti}{K}, \bar{X}.j = \frac{T.j}{h}, \quad \bar{X}.. = \frac{T}{hk}$$

Where X.. = General Mean

Out of all these the following algebraic relation is derived:

$$\sum_{ij}\sum = (Xij - \bar{X}..)^2 = \sum_{ij}\sum (Xij - \bar{X}i.)^2 + K (Xi - \bar{X}..)^2$$

The sum of the squares (S.S) on the left hand side is called Total sum of squires.

$\sum_j (Xij - Xi.)^2$ represents sum of squires of deviations of all values of i^{th} class from their class mean. This is called sum of squares within the i^{th} class. Hence, the first sum of squares on the right hand side represents the sum of squares within each class for all the classes. In a similar way, the second sum of squares on the right hand side is due to variation between class means and is called sum of squares between classes.

After finding out the mean sum of squares of between classes and within classes with the help of their respective degrees of freedom their ratio can be tested by the F test.

$$\text{Where} \quad F = \frac{\sum K(\bar{X}i. - \bar{X}..)^2}{\sum\sum (Xij - Xi.)^2} \times \frac{N - h}{h - 1}$$

with $V_1 = h-1$, $V_2 = N - h$

The results are tabulated in the following analysis of variance or ANOVA table.

TABLE - A

Sources of variation	D.F	S.S.	M.SS	F tabulated at 0.05 0.1
Between class means	h-1	$\sum k(Xi.-X..)^2$	$\frac{\sum K(Xi-X..)}{h-1}$	
Within classes	N-h	$\sum\sum_{ij}(Xij-Xi)^2$	$\frac{\sum\sum(Xij-Xi)^2}{N-h}$	
Total	N-1	$\sum\sum(Xij-X..)^2$		

Since the last part of this Chapter deals with a two factor classification of the analysis of variance, the data could be divided according to both rows and columns i.e. different varieties of HYV rice and different proportion of fertilizers the sum of squares is broken up as follows:

$$\sum\sum_{ij}(Xij-X..)^2 = K\sum(X_1.-X..)^2 + h\sum_j(X.j - X..)^2 + \sum\sum_{ij}(Xij-Xi.-Xj+X..)^2$$

or T.S.S. = Between Classes S.S. + Within Classes S.S + Error S.S.

After finding out the mean of the above four sums, the estimates given by S.S. between row 'means', column means are independent of the estimate given by the last i.e. error sum of squares. The analysis of variance is presented as follows:

TABLE - B

Source of variation	D.F.	S.S	M.S.S.	F
Between row	h-1	$K(Xi.-X..)^2$	SS/D.F.	
Between columns	k-1	$h(X.j-X.)^2$		
Error	(h-1)(k-1)	$_{ij}$ $(X\,ij-Xi.-Xj+X..)^2$		
Total	hk-1	$(Xij-X..)^2$		

The analysis of variance on the per hectare yield of different varieties of high yilding rice according to sub-divisions wise performance indicates that there is an insignificant variation of production between different subdivisions as suggested by the estimated variance ratio between subdivisions and within subdivisions. Since the calculated ratio does not exceed that of the tabulated at both 1 and 5 percent level of significance it could be concluded with confidence that the yield response of different high yielding varieties of rice does not vary significantly subdivision-wise.

The variance ratio between different HYV's and within HYVs(because of the spatial variation) suggests that the yield rate - given by different varieties varies to a greater extent. The reason could be attributed to non-suitability of the varieties with the prevailing climatic conditions. The following analysis of variance table presents the sum of squares in terms of the total variance, with the break up of variance between subdivisions, and variance within subdivisions, variance between fertilizer doses and variance within fertilizer doses, number of degrees of freedom and the F ratios tabulated and calculated

TABLE - XXIX

Analysis of Variance

Sources of variation	D.F.	S.S.	M.S.S	F	F at 0.05	0.01
Between sub-divisions	9	6137718.35	681968.71	0.75	1.91	2.66
Within sub-divisions	24	21755397.89	906474.91			
Total	33	27693116.24				

TABLE - XXX

Analysis of Variance

Sources of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between varieties of High Yielding rice	5	12602527.8	2520505.58	4.68	2.56	3.75
Within varieties of High Yielding rice	28	15090588.44	538949.59			
Total	33	27693116.24				

T.T.B. 4/7 :

Coming over to individual varieties performance one could see a very varied response according to place variation. The analysis of variance for T.T.B. 4/7 shows that the variation of per hectare yield between subdivisions is significant at 5 per cent level of significance but at one percent level the yield veriation is insignificant, since the calculated F ratio of between subdivisions and within subdivisions exceeds the tabulated F at 0.01 per cent level.

However, the variation of per hecter yield between fertilizer doses seems to be insignificant at both the levels. Hence, from the analysis of variance of the production of T.T.B 4/7 all over the subdivisions it could be infered that, this particular variety could be successfully grown if a little care is taken during the growth period of the plants and the variation of the soil fertility status is minimised by applying different types of fertilizers at its exact proportion. The climatic vagaries are however, to be kept in mind while growing this variety. The following table presents the sum of squares and F ratio's calculated and tabulated for T.T.B. 4/7 HYV rice.

TABLE - XXXI

Analysis of variance

Sources of variation	D.F.	S.S.	M.S	F	F at 0.05	0.01
Between subdivisions	6	2983038.85	497173.14	3.77	3.36	5.67
Within subdivisions	7	920462.01	131494.57			
Total	13	3903500.86				

TABLE - XXXII

Analysis of variance

Sources of variation	D.F.	S.S.	M.S.	F	F at 0.05	0.01
Between Fertilizer Doses	3	1877769.86	625923.29	3.09	3.71	6.55
Within Fertilizer Doses	10	2025731.00	202573.1			
Total	13	3903500.86				

JAYA :

The performance of JAYA HW in whole of plain subdivisions of Assam is also not that satisfactory as evident from the analysis of variance table. The yield variation between subdivisions comes out to be significant at 0.05 percent level, the calculated F ratio being greater than the tabulated. But 0.01 percent level of significance the variation is found to be insignificant. The reasons for such space variation could be of diverse nature such as climatic hazard, poor soil nutrition, cultivators own negligence and a host of others.

So far as the effect of fertilizer doses is concerned, it is noticed that the mean yield is not affected by the fertilizers at different proportion. The variance ratio of between fertilizer doses to within fertilizer doses shows that the ratio comes out to be very insignificant at the either level of significance. Therefore the null hypothesis is rejected at both 5% and 1% level of significance for which it could be infered that there is no significant difference between the mean per hectare yield of JAYA HYV so far as the effect of proportionate Nitrogen, Phosphorous and pottassium fertilizer doeses are concerned. The following tables present the source of variation, sum of squires, mean sum of squares, degrees of freedom, F ratio estimated and F ratio observed for mean yield of JAYA variety in the plain subdivisions of Assam Valley.

TABLE - XXXIII

Analysis of Variance

Source of variation	D.F	S.S	M.S.S.	F	F at 0.05	F at 0.01
Between sub-divisions	7	19398078.23	2771154.03	29.82	19.35	99.36
Within sub-divisions	2	185828.67	92914.34			
Total	9	195839.06.9				

TABLE - XXXIV

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S	F	F at 0.05	0.01
Between fertilizer doses	3	7816375.65	2605458.55	1.328	4.28	8.47
Within Fertilizer doses	6	11767531.25	1961255.3			
Total	9	19583906.9				

Since the fertilizer doses are applied as per the need of the soil nutrition deficiency so that the use of these does not disproportionately affect the mean yield, that the mean yields are not very different from each other, the space variation of the mean yields of this particular variety could be attritued to agro-climatic differences, and many socio-economic factors. In order to boost up the mean yields per hectare within a particular region, the different doses of N.P.K. could be manipulated as trials, so that the variation between the doses and within the region is minimum.

Pusa-33:

The performance of Pussa-33 appears to be quite favourable for its cultivation. The variation of mean yields between sub-divisions is insignificant at 0.05 percent level of significance as well as 0.01. The estimated F ratio is found to be less than the observed at both the levels. Keeping all other agro-climatic and socio economic factors constant, the variation in the mean yield of Pusa-33 over space is minimum.

Coming over to the effect of different fertilizer doses on the yield of this variety, it is observed that the effect between different N.P.K. doses on the mean yield is also very insignificant at both the levels of significance. The following analysis of variance table shows the sources of variation, degree of freedom, sum of squires, mean sum of squires, F ratio calculated and tabulated (at 0.05 and 0.01 levels)

TABLE - XXXV

Analysis of Variance
Pusa-33

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	4	2780329.98	695082.5	3.39	3.48	5.99
Within sub-divisions	10	2048974.42	204897.44			
Total	14	4829304.4				

TABLE - XXXVI

Analysis of Variance
Pusa-33

Source of variation	D.F	S.S.	M.S.S.	F	F at 0.05	0.01
Between Fertilizer doses	3	1915711.73	638570.58	2.41	3.59	6.22
Within Fertilizer doses	11	2913592.67	264872.06			
Total	14	4829304.4				

Summing up the over all performance of Pusa-33 in the plain areas of Brahmaputra valley, it could be recommended that the variety is the most suitable for its cultivation in the valley provided adequate care is taken in the methods of its cultivation, date of transplanting, application of fertilizer and irrigation at the nick of time. The mean yield could also be raised on the basis of trials of fertilizers at different propostion.

Pusa - 2-21 :

The average per hectare yield of Pusa-2-21 at different proportion of fertilizer doses obtained from the subdivisions of Goalpara, Gauhati, Nalbari, Nowgong, Jorhat and Golaghat indicates that the variation between subdivisions comes out to be statistically very insignificant as evident from the analysis of variance table. The F ratio of variance of between subdivisions to within subdivisions as estimated is less than that of the tabulated and that too it is less than unity. Hence, at both 5 percent and 1 percent level of significance the variation is insignificant.

Switching over to the effect of different fertilizer doses on the mean yield it is noticed that the effect between fertilizer doses is also very negligible. On the other hand the yield variation due to fertilizer doses is insignificant.

Since, this particular variety does not have a greater variance between subdivisions and between fertilizer doses, and the mean yield tends to be normally distributed over space, it could be suggested that this particular variety could be successfully grown if more emphasis is laid on the choice of suitable places and manipulation of suitable and proportionate N.P.K. doses in accordance with multiple trials, so that the mean yield is raised to optimum. The following are the analysis of variance tables for Pusa-2-21 high yielding variety of rice cultivated in Brahmaputra Valley.

