IMPACT OF IRRIGATION DEVELOPMENT ON RICE CULTIVATION IN BIHAR 1961-62 TO 1972-73

Dissertation submitted to the Jawaharlal Nehru University
in partial fulfilment of the requirements for
the Degree of
MASTER OF PHILOSOPHY

ASHOK KUMAR

CENTRE FOR THE STUDY OF REGIONAL DEVELOPMENT
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI–110067
February, 1982

JAWAHARLAL NEHRU UNIVERSITY

CENTRE FOR THE STUDY OF REGIONAL DEVELOPMENT,
SCHOOL OF SOCIAL SCIENCES

Gram : JAYENU

Telephone : 652282
652114

New Mehrauli Road,
NEW DELHI-110067.

We certify that the dissertation entitled "IMPACT OF IRRIGATION DEVELOPMENT ON RICE CULTIVATION IN BIHAR - 1961-62 to 1972-73," submitted by Shri ASHOK KUMAR in partial fulfilment for the DEGREE OF MASTER OF PHILOSOPHY of the University, is to best of our knowledge, a bonafide work and may be placed before examiners for evaluation.

Dated 10.2 1982

(K.S.SIVASAMI)
Supervisor

Dated 10.2. 1982

(G.S.BHALLA)
Chairman

A_C_K_N_O_W_L_E_D_G_E_M_E_N_T

I am glad to record my deep gratitude to my teacher and Supervisor, Dr. K.S.Sivasami for his valuable inspiring guidance throughout this study.

I am also deeply obliged to my former teacher Prof. Moonis Raza and Dr. B.L.Sinha for their perennial suggestion.

I am extremely grateful to Prof. G.S.Bhalla, Dr. G.K. Chadha, Dr. A.Kundu and all other faculty members for the inspiration and academic guidance.

My sincere thanks are due to Shri A.K.Jha, Shri B.R. Singh, Mr. M.H.Quasmi, Mr. R.A.Runi, Mr. N.K.Misra, Mr. Sunil Kumar Yadav, Mr. Bimlesh Kumar Yadav and Mr. Monoranjan Kumar Gupta for their ceaseless assistance while preparing this volume of work in several phases.

Shri Chinmaynath deserve special thanks who helped me in doing the photograph of the maps. Shri V.Murlidhar and Mr. H.Acharya are also deserve thanks who helped me in the computation of data. And my thanks are due to Shri A.K.Verma for typing the script in a very short time.

I wish to extend my sincere thanks to Librarians of J.N.U. Library, I.C.A.R. Library and Directorate of Economics and Statistics (Ministry of Agriculture) Library.

In the last, I thank all my friends and well wishers who helped me in some way or the other.

Ashok Kumar

Dated 10th February, 1982. (ASHOK KUMAR)

C_O_N_T_E_N_T_S

CHAPTER - III

IRRIGATION IN BIHAR

CHAPTER - IV

RICE IN BIHAR

oooooooooo

LIST OF TABLES

LIST OF MAPS AND DIAGRAMS

LIST OF APPENDICES

CHAPTER - I

INTRODUCTION

CHAPTER - I

After independence, particularly during the last two decades, there has been considerable change in almost all the parameters of agriculture in India.[1] In order to meet the growing demand for food of the teeming millions, agri-culture has been intensified on the one hand and on the other, attempts have been made to bring more and more areas under cultivation. From time to time the government has introduced new programmes and policies for the development of agriculture.

As a result of these new programmes and policies all the parameters of agriculture have under gone a change. The net sown area has increased considerably and the gross cropped area has almost doubled. The irrigated area has increased by about 108 per cent over the base year 1950-51. Thus by and large, the monetary returns per hectares have also increased a considerable extent.

But due to variation in physical and socio-economic conditions, these change in agriculture are not uniform all

---

1. M.L.Dantwala (1979), 'Agricultural policy in India since independence', in C.H.Shah (ed.), Agricultural development of India-policy and problems, (Delhi, Orient Longman Ltd.), p.23.

over the country either spatially or temporally. There are states like Maharashtra, Meghalaya and Assam where very little change has taken place; on the contrary in Haryana, Punjab, Rajasthan, Uttar Pradesh and Bihar significant changes have taken place in agriculture. Similarly during the certain periods of time the change has been slow and steady, whereas during some other period, a rapid change has been witnessed. This provides a very important and potential field of research in agricultural geography.