TABLE - XXXVII

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	5	3911152.02	782230.4	0.979	3.33	5.64
Within sub-divisions	10	7985341.42	798534.14			
Total	15	11896493.44				

TABLE - XXXVIII

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between Fer-tilisor doses	3	1019205.82	339735.27	0.37	3.49	5.95
Within Ferti-liser doses	12	10877287.62	906440.64			
Total	15	11896493.44				

IR-8

IR-8, another popular high yielding variety of the farmers in the valley is grown successfully. Samples of mean yields collected from the subdivisions of Goalpara, Nowgong, Jorhat, Tejpur and Mangaldoi, after having conducted an analysis of variance survey shows that the variation of mean yields between subdivisions has been found out in significant at either levels of significance i.e. 0.05 percent and 0.01 percent respectively.

The variation within sub-divisions could be clearly attributed to the effect of different fertilizer doses as evident from the basic data on the one hand and lots of unknown factors on the other. The F ratio between the subdivisions and within the subdivision comes out to be 3.91 which is less than the tabulated

F values 4.53 and 9.15 at 0.05 and 0.01 percent levels of significance respectively.

The variation between mean yields as affected by the different proportions of fertilizer doses also does not appear to be significant statistically. Rather, the variation between fertilizer doses is amazingly insignificant, the F ratio being 0.15 whereas the critical values of F at 0.05 percent and 0.01 percent are 4.35 and 8.45 respectively. On the contrary, one could say that there is absolutely no effect of fertilizer doses on the mean yield of IR-8. The following tables illustrate the variance statistics for IR-8 variety.

TABLE - XXXIX

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	4	8878646.74	2219661.605	3.91	4.53	9.15
Within sub-divisions	6	3405378.17	567563.02			
Total	10	12284024.91				

TABLE - XXXX

Analysis of Variance

IR-8

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between Fertilizer doses	3	757822.16	252607.32	0.153	4.35	8.45
Within Fertilizer doses	7	11526202.75	1646600.39			
Total	10	12284024.91				

However, the overall performance of IR-8 is not unsatisfactory in the valley. But the response of fertilizer doses seems to be even, so far as the return of per hectare yield is concerned. Since, the space variation in the mean output is very insignificant, it could be increased to a satisfactory level if the application of fertilizer doses could be effective.

The trials for the varieties conducted before 30th June were already discussed analysed and critically assessed with the help of the statistical technique called analysis of variance. According to the guide lines though it was decided to complete the trials by 30th June, even if the trial plots, are totally dry, the experimenter didn't take it seriously. As a result of that the transplantation was delayed and came to an end after 30th June only. In order to have a comparative picture of the mean return of the trial plots conducted before and after 30th June, the following discussion could be devoted to the analysis of variance of per acre yield average obtained after 30th June between subdivision and between varieties with the help of one factor, classification and the per acre yield of individual varieties with a break up of between subdivisions and between fertilizer doses.

The variances calculated as within and between for 50 observations and collected from 14 subdivisions covering the whole Brahmaputra valley, show that the variation of the mean yields is very significant at both 0.05 and 0.01 level, so far as space variation is concerned. The reason for such variation could be attributed to random physico-socio-economic factors.

If the total variation is broken up as the variation between different varieties and within them, the F ratio comes out to be specbacularly insignificant as compared to that of the tabulated at either levels of significance i.e. 0.05 and 0.01 respectively. Therefore, it is clear that the mean yields given by different varieties within a particular area are not very different from each other or there is no difference between the varietal mean yields. The following are the analysis of variance tables prepared for showing the variation between subdivisions and within subdivisions and the variation between varieties and within varieties.

TABLE - XXXXI

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	F at 0.01
Between sub-divisions	6	12871365.58	2145227.59	4.98	2.34	3.29
Within sub-divisions	43	18488041.74	429954.46			
Total	49	31359437.32	6016830.58			

TABLE - XXXXII

Analysis of Variance

Source of variation	D.F	S.S.	M.S.S	F	F at 0.05	F at 0.01
Between varieties	13	1422144.47	109395.73	0.13	2.09	2.84
Within varieties	36	29937292.85	831591.47			
Total	49	31359437.32	6016830.58			

Average output obtained from different subdivisions under different varieties when compared with that of the same trials conducted before 30th June, gives a very reverse picture. While the space variation of the average yield was very insignificant the 'F' ratio being less than 1 in case of trial conducted before

30th June, it is found to be significant for the trials conducted after 30th June. In a similar manner, the variation due to varieties is also coming out surprisingly insignificant the 'F' ratio being 0.13 while it was just the reverse in case of trials conducted before 30th June. Therefore it's clear that the variation due to varieties and due to subdivision is because of the random factors which are yet to be investigated.

T.T.B. 4/7:

The performance of this variety which had been transplanted after 30th June also appears to be little changed. The effect due to space variation on the mean yield was significant 0.05 level and insignificant 0.01 percent but in this case, according to the analysis of variance table, the variation is significant at both the levels. So its distinct that the difference between the mean yields started becoming more and more varied as the transplantation was delayed due to uncertainty of rainfall. When the observations were further analysed to study the variation due to the four different kinds of NPK fertilizer doses it was noticed that variation was insignificant at both the levels of significance. But the variance of the trials conducted before 30th June show that, though the same is insignificant at both the levels but the 'F' ratio appears to have a tendency towards the variation towards the significance levels. The following tables show the variance ratios calculated for the trials conducted after 30th June for the subdivisions Dhubri, Kokrajhar, Goalpara, Gauhati, Rangia, Mangaldoi, Tejpur, Nowgong, Jorhat, Dibrugarh and Tinsukia.

TABLE - XXXXIII

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	10	17504735.61	1750473.561	22.481	2.45	3.59
Within sub-divisions	17	1323680.25	77863.544			
Total	27	18828415.86				

TABLE - XXXXIV

Analysis of variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between Fertilizer doses	3	2097445.285	699148.42	1.002	3.01	4.72
Within fertilizer doses	24	16730970.575	697123.734			
Total	27	18828415.86	697348.735			

JAYA :

Jaya HYV rice grown in Sali season and transplanted after 30th June particularly in this case show very insignificant variation due in the mean yield due to spatial variation and fertilizer doses respectively. In the previous case, the statistical significance of the average return in kg/ha. was significant at 5 percent level and insignificant at 0.01 per cent level due to its cultivation in different subdivisions, but the observations collected from the trial plots after 30th June indicate negligible differences at either levels of significance. Meaning thereby the trend of variation has been minimised when it was grown after the deadline i.e. 30th June. The 'F' ratio was 29.82 as against 19.35 and 99.36 tabulated for 0.05 and 0.01

percent levels respectively. It became 0.57 as calculated against 0.2 and 3.26 tabulated for 5 percent and 1 percent levels of significance. The reason could be attributed to the numbers of samples collected. The number of observations in the first case was only 9 where as in this case the same is 33 in number. The subdivisions growing JAY variety after 30th June are Dhubri, Kokrajhar, Goalpara, Barpeta, Gauhati, Rangia, Mangaldoi, Tejpur, Nowgong, Jorhat, Dibrugarh, Tinsukia and North Lakhimpur. So this variety is almost covered by the entire valley.

Variation due to fertilizer doses is found to be insignificant at both early and late transplanting. Results obtained from the trials of early transplanatation show the 'F' ratio nearing unity, where as in that of late it is quite less than 1 i.e. 0.673. So in the late case the fertilizer doses have affected the mean yield more uniformly than the early, thereby reducing the variation to minimum. The analysis of variance tables present at one factor classification the sources of variation degrees of freedom, sum of squires, mean sum of squires, F ratio calculated and tabulated for the JAYA variety of high yielding rice transplanted after June 30th 1977-78.

TABLE - XXXXV

Analysis of variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	11	5812503.73	528409.43	0.57	2.3	3.26
Within sub-divisions	22	20393266.51	926966.65			
Total	33	26205770.24	794114.249			

TABLE - XXXXV

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S.	F	F at 0.05	0.01
Between fer-tilizer doses	3	1653322.74	551107.58	0.673	2.92	4.51
Within Ferti-lizer doses	30	24552447.5	818414.92			
Total	33	26205770.24	7914114.249			

Pusa-2-21:

Pusa 2-21 variety seems to be very sensitive to agro-climatic factors as evident from the analysis of variance of mean per acre yield. The late transplantation of this crop because of the late arrival of monsoon gives the variance ratio for the mean yield surprisingly more than the tabulated due to subdivisions and due to fertilizer doses in separate as an one factor classification. The 'F' ratio for early transplantation was 0.979 showing the variation due to subdivisions and has gone up to 411.329 in the late stage. The subdivisions growing this variety are Dhubri, Gauhati, Mangaldoi, Tezpur, Nowgong and Jorhat from which 18 samples have been collected.

The effect on mean yield due to fertilizers is also spectacular in this case. The 'F' ratio calculated is 83.924 as against 3.29 and 5.42 tabulated at 0.05 and 0.01 levels of significance. But in the early transplantation, the variation attributed to the fertilizer doses has been found very negligible as clear from the variance ratio which is 0.37 against 3.49 and 5.95 at 5 and1percent levels of statistical significance. However, the reasons for such spectacular changes in the variation of average yield have been reported by the government agencies as the late monsoon, late supply of fertilizers and non-availability of seeds. The following are the analysis of variance tables for Pusa-2-21 grown after 30th June. If the package practices are followed properly and the schedule of transplanting, watering and manuring is stáck to, the variety could give better yield.

TABLE - XXXXVII

Analysis of Variance

Source of variation	D.F	S.S	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	7	93780293.08	13397184.73	411.33	301	4.89
Within sub-divisions	11	358274.92	32570.447			
Total	18	941385.68				

TABLE - XXXXVIII

Analysis of Variance

Source of variation	D.F	S.S	M.S.S	F	F at 0.05	0.01
Between Fertilizer doses	3	88845381.02	29615127.006	83.924	3.29	5.42
Within fertilizer doses	15	5293186.98	352879.132			
Total	18	941385.68				

Pusa-33 :

The performance of Pusa-33 in the subdivisions of Dhubri, Kokrajhar, Nalbari, Gauhati, Rangia, Mangaldoi, Tejpur, Nowgong, Dibrugarh and Tinsukia, appears to be uniform so far as the mean output in terms of kg/ha is concerned. The mean yield is least affected due to the space difference and fertilizer application emerging out of the comparative study of the analysis of variance results. The 'F' ratio's calculated for the plots of dry transplantation showing the variation due to subdivisions and fertilizer doses in separate as one factor classification are insignificant where as the same has been found also insignificant even if transplanted under rainfed condition. The 'F' ratio for early transplantation has got a tendency towards the critical value of significance at 0.05 percent which shows variance due to subdivision. However this trend has been reduced to minimum nearing to unity i.e. 1.495 against the tabulated values 2.46 and 3.6 for 5 percent and 1 percent levels of significance respectively.

The variation due to fertilizer doses also had a similar trend in the former case and is noticed to have been decreased in the later, the 'F' ratio being 1.931 as against 3.01 and 4.72 at either levels. So, there appears to be greater prospective for Pusa-33 to be grown in the valley since the yield variation is insignificant due to both spatial variation and fertilizer uses. The variety has a greater adaptability to the existing environmental factors in the valley than any other in a relative term. The tables presented below show in an one way classification, the sources of variation degrees of freedom, sum of squires, mean sum of squires, 'F' ratio calculated and 'F' ratio tabulated for 0.05 and 0.01 levels of significance.

TABLE - XXXXIX

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S	F	F at 0.05	F at 0.01
Between sub-divisions	9	3959399.3	439933.29	1.495	2.46	3.6
Within sub-divisions	18	5295382.81	294187.93			
Total	27	9254782.11	342769.77			

TABLE - XXXXX

Analysis of Variance

Source of variation	D.F	S.S	M.S.S	F	F at 0.05	0.01
Between Fertilizer doses	3	1799634.6	599878.2	1.931	3.01	4.72
Within fertilizer doses	24	7455147.51	310631.1463			
Total	27	9254782.11	342769.77			

IR - 8 :

A reverse picture also emerges out of the analysis of variance of the mean yields collected from 15 trial plots for the sub-divisions of Kokrajhar, Gauhati, Tejpur, Nowgong, Jorhat and North Lakhimpur. The variation due to subdivisions is spectacular, the 'F' ratio being 9.18 against the tabulated 3.48 and 6.06 for 0.05 and 0.01 percent levels of significance respectively as compared to the same for the trials conducted before 30th June under dry transplantation which shows insignificant 'F' ratio.

The variation due to the effect of fertilizer doses on the mean yields also comes out significant in the late transplanting under rainfed condition. The 'F' ratio is 9.33 which is greater than the tabulated F values 3.59 and 6.22 at 5 and 1 percent levels respectively. But for the variance of the early transplantation under dry condition is very insignificant so far as the difference in the mean yields is concerned. The following analysis of variance tables illustrate the break up of the total variance, degrees of freedom and the F ratio's calculated and tabulated.

TABLE - XXXXXI

Analysis of Variance

Source of variation	D.F	S.S	M.S.S.	F	F at 0.05	0.01
Between sub-divisions	5	9089131.184	1817826.24	9.18	3.48	6.06
Within sub-divisions	9	1794375.75	199375.08			
Total	14	10883506.934				

TABLE - XXXXXII

Analysis of Variance

Source of variation	D.F	S.S	M.S.S.	F	F at 0.05	0.01
Between fertilizer doses	3	2206438.184	735479.395	9.33	3.59	6.22
Within fertilizer doses	11	8677068.75	78824.43			
Total	14	10885506.934				

The reason for such radical change in variation could be attributed to the practices package, late monsoon and several random factors physical and socio-economic.

Summing up the whole situation on the response of different varieties of HYV rice to fertilizer doses it could be said that, there are few varieties which were found suitable in different parts of the valley of Brahmaputra on the basis of their performance in Sali season only. The varieties have been suggested with the help of the statistical technique called Analysis of variance. According to the results of the analysis, it has been concluded that Pusa 33, Pusa 2-21 IR-8 were the most favourable varieties cultivated in Sali season before 30th June 1977. Though T.T.B. 4/7 and Jaya seem to be little unfavourable still they can give better yield if adequate care is taken. But the varieties transplanted after 30th June such as Jaya and Pusa-33 appear to be favourable and all others have shown significant variation in their yield rate. T.T.B. 4/7 variety has shown worse performance when it was grown after 30th June 1977 and this could be concluded as an unsuitable variety to be cultivated in the agro-climatic and ecological set up of the Lower Brahmaputra valley.

CHAPTER – VI

AGRO-CLIMATIC FACTORS AND RICE PRODUCTIVITY

As per the informations available in the last discussion concerning the per hectare productivity of rice in general in the Brahmaputra Valley and the recently introduced high yielding varieties of rice in particular, it is evident that the cultivation of HYV rice has become popular among the large and small farmers because it is nuetral to the scale and gives higher output per unit area. The study made both in the farm management and farmers field reveal that the average per hectare yield of HYV is more or less double to the local traditional varieties. However, the expected yield of HYV is never noticed in the farmers field excepting few farm level performance where adequate care is taken right from transplanting till harvesting of HYV rice. The factors both environmental and socio-economic responsible for such poor yield have got to be investigated, since the HYV cultivation is supposed to be done in a very controlled agro-physical set-up because of the sensitivity of these plants. An urgent need is therefore felt necessary to predict the yield of HYV rice in the prevailing climatic conditions with the help of sophisticated mathematical model. Here in the present Chapter an attempt, has been made to establish a multivariate relationship between the per hectare productivity of HYV rice and the soil and climatic determinants in the lower Brahmaputra Valley. The yield has been predicted with the help of multivariate regression analysis and a comparative study of the explanatory power of the variables has been studied with the help of co-efficient of determinations in a step-wise regression analysis model where every additional variable contributes its own explanation on productivity of a particular crop. The multivariate linear regression analysis model is explained as follows.

If a linear relationship exists between a dependent variable Y and K-1 independent variables such as X_2, X_3, ----- X_k and an error term U, then the relationship between a set of such values can be written as:

$$Yi = \beta_1 + \beta_2 x_{2i} + \beta_3 X_{3i} + \ldots\ldots + \beta_k X_{ki} + U_i$$

where $i = 1, 2, \ldots\ldots\ldots$

The n equations above could be written in the following Matrix form as :

$$Y = X\beta + U$$

where $Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}$ $\quad X = \begin{bmatrix} 1 & X_{21} & X_{31} & \ldots\ldots & X_{k1} \\ 1 & X_{22} & X_{32} & \ldots\ldots & X_{k2} \\ 1 & X_{2n} & X_{3n} & \ldots\ldots & X_{kn} \end{bmatrix}$

$\beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_k \end{bmatrix}$ and $V = \begin{bmatrix} U_1 \\ V_2 \\ U_k \end{bmatrix}$

Since B_1, i.e. the intercept of the above linear equation does not have any variable, units have been inserted in the first column of X. So far as other columns of X are concerned, n values of K-1 independent variables are observed.

The real values of B coefficients cannot be found out because of the error term which remains unknown and because of several limitations in our data. However, the estimated B co-efficients can be worked out with the help of the principles of least squares under the following four assumptions P for the error term U.

1. - Mean of the error term i.e. U = 0
2. Each error term is independent of itself.
3. Variance of U is always constant.
4. All the independent variables do not have linear relationship among themselves.

For establishing the above multivariate relationship between the agro-climatic factors and productivity of the HYV of rice in the region the community Development Blocks have been taken as the unit area of study. There are forty three Community Development Blocks in the region. The data for all the blocks was taken. from the Yield Estimation Survey of HYV sali rice conducted by the Directorate of agriculture, Government of Assam for the year 1977-78. The survey is based on a crop cutting experiment conducted in many sample villages of these blocks. So, the actual yield rate has been observed in every 25 sq. metre plots. The per hectare yield has been calculated with the help of the observed yields from at least two experimental plots of a village. After having calculated the per hectare yield, the average yield of HYV rice for every block has been determined taking the villages in that block into account.

The Agro-climatic variables chosen for the study are:

(i) Soil nutrient index,
(ii) Soil texture index,
(iii) Soil pH index,
(iv) Rainfall in mm,
(v) Temperature in ^{o}C, and
(vi) Air relative humidity in terms of percentage etc.

The method of preparation of soil indices has been discussed in Chapter-II.. But the climatic parametres have been considered for the year 1977-78 only. Since the transplantation and harvest of early Ahu and Sali rice range between May and December, average monthly values of rainfall, temperature and humidity have been considered only for this particular period. (Fig. showing the super imposition of isohyte, isotherm and per hectare yield of HYV rice for 1977-78). Another limitation in using these parameters is that the average monthly values of climatic variables from May to November have been taken as the same for the surrounding blocks for a particular Rainfall Recording Station because such data is not available for all the sample unit. For certain blocks, therefore, these values are taken with the help of interpolation technique where its difficult to find out the exact situation of these variables.

The calculation for the Multi-variate Linear Regression analysis has been done with the help of micro-computer of the Department (1121). After having the regression coefficients, and the statistical constant i.e. the interest of the equation the estimated yield rate for every block is found out. And finally the residuals have been calculated by substracting the estimated yield rates from the observed one's for every block taken into consideration in the model.

It has been presumed that there is a substantial difference in yield rate between the local traditional varieties and high yielding varieties and within the high yielding varieties, the productivity differs as per the different systems of cultivation practices such as package, non-package and partial package. Here, the average performance of HYV rice in terms of productivity in kg. per hectare, obtained from the said systems of practices has been taken into consideration. Therefore the regression analysis has been applied for three kinds of performance of rice in separate taking the unit area for the first two models as subdivisions and the last one as blocks in order to have a comparative picture of

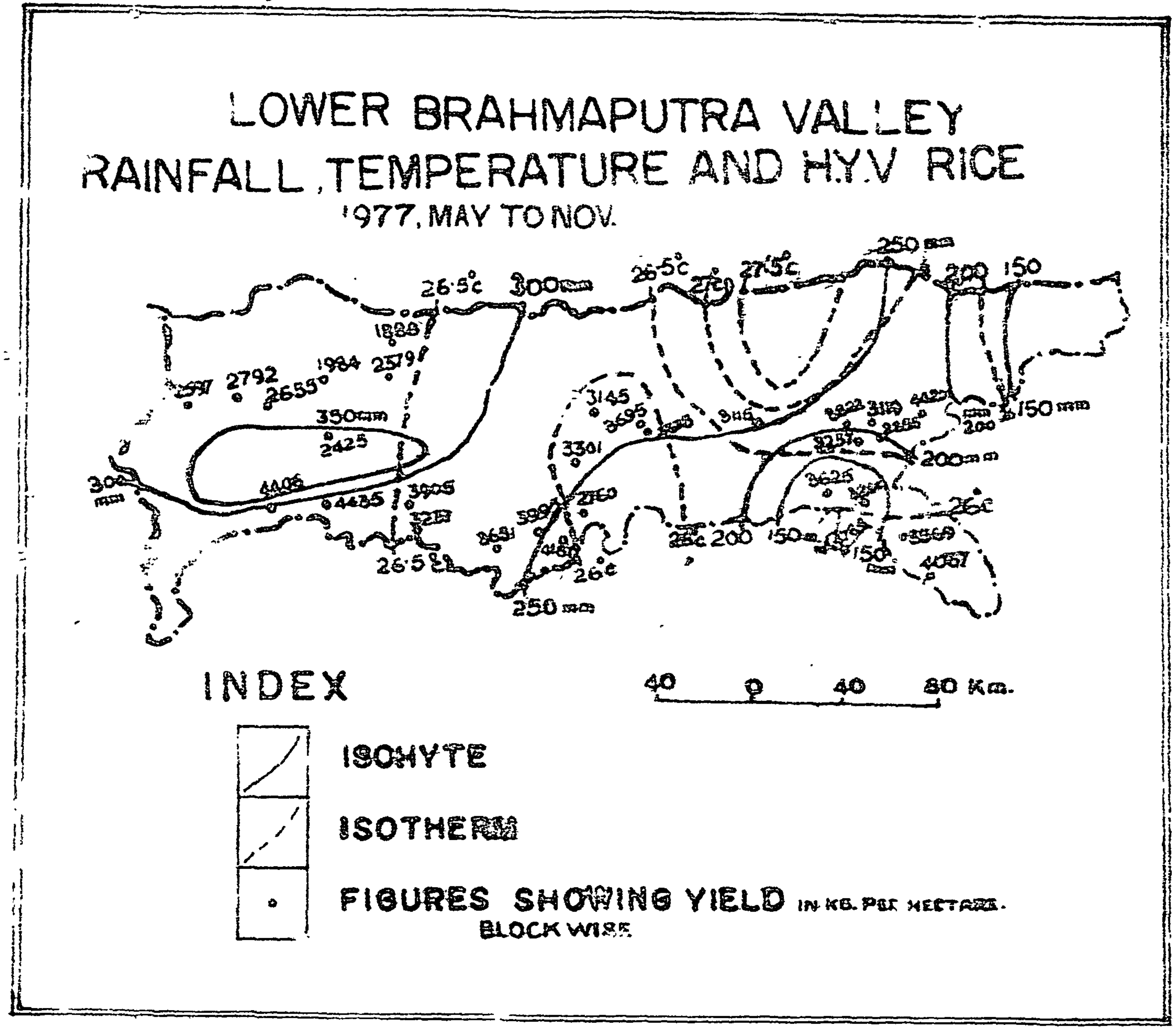
LOWER BRAHMAPUTRA VALLEY
RAINFALL, TEMPERATURE AND H.Y.V RICE
1977, MAY TO NOV.
26·5°c
300mm
26·5°c
27°c
27·5°c
250 mm
200
150
1888
1984
2579
2792
2655
350mm
2425
4406
4435
3905
26·5°c
300 mm
3145
3695
3301
250 mm
26°c
200
150 mm
200 mm
26°c
3625
4067
INDEX
40 0 40 80 Km.
ISOHYTE
ISOTHERM
FIGURES SHOWING YIELD IN KG. PER HECTARE.
BLOCK WISE