The most important feature of agriculture in India is the predominance of food crops. Among the food crops rice occupies the pride of place. In fact in the rice belt of India, all agricultural activities are geared to and controlled by the considerations for growing rice. Therefore no agricultural development is possible without modernising and improving the rice cultivation in India.

Among the rice growing states in India, Bihar has the largest area under rice. As on 1970-71 the area under rice was 5,232,200 hectares. Rice occupies nearly 62 per cent of the gross sown area. But the yield of rice in Bihar is poor. It is only 841 kg/hectare* when compared

---

* This is below the all India average yield of rice i.e. 1,146 kg/hectare.

with the yield of rice in Punjab, which is 2,042 kg/hec., the yield in Bihar amounts to only half of the best yield obtained in other states of India. There is great scope for increasing the yield of rice in Bihar. The increase in the yield of rice and corresponding rise in rice production might pave way for reducing the area under rice and introduce more profitable crops as the area under rice is very high in Bihar.

One of the most common means of increasing the production or the yield is by irrigation. Irrigation frees the rice cultivation from the vagaries of rainfall and thereby stablises the yield. It also helps to grow more than one crops of rice. Besides directly affecting the area, irrigation also provides the base for putting more modern inputs, interms of fertilizer, high yielding varieties, which will substantially increase the yield. All in combination leads to higher productivity.

The irrigation development is uneven in the districts of Bihar. Five districts (out of 17) are having rapid development in total irrigated area due to Sone, Kosi and Gandak Project, they are: Champaran 1.61 lakh acres in 1960-61 to 8.68 lakh acres in 1972-73), Shahabad (12.53 to 17.17), Saran (1.64 to 4.04), Saharsa (0.70 to 2.65), Purnea (0.14 to 2.07). Except Gaya, Santhal Parganas, Hazaribagh, Palamau