Fig. 14

the impact of the soil temperature and rainfall variables on the per hectare productivity according to the size of the unit area as well as the main varietal difference.

Finally the step-wise regression analysis has been applied for the high yielding varieties in general with the set objective to know the impact of each additional variable one after another in explaining the over all productivity variation.

Since some transformation in the boundaries of the Community Development Block was in progress and the author could not succeed in obtaining a map showing the Blockwise picture of the area, the figures relating to the per hectare yield have been shown on the approximate location of the blocks and the thematic maps concerning the soil nutrient indices have been prepared with the help of simple circles of varying sizes. The location of few blocks have not been identified because of inadequacy in the availability of authentic maps. The analysis breaks up from subdivision to block level as follows:

Regression Analysis for

- Subdivisionwise performance of Traditional varieties of rice
- Subdivisionwise and Blockwise performance of HYV rice

<u>Analysis</u> :

Having a look at the results obtained out the multiple regression analysis for the subdivisions, Dhubri, Goalpara, Gauhati Kokrajhar, Marigaon and Nowgong, it is noticed that the average productivity of the local traditional varieties of rice comes out to be 858.833 kg. per hectare which has been further hypothetically considered as a dependent phenomenon on the physical variables such as soil nutrient index, texture index, pH index, rainfall, temperature and relative humidity, for which the average quantitatively assessed values are 6.473, 1.96, 2.701, 171.472, 24.58 and 84.173 respectively. Taking all the variables together including the per hectare productivity, the following inter correlation matrix emerges showing the bivariate relationship between the variables.

TABLE - XXXXXIII

Matrix of Inter Correlation

x_1	x_2	x_3	x_4	x_5	x_6	Y
1	0.181	0.057	0.755	0.095	0.454	-0.082
	1	-0.773	0.048	-0.538	0.089	-0.824
		1	0.312	0.196	-0.078	0.417
			1	-0. 36	0.337	-0.131
				1	-0.229	0. 51
					1	0. 37
						1

Coming over to the question of significance and insignificance correlation coefficient values, it will be seen that the above properties could always be compared with the tabulated 't' values* after having found out the same with the help of the following formula.

$$t = r \frac{n - 2}{1 - r^2} \text{ , for } n - 2 \text{ d.f}$$

where r = Correlation coefficient

n = No of observation.

Since the present study is based on six observations and seven variables, most of the correlation coefficients are coming insignificant at either directions positive and negative at 5 per cent and 1 percent level of significance. Positive correlation is

* t values at $\frac{0.05}{2.78}$ $\frac{0.01}{4.6}$ $\frac{0.5}{.741}$ $\frac{0.1}{2.13}$ tabulated

found between soil nutrient index and texture index, rainfall between pH index and rainfall, temperature and per hectare yield of HYV rice, between rainfall and temperature, between temperature and yield and finally between relative humidity and yield.

Amongst all the above positively correlated variables none of the pairs is found having a positive and significant correlation coefficient at 5 percent and 1 percent level of significance. But at 10 percent level nutrient index and rainfall have a significant relationship, for which the correlation coefficient is 0.755. The reason is attributed to the terrain condition where water logging persists and on the other hand the water helps increase the process of decomposition of the organic materials inside the soil. Very significant or no correlation exists between Nutrient index and Soil^{pH}, air temperature, between texture index and rainfall, humidity since the coefficient of correlation are less than 0.1 i.e. approaching 0.0. All other positively correlated variables are though having the coefficients more than 0.1, nevertheless they stand nowhere, as far as the different levels of significances are concerned. The reason might be due to less number of observations and could be proved when our number of observations are fairly more in case of block level study than the present case.

Few negative coefficients of correlations are also observed between soil nutrients index and yield rate, between texture and pH index temperature, and yield and between p^{H} and humidity, between rainfall and temperature and yield and finally between temperature and humidity. But the negative correlation between nutrient index and yield rate seems to be very insignificant as evident from the r value which is less than -0.1. Though these two variables have a negative trend in relationship, still it could be infered that there seems to be no relationship between them. Similar relationship having negative trend but the r values approaching 0, is observed between p^H and humidity. Excepting these two paired variables, all others are having fairly negative correlation coefficients among which texture index and p^H index are having significant correlation at 10 percent level of significance. The correlation coefficient between soil texture and air temperature also shows a negative trend which is significant only at 50 percent level and insignificant at all other. But very high negative correlation is observed between soil texture and per hectare yield which is also significant both at 5 percent and 1 percent levels of significance. This is because of the medium textured soil which is not very much favourable for a better yield. Hence as the index goes on increasing, the yield rate goes on decreasing. This type of soils have a low soil moisture retaintion capacity, hence less amount of nutrition and so on. The yield rate shows a negative relationship with texture index and rainfall but with pH index it is positive and significant at 50 percent level and insignificant at all other. It is also positively correlated with temperature and humidity However in both these cases, the 'r' values are significant at 50 percent level and insignificant at all others.

In case of traditional varieties of rice the climatic parameters had been taken such as mean monthly rainfall for the period 1974-77, average monthly daily temperature 1931-60 and humidity for 1974-77. But for subdivisionwise performance of high yielding varieties, mean monthly climatic parameters from May to November have been taken into consideration for the year 1977-78 only, since the experimental study of Sali (HYV) rice was conducted for the same year. The matrix of inter-correlation between the variables and the regression coefficient are given below.

TABLE - XXXXXIV

Matrix of Inter Correlation

X_1	X_2	X_3	X_4	X_5	X_6	Y
1	0.27	0.041	0.176	0.476	0.576	0.388
	1	-0. 77	0. 84	0.717	0.478	0.065
		1	-0. 60	-0.237	-0.175	-0.238
			1	0. 83	0. 68	-0.427
				1	0.879	-0. 34
					1	-0.276
						1

Regression coefficients

X_1	468.0
X_2	513.36
X_3	-744.6
X_4	-1.51
X_5	-12.75
X_6	4.99

The positive correlation coefficient is found between soil nutrient index and texture index, rainfall, temperature humidity, per hectare yield, between texture index and rainfall, temperature humidity and between rainfall and temperature and humidity and between temperature and humidity. Among these positively correlated paired variables, the correlation coefficients between soil texture and rainfall, rainfall and temperature, and temperature and humidity are significant both at 1 percent and 5 percent levels of significance. All other pairs are having positive correlations and that too, very insignificant. There are eight pairs of variables such as texture index and pH index, pH index and rainfall, pH and temperature, pH and humidity, pH and yield rainfall and yield, temperature and yield and humidity and yield which are having negative correlationship between them. Among them texture index and pH are having very high negative correlation coefficient and significant at 10 percent level of significance.

Coming over to the estimated value of the per hectare productivity of HYV in the subdivisions of Dhubri, Goalpara, Gauhati, Kokrajhar, Marigaon and Nowgong, one could see that the observed productivity in the said subdivisions is more or less same as the estimated hence the basic residuals for each areal unit approaches zero. Here the residuals as meaningful indicators suggest that in subdivision level, the positive factors are more relatively spectacular than the negative, showing the productivity equal to or slightly less than the average.

It could be more meaningful in explaining the impact of positive and negative factors on the per hectare productivity of rice, if the subdivisions are further disintegrated into micro areas. In the present case community development blocks have been presumed as the unit area of study.

For a micro level study concerning the impact of agro-climatic environment on the productivity of High Yielding Varieties of rice in the lower Brahmaputra Valley, 33 community development blocks have been taken into consideration. The variables chosen earlier in case of subdivisional level study are same as here. Since the central theme of this sort of studies is to predict the dependent variable in terms of its estimated value with the help of several independent factors, here though more emphasis has been laid on the relationship between the dependent variable i.e. yield and several independent factors, nevertheless it is felt worthwhile to discuss in detail how strong the inter-relationship of all the variables among themselves.

The average values of the variables are 6.795, 1.795, 2.776, 400.305, 26.33, 86.79 and 3418.121 for soil nutrient index, texture index, soil reaction or pH index, rainfall, temperature humidity and per hectare yield of HYV rice respectively.

Here, the per hectare output of HYV rice has been calculated as the average of the package and non-package system of the practices of cultivation. In package practice, HYV rice is grown with the application of fertilizers, pesticides, insecticides and controlled and timely water supply. So the yields obtained with package programme and without it have been averaged out in order to see the influence of soil and climatic condition on the productivity. However, the relationship between the yield and the agro-climatic variables has got to be highlighted rather than the same among themselves. The following tables present the matrix of inter-correlation of the variables and the regression coefficients.

TABLE - XXXXXV

Matrix of inter-correlation

X_1	X_2	X_3	X_4	X_5	X_6	Y
1.00	0.087	0.083	0.428	0.558	0.261	-0.155
	1.00	-0.2	0.388	0.343	-0.248	-0.207
		1.00	0.237	0.197	0.208	-0.090
			1.00	0.740	0.382	-0.387
				1.00	0.409	-0.501
					1.00	-0.219
						1.00

Regression coefficients

X_1	240.63
X_2	13.34
X_3	126.65
X_4	-1.36
X_5	-2671.03
X_6	-12.99

At a glance to the correlation Matrix it is vivid that the individual physical variables have all got negative relationship with the yield and that too there seems to be no relationship between the index of soil reaction or p^H and yield the correlation co-efficient being 0.090. So far as the relationship between all other variables and the yield is concerned, rainfall and yield have negative and significant relationship. The reason might be attributed to undesired amount of rainfall which adversely affect the yield, since HYV rice needs a very controlled and timely irrigation. The correlation coefficient is tested to be significamt both at 5 percent and 1 percent level of significance. The relationship between temperature and yield is also found to be very significant both at 5 percent and 1 percent levels of significance in a negative direction. Meaning thereby there is an adverse effect on the per hectare yield of HYV if the air temperature rises beyond 25^{o}C which has been discussed in the introductory chapter. Therefore the air temperature stands as an unfavourable factor for the growth of HYV rice plants in the valley. Though the correlation coefficient between the atmospheric relative humidity and the yield is found negative and -0.219, it is significant only at 50 percent and insignificant at all other levels the relationship is insignificant. The reason could be the prolonged persistence of higher percentage of humidity in the air which is sometimes unfavourable for rice growth. Soil nutrient index and yield are also negatively correlated, it is significant at 50 percent level. The reason is that the process of decomposition of organic materials, available phosphorous and pottassium in water logged areas are more prominent and undesired for high yielding varieties growth, thereby a negatively affecting the grain yield. Soil texture is also negatively correlated with the grainyield of HYV rice. The soil texture is found to be medium in category which is sandy loam and loamy in a very wider scale. This sort of soils do not have got moisture retaining capacity for natural nutrition development process and would have been favourable for better yield of the plants had it been clayey soil widely. The 'r' value is insignificant at all other excepting the 50 percent level.

Results of the correlation coefficient between the soil and climatic variables show that, positive correlation exists between almost all the pairs of the six variables excepting the pairs nutrient index and pH and texture which have, though got negative and positive trend respectively in their relationship, still, there seems to be no relationship as evident from the 'r' value, approaching zero. But significant positive correlation exists between nutrient index and rainfall only at 5 percent level of significance between nutrient index and temperature at both 5 percent and 1 percent level, between texture index and temperature at 10 percent level, between rainfall and temperature at 5 percent and 1 percent level, between rainfall and humidity at 10 percent level and finally between temperature and humidity at 2 percent level. So the reasons for such relationship are obvious for the above paired variables.

Switching over to the estimated values of the dependent variable i.e. yield, prominent differences are marked when compared with the observed yield per hectare. It is further noticed that the estimated yield rates for a good number of blocks are more than that of the observed. Therefore, clear picture emerges when the basic residuals are calculated in order to sort out the areas having positive as well as negative residuals for a better explanation of the favourable and adverse impact of the physical determinants on yield estimation.

Basic residuals are the difference between the observed and the estimated values of the dependent variables and may be either positive or negative values. So (Y - Y) gives the basic residual, where Y is the observed value and Y is the estimated value. Since the residual maps are very useful in formulating hypothesis, under certain circumstances, the spatial pattern of these residuals helps compare other spatial pattern of phenomena with it provided they occur in obsolute values.

The residuals calculated reveal that the positive basic residuals vary between 1.085 and 1658.79 for the blocks of Kamalpur and Mayang as the lowest and highest respectively. Similarly the negative residuals have a variation between -105.34 and -1188.37 for the blocks of Dadhndi and Sidli respectively. Negative residuals as evident from table - (in the appendix -) are more in number than the positive. As many as 20 blocks have negative residual and that of the rest 13 have positive. Out of 13 blocks having positive residuals 8 and 3 come within medium and high da ss group respectively. The rest 2 have very high positive residuals which exceed two lines the standard error of estimates.

The standard error of the estimated* has been used here in classifying the residuals in different categories. With the presumption that the distribution of residuals are normal and using the properties of normal distribution the residuals have been divided into six categories as,

0 to 1 standard error of estimate

+ 1 SE to + 2 S.E.

+ 2 S.E. and above

0 to -1 S.E.

- 1 S.E. to - 2 S.E.

-2 S.E. and less than that.

when the residuals show more than 2 S.E., they should be dropped out of the analysis, since some serious abnormality might be there in the observations.

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* Standard error of estimates

$$= \sqrt{\frac{(Y - Y)^2}{n - 1}}$$

The following frequency tables present the different categories of basic residuals.

TABLE - XXXXXVI

Frequency table showing positive negative Residuals

Class group	Frequency	Categories
0 -742.16	8	Medium Positive
742.16-1484.32	3	High Positive
1484.32 +	2	Very High Positive
Total	13	

TABLE - XXXXXVII

Class group	Frequency	Categories
0 - -742.16	16	Medium negative
-742.16 - -1484.32	4	High negative
-1484.32	0	Very high Negative
Total	20	

From the above tables it is distinct that the role of positive factors which generally determine more than the average per hectare productivity is less significant than the negative. In the lower Brahmaputra valley negative factors dominate thereby causing lower yield in kg. per hectare for the high yielding varieties of rice. In the frequency table, showing the blocks of negative residuals it is noticed that four blocks are coming under the high negative residual group. As many as 16 blocks are within the medium negative group. The name of all the blocks having positive and negative residuals has been mentioned in Table - Appendix - .

Stepwise Regression Analysis:

While attempting a multiple regression analysis, it is useful to know how the parameters change in adding the new variables one after another. This statistical procedure is known as step-wise regression analysis and is helpful in several ways.

It highlights the contribution of an added variable in explaining the dependent variable with the help of the changing R^2 i.e. the coefficient of determination in every step. It tells whether the new variable is worth considering in the modeal or not. It also helps in knowing the changes in the values of regression coefficients.

In order to explain the productivity of High Yielding Varieties of rice in lower Brahmaputra Valley the variables chosen are same as in the multiple regression analysis.

The results of the stepwise regression analysis are given below:

TABLE - XXXXXVIII

Variables	Regression Coefficients	R^2	R^2x100	Increase in R^2
Step 1				
X_1	- 187.92	0.020	2	-
Step 2				
X_1	- 167.16	0.025	2.5	0.005
X_2	- 373.20			
Step 3				
X_1	- 179.12			
X_2	- 428.42	0.028	2.8	0.003
X_3	- 340.94			
Step 4				
X_1	1.01	0.030	3	0.002
X_2	- 146.61			
X_3	- 51.68			
X_4	- 1.06			

Contd..

Contd...

Variables	Regression coefficients	R^2	R^2x100	Increase in R^2
Step 5				
X_1	164.55	0.070	7	0.04
X_2	31.18			
X_3	27.74			
X_4	- 3.14			
X_5	-2620.81			
Step 6				
X_1	240.63	0.12	12	0.05
X_2	-13.34			
X_3	126.65			
X_4	- 1.36			
X_5	-2671.03			
X_6	-12.99			

A glance at the above table reveals that the soil variables such as nutrient index, texture index and pH index and rainfall together explain only 3 percent of variation in the productivity of HYV rice. Out of this proportion, nutrient index alone explains 2 percent as evident from the R^2 value mentioned in the above table. Therefore the contribution of soil texture, pH and rainfall appears to be very insignificant in explaining the dependent variable. The value of R^2 is observed to have gone up to 0.07 in the fifth step of the analysis where temperature has been taken as an added variable. Hence a net increase of 0.04 in R^2 is because of the additional variable temperature. Switching over to the 6th step of the analysis, it is noted that the explanatory power of all the variables has reached only 0.12, when the last variable air relative humidity was added. In the sixth step there has been an increasing of 0.05 in R^2 i.e. 5 percent. However it can be concluded that the variables appear to be inefficient in explaining the variations of productivity of HYV rice in lower Brahmaputra Valley. Out of the above variables only few of them should be chosen for best fit in the model. Moreover, these selected variables would give better explanation.

CHAPTER - VII

FINDINGS AND SUGGESTIONS

In the present study an attempt has been made to analyse the spatial patterns of the High Yielding Varieties of rice in the Lower Brahmaputra Valley to ascertain the influence of agro-climatic indicators on their diffusion, distribution and productivity. Scientific data available for the study, especially at the micro-level, is however, inadequate and the problem gets accentuated when one starts probing at a more detailed unit level. The work is however, based mainly on secondary data and information gathered during the field work by the author.

In the first part of the dissertation a general physical setup of the area - the Lower Brahmaputra Valley, has been made giving the geology, structure, rainfall and its variability, soils, their textural properties and pH values with a set objective to correlate them with the productivity pattern of the High Yielding Varieties in the region. This part concentrates with the environmental requirements and adaptation of rice in general and the recently introduced high yielding varieties in particular. Since different varieties of rice have different adaptability to their surroundings, a general discussion over the physiological process and varietal characteristics of High Yielding Varieties in relation to various factors of climate and soil have also been probed into.

So far as the physical landscape of the region is concerned it is unique, covered by the new and old alluvium, deposited by the Brahmaputra and its numerous tributaries. Throughout the region, right from the upper most part of the valley in the east down to Dhubri in the west where the valley terminates; and from the northern flank up to the southern limits, there are spectacular differences in the drainage network, vegetation coverage, rainfall amount and reliability, soil nutrients and consequently after every ten kilometers the agro-climatic set up imperceptably changes. The valley is well drained by the Brahmaputra and its tributaries which in the rainy season inundated the neighbouring areas, endangering the agricultural landscape and damaging the kharif crops, partly or fully. The valley is also dominated by such features as alluvial fans, levees and char etc.

After giving a systematic account of the physical setting the valley has been divided into three macro-regions - such as the tropical humid region (the upper parts of the valley); the sub-tropical dry (the central parts of the valley); and the subtropical humid (the lower parts of the valley). The region selected for study, being situated in the high rainfall zone of the country experiences very effective rainfall especially in the summer monsoon season. There are micro-level variations in the variability of rainfall which varies significantly from season to season and month to month. Within the season of general rains (Kharif season) the rainfall variability is more in June and September i.e. at the onset and ending parts of the summer monsoon. Such fluctuations in the amount of rainfall, often than never leads to floods in the region and result into crop damage. In general the eastern and western parts of the area are more wet which reflects in the high degree of rainfall reliability in these parts.

The soil nuitrients, texture and moisture retaining capacity have also been examined carefully with the help of secondary data obtained from the Regional Soil Laboratories and it has been found that the organic matters and humus contents of the soils decrease from west to east, following almost the rainfall distributional patterns i.e. wet areas having more humus as compared to the relatively drier parts. As a matter of fact the organic matters get decomposed under more humid and warm conditions with ease and at a faster rate. The proportion of sand also increases in the alluvial soil of the region going west to east ward. The soil reaction (pH value) however, does not show any significant variation in the different blocks of the valley.

Arriving at the cropping patterns of rice in general and the High Yielding Varieties in particular it has been found that though rice in the dominant crop of the region occupying at least sixty percent of the total cropped area in each of the component areal units (except Barpeta) and being sown upto 90 percent of the gross cropped land in some of the blocks, its density pattens reveal striking spatial variations. The study also reveals that rice is predominantly grown in the Kharif season when the agro-climatic conditions are probably ideal for its cultivation. It is more extensively grown in the proximal and peripheral subdivisions and blocks of the Brahmaputra river in the area of study. The area occupied by rice and its High Yielding Varieties is more in the Kharif season in which heavy amounts of rainfall are recorded. The Kharif concentration of the crop trends to reveal the average picture of rice cultivation. In many of the areal units rice cultivation during the rabi season is absent or insignificant.

Area devoted to High Yielding Varieties in each of the component areal units and the physico-socio-economic factors responsible for their diffusion and performance have also been analysed which show that the performance of the High Yielding Varieties - both at the farm and the block levels have not shown optimistic and satisfactory results. Inspite of the fact that the productivity of the new varieties is more than double in comparison to the indigenous and traditional varieties but when the economy of the crop is taken into account, especially the cost of inputs, the returns are hardly rewarding and in many cases uneconomic. The causes for such a situation may be physical and social which need more research and investigations.

To correlate the productivity of the High Yielding Varieties with the agro-climatic parametres of the region a multi-variate analysis has been made. The multivariate analysis highlights: (1) the inter-relations between the agro-climatic variables, (2) the correlation between the yield and every individual variable, (3) the multiple correlations within all the variables and (4) the prediction of the yield with the help of all the agro-climatic indicators.

About the correlation coefficients between the agro-climatic variables in the region, it is observed that significant positive correlation exists between soil nutrient index and rainfall at 2 percent level of significance. Nutrient index and temperature are also found to be highly and positively correlated at 1 percent level of significance. There is positive but less significant correlation between nutrient index and air relative humidity. This is found to be significant only at 50 percent level. Soil texture and pH values have come out to be negatively correlated only at 50 percent level. Soil texture and rainfall are positively correlated and found significant at 50 percent level. Soil texture and temperature have positive correlation at 10 percent level of significance. But soil texture has a negative correlation with air relative humidity though significant only at 50 percent level. Soil pH and rainfall are found to be having positive correlation but insig-

insignificant at all the levels excepting 50 percent. Soil pH and temperature are also positively correlated but significant at 50 percent level only. A similar positive correlation exists between soil pH and relative humidity, but significant at 50 per cent level only. The most significant and high positive correlation exists between rainfall and temperature, the correlation co-efficient being 0.741 and statistically significant at 1 percent level of significance. Rainfall and humidity are also found to be having positive correlation and significant at 5 percent level of significance. Finally, temperature and humidity are found to be positively and highly correlated and the significance level is 2 percent.

The correlation co-efficients between every individual independent variable and the dependent variable i.e. productivity of the HYV of rice reveals that the relationship between the per hectare yield of HYV rice and the physical indicators in the lower Brahmaputra valley is found to be negative in every case. And that too insignificant positive correlations exist between yield and soil nutrients, yield and soil pH (tend to no correlation), yield and relative humidity. All the above paired variables except yield and soil pH have correlation coefficients which are significant only at the 50 percent level. Significant negative correlation however, exists between rainfall and yields of HYV rice and the significance level is 5 percent. Similarly temperature and per hectare yield are also highly and negatively correlated at 1 percent level of significance and 99 percent level of confidence. Taking all the variables together into consideration the multiple correlation coefficient comes out to be positive but insignificant at all other levels except 50 percent.

Out of the analysis concerning the subdivisionwise per hectare yield of traditional and HYV rice and the agro-climatic determinants a very interesting picture emerges out. In the case of traditional varieties, there seems to be no correlation between the soil nutrient index and per hectare yield. There is high negative correlation between per hectare yield and soil texture and significant at 1 percent level. Soil pH and yield of local varieties of rice have positive correlation which is significant only at 50 percent level.

Rainfall again appears to be unfavourable for better yield of local varieties because of the negative correlation among themselves which is though very insignificant. The yield relation between temperature and relative humidity though positive but significant only at 50 percent level.

In case of HYV of rice at subdivision level, it is found that excepting nutrient index all other variables are negatively correlated with the per hectare yield and that too at 50 percent level only.

With the help of the multiple regression analysis the perhectare yields for every community development block has been predicted. The estimated yields per hectare reveals increase in yields in many cases than a real decrease. After having found out the estimated yields the residual analysis has been done and it is further seen, that negative residuals are more dominant than positive because of the unfavourable climatic and soil conditions.

The step-wise regression analysis which enable to express the change in explanatory power of the independent variables in explaining the dependent with the help of every additional variables in the model. It has been concluded that as the variables are added one by one in the model the explanatory power of the variables starts increasing. But the increase is observed to be very low. The co-efficient of determination R^2 shows an upward trend from 0.02 to 0.12 from step 1 to step 6 respectively. Therefore contribution of the variables in explaining the productivity is very low. The explanatory power of the variables as evident from R^2 has gone up from 0.02 to 0.03 percent till the 4th step. But when the fifth variable i.e. the temperature was added the R^2 again went up to 0.07 i.e. 7 percent. And it started having upward trend in explaining the yield variation till the last and the sixth variable i.e. air relative humidity was added. Hence all the six variables together explain only 12 percent variation R^2 being 0.12. However it is very distinct that the variables chosen seem to be very inefficient in explaining the dependent variable.

The final and sixth chapter of the dissertation deals with an analysis of variance of mean yield rates of different specific varieties of HYV rice grown in various parts of the valley. As per the results of the analysis some particular varieties such as, Pusa-33, Pusa 2-21, IR-8 and Jaya were found favourable for cultivation under both dry and rainfed condition. However, Pusa-33 has been found as the most suitable which gives satisfactory response in both dry and rainfed condition. In case of Pusa-33 the yield variation is observed to be insignificant both due to fertilizer dozes and space variation. Hence, this variety could be successfully grown with adequate care and inputs.

Although there are speculations on the diffusion, spread and performance of the HYV of rice in the Lower Brahmaputra Valley the study reveals that the region is lacking behind in the productivity of rice. On the basis of multi-variate analysis made in the present venture the author ascertained that the region has the ecological set up, conducive for the cultivation of HYV of rice and their diffusion has therefore great scope. In order to obtain the desired results more research is however, to be done both in the agro-climatic set up and cultural melieu of the region on the one hand and the physiology of the new varieties of rice on the other. The following suggestions in the opinion of the author will go a long way in popularising the HYV and in raising their productivity in the highly fertile and extensively cultivated tract of the Lower Brahmaputra Valley.

In the analysis of agro-climatic indicators it was found that the data about temperature, rainfall, relative humidity, sunshine and cloudiness is highly inadequate. The HYV are highly sensitive to those weather elements, especially at the flowering and grain formation periods and in the absence of adequate meteorological informations which keeps the farmer guessing the weather conditions, probably affects the outturns adversely. Installation of more meteorological and rainfall recording stations is therefore a pre-requisite for the success of HYV of rice. Such climatic data will help in making timely and more reliable weather forcasts enabling the farmers to adjust and regularise their agricultural operations accordingly. A similar point is observed about the properties of soils. The soil regional laboratories got enough data but the informations need to be plotted on large scale maps and explained to the respective farmers so that they may apply the deficient components of soil nutrients in the right proportion. Though the task is expensive and needs careful planning but looking at the food requirements of the tremendously increasing population of the region and the country, such steps cannot be delayed for long.

The diffusion of HYV of rice in the region inspite of their unsatisfactory performance is imperative as they have several advantages over the traditional varieties. The HYV permit shorter cropping cycles and thereby, enables the farmer to economize on water. In fact the HYV require less amount of water per unit of output. The short cycles of cropping permit multiple cropping and thus in effect economize on land. The HYV under optimal conditions utilize more labour, keeping the farmers busy in different agricultural operations throughout the year, thereby increasing farm and ultimately rural employment. The new varieties are land substituting and more labour using innovation. They are also neutral to the scale and therefore usable by small and big farmers alike. But the study shows that there is inter-block, intra-block, inter-tenancy inter-soil and inter field variations in the productivity of rice moving from the more wet district of the west (Goalpara) to the relatively dry districts of the east (Nowgong and Kamrup).

The soil analysis shows that humus contents in the soil of Nowgong and Kamrup are deficient. With the help of more manures the fertility and productivity of these districts can, appreciably increase the productivity of rice in the region.

From the study made the author arrived at the result that it is not the total amount of rainfall but its timely distribution over the different phases of crop growth which determines the total output. The chemical fertilizers which are costly inputs cannot be used with confidence by the farmers especially in the Ahu rice crop during the winter season when the weather is clear, cool and rainless. The winter rice crop in the region could be ideally grown if provisions for controlled irrigation through canals, tanks, wells and tube-wells could be made. The first irrigation around the third week of sowing alone raises yield by as much as 30 per cent than when it is delayed. In fact for rice lack of moisture in the primor dial initiation, flowering and milk stage can reduce yield to the extent of 50 percent.* Without irrigation a surfiet of other inputs would therefore be of no avail. If the required five to six irrigation could be made available to the winter rice crop at the critical stages of plant growth, e.g. tilling, grain formation and grain filling the production can be increased significantly. The author therefore has a strong conviction that more area with the help of artificial irrigation should be brought under HYV of rice especially in the winter season.

As the HYV do not thrive well in the waterlogged and heavy rainfall areas, they should therefore should not be grown in such areas especially in the season of general rains. In the district of Goalpara which records over 200 cum of rainfall annually and often subjected to floods and waterlogging, such variations by grown in selected land well drained areas. Since the HYV of rice requires costly inputs the farmers who want to adopt them must have operational capital to purchase seeds, fertilizers, insecticides, pesticides, weedicides and spraying and other equipments. Most of the farmers of the Lower Brahmaputra Valley particularly the smaller ones have no surplus over consumption and therefore no operational capital at their disposal. The agrarian institutions like banks and co-operative societies have great responsibilities of judicious advancement of loans to all farmers irrespective of the size of their holdings and status in the society. It has been found that the credit agencies in the region, serve the larger, politically powerful and economically well-off farmers. Consequently the poor

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* Sen, B, 1974 - The Green Revolution - India, New Delhi pp 26-27.

farmers are being deprived of adequate inputs, so essential for the success of HYV. Some standard and impartial mechanisation is therefore to be evolved to reduce the difference of diffusion and production of these varieties - the lands of the big and the small farmers.

Apart from financial aspect the extension machinary should be most extensive and efficient. The optimum use of inputs can be made only if proper supervision to the cultivators is available, which depends on the type of extension machinary evolved and the personal employed. There should be a perfect co-ordination between farmers, extension agents, farm supervisors, technologists, researchers, planners and administrators. Any slackness in the co-ordination especially the research and diffusion of innovations may further retard the progress towards the adoption of HYV in the region and the progress made towards the adoption of new varieties. The diffusion and spread of the HYV of rice for which a resonably good agro-climatic setup is available in the Lower Brahmaputra Valley should not acerbate, social, economic and political tensions in the large farmers and small farmers and the land owners and landless labourers. It is therefore to be seen the diffusion and spread of the High Yielding varieties in the region should not only increase the output but also be a force for development in its widest sense removing the regional inequalities and imbalances.

APPENDICES

TABLE - I

Response of the rice plant to varying temperature at different growth stages.

Growth stage	Critical temperature(°C)			References
	Low	High	Optimum	
Germination	16-19	45	18-40	Chang and Vergara (1971);Nishiyama (1976)
Seedling emergence and establishment	12-35	35	25-30	Nishiyama(1976)
Rooting	16	35	25-28	Nishiyama(1976)
Leaf elongation	7-12	45	31	Nishiyama(1976)
Tillering	9-16	33	25-31	Nishiyama(1976)
Initiation of panicle primordia	15	-	-	Owen(1969,1972a, b)
Panicle differentiation	15-20	30	-	Nishiyama(1976); Satake(1969)
Anthesis	22	35-36	30-33	Poggendorft(1932); Kusanagi and Washio (1974);Sato et al (1973);Tanaka and Wada (1955); Vergara et al (1970)
Ripening	12-18	30	20-29	Nishiyama(1976); Yoshida and Parao (1976)

Source- IRRI Research Paper Series, No-30, July 1978 pp.6

Source - IRRI Research Paper Series, No.30, July 1978 pp.6.

TABLE - II

Total Monthly Rainfall (1931-60)
(in mm)

Stations	Jan.	Feb.	March.	April	May	June	July	Aug.	Sept
Dibrugarh	34.9	60.8	99.8	203.6	356.3	514	516.5	417.7	341.5
Sibsagar	29.7	46.5	94.6	218.2	361.1	390.8	476.3	400.2	301.8
Tejpur	15.1	22.5	55.3	148.7	306.1	296.8	336.3	312.8	236.2
Gauhati	11.4	18.3	53.4	125.9	273.6	293.4	301.5	263.0	190.0
Dhubri	11.2	19.2	45.3	154.2	418.5	644.3	447.7	305.3	331.4
Nowgong	2.3	16.5	8.4	2.3	6.8	90.4	341.6	341.0	168.8
Silchar	14.6	44.7	97	312.5	493.3	605.2	546.5	475.3	378.4

Contd..

Cont....

Stations	October	November	December	Mean monthly rainfall in mm	Mean annual rainfall in mm	Monsoon rainfall percentage in mm (June - Sept.)
Dibrugarh	165.7	27.3	22.3	229.95	2759.4	64.86
Sibsagar	135.5	30.1	19.5	208.69	2504.3	62.66
Tejpur	132.8	22.6	9.2	157.86	1894.4	62.40
Gauhati	90 .1	11.5	5.0	139.43	1673.2	62.63
Dhubri	135.1	11.8	1.2	210.43	2525.2	68.46
Nowgong	29.4	10.0	5.7	86.99	1043.9	90.22
Silchar	207.0	44.0	6.9	268.78	3225.4	62.18

TABLE - III

Lower Brahmaputra Valley - Mean Monthly Temperature 1977

Stations	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Dhubri	17.00	20.35	25.1	23.4	25.7	26.75	28.2	28.7	28.65
Gauhati	16.05	19.65	23.75	23.1	25.25	26.95	28.75	28.45	28.45
Rangia	16.5	19.9	23.75	22.55	25.2	26.55	28.75	28.8	28.0
Majbat	16.4	18.3	22.5	22.55	25.25	26.65	29.2	28.4	28.2
Tezpur	17.95	21.2	25.25	24.5	25.35	27.15	29.6	28.95	29.25
Gohpur	14.55	18.2	20.0	21.85	24.15	26.15	28.4	27.3	29.8
Lumding	16.	18.95	23.85	23.6	25.35	27	28.95	28.85	24.4

Contd......

Conted......

Stations	Oct.	Nov.	Dec.	Mean annual	Average monthly temperature in °C (May to Nov.)
Dhubri	25.05	23.1	-	24.72	26.59
Gauhati	24.4	22.0	18.2	23.75	26.32
Rangia	24.05	22.25	18.85	23.76	26.22
Majbat	24.3	21.2	17.85	23.4	27.60
Tezpur	25.55	21.45	18.45	24.55	26.75
Gohpur	23.6	19.65	16.65	22.36	25.43
Lumding	24.40	21.35	18.6	23.44	25.75

TABLE - IV

Soil Nutrient Index

Blocks	Nutrient index Nitrogen (N)	Nutrient Index Phosphorous (P)	Nutrient Index Potassium (K)
Chhaygaon	2.28 M	1.64 L	1.76 M
Rani	2.48 H	1.58 L	1.73 M
Rampur	2.24 M	1.60 L	2.16 M
Dimoria	2.00 M	1.91 M	2.23 M
Chamaria	2.10 M	1.42 L	1.49 L
Rangia	2.13 M	1.81 M	1.7 M
Karara	1.93 M	1.62 L	1.65 L
Kamalpur	2.07 M	1.83 M	1.51 L
Hazo	2.13 M	1.54 L	1.13 L
Boko	2.51 H	1.64 L	1.51 L
Lakhipur	2.24 M	1. 69 M	1.45 L
Balijana	2.44 H	1.86 M	2.1 M
Dudhnoi	2.54 H	1.73 M	1.72 M
Matia	2.68 H	1.62 L	1.98 M
Srijangram	2.36 H	1.92 M	1.33 L
Boitamari	2.42 H	1 .78 M	1.5 L
Dotama	2.49 H	2.13 M	1.64 L
Kokrajhar	2.95 H	2.06 M	1.11 L
Sidlichirang	2.51 H	2.28 M	1.74 M
Manikpur	1.7 M	2.12 M	1.43 L
Kachhugaon	2.4 H	2.14 M	1.48 L
Gossaigaon	2.4 H	2.14 M	1.48 L
Borobazar	2.4 H	2.14 M	1.48 L
Gauripur	1.87 M	1.08 L	1.95 M
Bilasipara	2.29 M	1 . 7[illegible] M	1.43 L
Chapar	2.29 M	2.03 M	1.5 L
S. South Salmora	3.20 H	1.96 M	1.11 L
Mankachar	2.29 M	1.76 M	1.43 L
Agomoni	2.11 M	2.05 M	1.37 L
Golakgunge	1.98 M	1.69 M	1.26 L
Khagarijan	2.35 H	2.69 M	1.01 L
Jugijan	2.4 H	1.67 L	2.37 H
Rupali	2.02 M	2.05 M	1.30 L
Lanka	1.95 M	1.62 M	1.07 L
Batadraba	2.64 H	2.08 M	1.78 M
Juria	2.06 M	1.8 M	1.00 L
Kaliabar	2.37 H	2.21 M	1.84 M
Kathiatoli	2.14 M	1.89 M	1.18 L
Kaplli	2.35 H	1.78 M	1.15 L
Lawkhowa	1.77 M	2.3 M	1.29 L
Loharighat	1.9 M	1 .78 M	1.07 L
Bhurbandha	1.73 M	1.73 L	1.01 L
Mayang	2.31 M	2.17 M	1.20 L

M = Medium
L = Low
H = High

TABLE – V

Area, Production and Average Yield of Rice in Assam, 1950–51 to 1975–76 with Index Numbers

(Base= 1952–53=100)

Year £	Area		Production		A. Yield	
	Hectares	Index	in Lakh Tonnes	Index	Kg/Ha	Index
1950–51	1492020	80.43	12.75	82.62	855	102.76
1951–52	1783589	96.15	14.12	91.50	793	95 .31
1952–53	1854937	100.00	15.44	100.00	832	100.00
1953–54	1573906	84.85	15.18	98.33	965	115.98
1954–55	1560723	84.14	15.66	101.46	1004	120.67
1955–56	1600827	86.30	15.40	99.79	963	115.74
1956–57	1601940	86.36	16.17	104.78	1010	121.39
1957–58	1593556	85.99	15.37	99.57	965	115.98
1958–59	1690242	91.12	15.89	102.97	941	113.10
1959–60	1696502	91.46	16.67	107.99	983	118.15
1960–61	1716154	92.52	16.33	105.76	968	116.34
1961–62	1755938	94.62	16.48	106.74	985	118.39
1962–63	1777520	95.83	14.76	95.60	956	102.88
1963–64	1754979	94.61	17.54	113.62	1015	121.99
1964–65	1779168	95.92	17.88	115.84	1021	122.71
1965–66	1797546	96.91	17.13	110.96	968	116.34
1966–67	1851815	99.83	1632	105.72	895	107.57
1967–68	1886831	101.72	17.87	115.76	957	115.02
1968–69	1952790	105.28	19.89	128.85	1035	124.40
1969–70	1967598	106.07	19.67	127.42	916	110.09
1970–71	1968370	106.12	19.80	128.22	1022	122.83
1971–72	1967530	106.07	19.08	123.58	985	118.39
1972–73	2068770	111.53	21.77	140.99	1052	126.44
1973–74	2077820	112.02	20.66	133.81	994	119.47
1974–75	2057500	110.92	19.83	128.47	960	115.39
1975–76	2199053	118.55	22.49	145.69	1038	124.76

Source: (1) Estimates of Area and Production of Principal Crops in India, 1950–51 to 1964–65, Directorate of Economics & Statistics, Ministry of Agriculture. Government of India.

(2) Directorate of Economics & Statistics, Government of Assam.

TABLE - VI

Average of Annual Rate of Increase or Decrease in Index Numbers (by periods)

Year	Rice
1951-52 to 1955-56	+ 0.37
1956-57 to 1960-61	+ 1.25
1951-52 to 1960-61	+ 0.81
1961-62 to 1965-66	+ 1.42
1966-67 to 1968-69	+ 5.36
1969-70 to 1975-76	+ 2.05
1950-51 to 1975-76	+ 1.83

TABLE - VII

Annual Linear Growth Rate in Production and Productivity of Rice group in Assam 1950-51 to 1965-76

Crops.	Annual Linear Growth rates of	
	Production	Productivity
Rice	+ 1.58	+ 0.61

TABLE - VIII

Lower Brahmaputra valley - Total Monthly Rainfall, 1977 in mm

Stations	Total	Mean Annual	Monthly Mean (M to N)
Kampur	1294.7	107.89	147.24
Gohpur	1098.2	91.51	29.60
Majbat	2509.9	209.16	288.28
Barpeta	2323.9	193.66	300.15
Gauhati	2209.	184.09	246.57
Tejpur	2141	178.4	239.8
Kokrajhar	2804.7	233.73	338.38
Bilasipara	15480.8	1290.06	1814.4
Dhubri	3349	279.08	199.57
Lumding	-	-	171.5

TABLE - IX

Annual percentage Variation Over Preceding Years in the Index Numbers of Output of Rice in Assam, 1950-51 to 1975-76

Year	Percentage in Index Numbers Rice
1950-51	--
1951-52	+ 1.07
1952-53	+ 0.93
1953-54	- 1.67
1954-55	+ 3.18
1955-56	- 1.64
1956-57	+ 5.00
1957-58	- 4.97
1958-59	+ 3.41
1959-60	+ 4.88
1960-61	- 2.06
1961-62	+ 0.93
1962-63	-10.44
1963-64	+18.85
1964-65	+ 1.95
1965-66	- 4.21
1966-67	- 4.72
1967-68	+ 9.50
1968-69	+11.30
1969-70	- 1.11
1970-71	+ 0.66
1971-72	- 3.65
1972-73	+14.09
1973-74	- 5.09
1974-75	- 5.09
1975-76	+13.41

TABLE - X

Yield-rate of early Ahu (HYV) in kg/ha

(The figures within bracket indicate number of experiment)

Subdivision	Full package	Partial package			Non-package	Pooled
		Fertilizer alone	Irrigation alone	Combined		
1. Dhubri	1585(8)	-	1421(5)	1421(5)	1303(2)	1386(15)
2. Kokrajhar	2231(12)	-	1810(5)	1810(5)	-	2107(17)
3. Goalpara	-	1922(2)	-	1922(2)	-	1922(2)
4. Gauhati	2339(13)	-	1955(18)	1955(18)	1536(8)	1997(39)
5. Nalbari	2254(3)	2238(2)	2089(6)	2203(8)	1974(4)	2152(15)
6. Barpeta	2736(4)	2184(6)	-	2184(6)	1472(7)	2021(17)
7. Nowgong	2080(13)	1915(2)	1546(4)	1667(6)	1373(8)	1779(27)
8. Marigaon	2085(8)	2183(1)	1977(4)	2018(5)	-	2058(13)
9. Mangaldoi	3523(5)	-	1790(20)	1790(10)	-	2367(15)
10. Diphu	-	-	3511(2)	3511(2)	2215(4)	2647(6)
11. Hamren	-	-	-	-	2710(3)	2710(3)
Average	2232(66)	2110(13)	1905(54)	1954(67)	1696(36)	2008(169)

TABLE - XI

SUBDIVISION WISE PERFORMANCE OF HYV TRIALS CONDUCTED AFTER AND BEFORE 30th June 1977-78

Name of the Subdivisions	Yield in kg/ha. after 30th June (Transplantation)	Yield in kg/ha before 30th June	Average yield in kg/ha	Nutrient index	Texture Index	pH index	Mean monthly rainfall in mm (Nov to June)	Temp. in °C	Relative Humidity in percentage	Estimated yield (y)	Basic residual (Y - Y)
Dhubri	2136	1864	2000	6.632	2.956	2.022	1237.675	26.49	88.21	1999.975	.0247
Goalpara	816	1772	1894	6.117	1.967	2.884	784.133	26.47	87.56	1293.971	.0286
Gauhati	2560	2618	2589	6.611	2.16	2.67	246.56	26.27	85.13	2588.966	.0338
Kokrajhar	1852	-	1852	7.235	2.003	2.996	720.481	26.49	88.25	1851.97	.0299
Mariegaon	2286	1360	1823	6.035	1.315	2.805	219.268	26.07	83.92	1822.967	.033
Nowgong	2304	2149	2227	6.709	1.362	2.829	175.187	26.25	87.48	2226.964	.036
Regression coefficients				468.002	513.364	-744.6	-1.516	-12.753	4.993		
Intercept of the regression equation			657.973								

TABLE - XII

SUBDIVISION WISE PERFORMANCE OF TRADITIONAL VARIETIES 1974-77

Name of the subdivision	Yield in kg/ha after 30th june (Transplantation	Yield in kg/ha before 30th June	Average yield in kg/ha	Nutrient index	Texture Index	pH Index	Mean monthly rain-fall in mm (1974-77)	Temp. °C average (1931-60)	Relative Humidity in per centage	Estimated yield (Y)	Basic residual (Y - Y)
Dhubri			829	6.632	2.956	2.022	158.19	24.35	85.33	829.093	.093
Goalpara			860	6.117	1.967	2.884	129.88	24.35	85.00	860.072	.072
Gauhati			810	6.1110	2.16	2.67	139.69	24.6	81.00	810.081	.081
Kokrajhar			845	7.235	2.003	2.996	297.49	24.35	85.16	845.197	.197
Marigaon			905	6.035	1.315	2.805	168.44	24.48	84.33	905.101	.101
Nowgong			904	6.709	1.362	2.889	135.143	25.35	84.22	912.440	8.44
Regression coefficients				-4.307	-74.659	-48.474	-0.028	8.16	11.949		
Intercept of the regression equation			-38.302								

TABLE - XIII

Yield-rate of Regular Ahu(HYV) in kg/ha

The figures within bracket indicate number of experiment

Sub-division	Full-package	Partial package			Non-package	Pooled
		Fertilizer alone	Irrigation alone	Combined		
1. Dhubri	1691(8)	1412(5)	1019(5)	1216(10)	785(2)	1363(2)
2. Kokrajhar	2426(7)	-	1846(10)	1846(10)	1032(4)	1884(21)
3. Goalpara	-	1868(10)	1666(2)	1834(12)	1738(27)	1767(39)
4. Gauhati	2414(21)	2377(3)	2087(17)	2130(20)	1681(32)	2015(73)
5. Nalbari	3329(3)	2685(1)	2007(1)	2082(9)	1937(11)	2175(23)
6. Barpeta	-	2426(6)	-	2426(6)	1512(8)	1903(14)
7. Nowgong	2539(32)	2123(5)	1975(12)	2019(17)	1258(16)	2088(65)
8. Marigaon	2470(8)	2280(1)	2249(6)	2253(7)	1398(5)	2126(20)
9. Mangaldoi	2870(11)	-	2233(11)	2233(11)	1750(5)	2403(27)
10. Diphu	-	-	2502(4)	2502(4)	2306(8)	2371(12)
11. Hamren	-	-	-	-	2389(3)	2389(3)
Average	2486(90)	2032(31)	2002(75)	2011(106)	1664(121)	2013(317)

Table - XIV

AGRO-CLIMATIC VARIABLES AND
ESTIMATED YIELD OF HYV RICE

	Nutrient Index	Texture Index	pH Index	Rainfall in mm.	Temperature in °C	Humidity in pots	Yield in kg/ha (Pack + Nonpack) Average (y)	Estimated Yield (y)	(Y - Y)	
1	2	3	4	5	6	7	8	9	10	
Chhaygaon	6.82	1.997	2.834	246.56	26.27	87.14	3995	3609.38	+391.62	m
Rani	7.03	1.994	2.722	246.56	26.29	85.52	2760	3613.39	-853.392	H
Rampur	6.97	2.0	2.879	246.56	26.29	85.52	4187	3618.759	+568.24	Mi
Dimoria	7.14	2.0	2.763	246.56	26.29	85.52	2666	3644.974	-978.974	Hi
Rangia	6.705	1.99	2.865	246.56	26.22	81.42	3145	3793.588	-648.588	Me
Karara	6.165	2.944	2.03	246.56	26.29	85.52	3695	3304.917	+390.082	Me
Kamalpur	6.445	2.797	2.006	246.56	26.19	82.78	3675	3673.911	+1.085	Me
Hajo	5.865	1.99	2.796	246.56	26.23	85.23	3301	3506.513	-205.513	Me
Boko	6.915	1.995	2.803	246.56	26.32	87.14	3651	3494.79	+156.21	Me
Lakhipur	6.5	1.97	2.943	784.133	2 6.48	88.64	4406	2893.03	+1512.96	Ve
Balijana	7.62	1.993	2.706	784.133	26.49	87.39	4435	3121.74	+1313.26	Hi
Dudhudi	7.26	2.0	2.787	784.133	26.38	87.14	3237	3342.34	-105.34	Me
Matia	7.62	1.989	2.835	784.133	26.49	87.39	3905	3138.13	+766.87	Hi
Boitamari	6.91	1.881	2.713	784.133	26.49	87.39	2425	2953.27	-528.27	Med
Dotoma	7.505	1.991	2.996	784.133	26.49	87.39	2792	3130.83	-338.83	
Kokrajhar	7.595	1.997	3.00	784.133	26.49	89.39	2655	3126.93	-471.93	
Sidli	7.785	2.018	3.00	784.133	26.49	89.39	1984	3172.37	-1188.37	Hig
Manikpur	6.1	2.006	2.988	784.133	26.49	87.39	2379	2791.53	-412.53	Med
Gossaigaon	7.22	2.003	2.996	784.133	26.49	89.39	2597	3036.10	-439.10	
Borobazar	7.22	2.003	2.996	784.133	26.49	87.39	1888	3062.08	-1174.08	Hig
Khagarijan	7.225	1.34	2.95	175.187	26.28	88.18	3119	3699.78	-580.78	Med
Jugijan	7.64	1.05	2.95	175.187	26.28	88.18	3569	3803.52	-234.51	
Rupali	6.38	1.89	2.94	175.187	26.28	88.18	3257	3491.64	-234.64	
Lanka	5.615	1.24	2.83	203.13	25.85	88.99	4067	4432.73	-365.73	
Batadraba	7.82	1.21	1.195	175.187	26.28	88.18	3299	3622.41	-323.41	
Juria	5.89	1.27	2.95	175.187	26.28	88.18	3822	3379.48	+442.52	Med.
Kaliabar	7.605	1.37	2.93	175.187	26.28	83.92	4420	3843.63	+576.37	
Kathiatoli	6.218	1.32	2.99	147.243	26.28	88.18	4784	3466.60	+1317.39	Hig
Kapili	6.455	1.39	2.92	175.187	26.28	88.18	3625	3510.03	+114.96	Med
Kawkhowa	6.245	1.19	2.92	175.187	26.28	88.18	2855	3462.17	-607.17	Med
Loharighat	5.7	1.78	2.76	175.187	26.32	83.92	3115	3251.38	-136.38	
Bhurbandha	5.335	1.17	2.86	219.268	26.07	83.92	3264	3846.13	-582.13	Very
Mayang	6.735	1.46	2.75	219.268	26.07	83.92	5824	4165.21	+1658.79	
Regression	240.63	13.349	126.659	-0.136	-2671.032	-12.991.				

Intercept of the equation - 72969.569

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