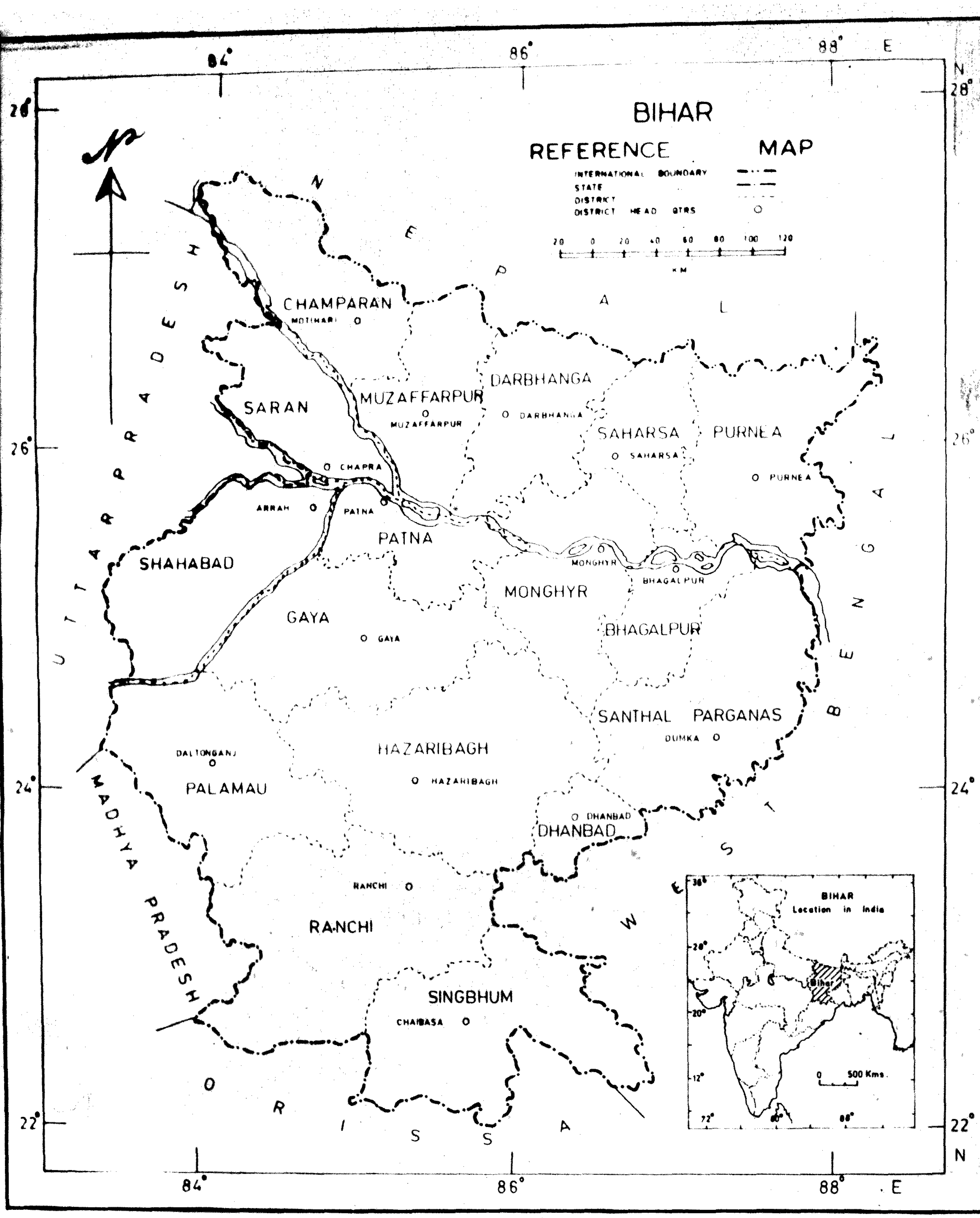

BIHAR
REFERENCE MAP
INTERNATIONAL BOUNDARY
STATE
DISTRICT
DISTRICT HEAD QTRS
KM
CHAMPARAN
MOTIHARI
SARAN
MUZAFFARPUR
DARBHANGA
SAHARSA
PURNEA
CHAPRA
ARRAH
PATNA
SHAHABAD
GAYA
MONGHYR
BHAGALPUR
SANTHAL PARGANAS
DUMKA
HAZARIBAGH
DALTONGANJ
PALAMAU
DHANBAD
RANCHI
SINGHBHUM
CHAIBASA
NEPAL
UTTAR PRADESH
MADHYA PRADESH
ORISSA
WEST BENGAL
BIHAR
Location in India
500 Kms.

Fig.1

and Singhbhum all the 12 districts have increased their irrigated area.

As a matter of fact, the yield of a crop is dependent on a number of factors such as - physical, technological and institutional. In the present study, the investigation is largely confined to the impact of some of the parameters on the yield of rice. The parameters considered are rainfall, irrigation and water availability. Since water is the leading input in case of rice crop, it has been considered as a determinant of rice yield.

1.2 Objective of the Study :

In the agricultural geography of Bihar rice not only occupies a predominant position interms of area and production but also ., in a way, determines the cultivation of other crops. Infact the calender for all other crops are adjusted to that of rice. Any improvement in rice cultivation will, therefore, have a direct impact on other crops thereby on the agricultural economy of this state.

Among the cereal crops rice is the most water loving plant and its optimal growth is determined by the timely availability of plenty of water. Bihar is well endowed with adequate quantity of water. But its distribution over space and time is not conducive for optimal growth of rice. The rainfall being uncertain both interms of quantity and time, yield of rice is low and production of rice is highly variable. Through irrigation it is possible to bring in improvement on both these aspects.

Since independence there has been a significant increase in the irrigated area in Bihar. The present study attempts to find out the extent to which those expectations from irrigation development have been realised. In Bihar three crops of rice are grown - Autumn, Winter and Summer. The impact of irrigation development in the districts of Bihar on area and yield of each of these crops and also of gross rice crop is the main objective of the study.

Canal, Tank, Well and Tubewell and others are the main sources of irrigation in Bihar. The sources of irrigation are unevenly distributed and the development of each source of irrigation is also not uniform. The varying impacts of each source of irrigation on different crops of rice are studies in this dissertation.

The net impact of irrigation development can best be ascertained through an analysis of production. To what extent the irrigation development has led to the reduction in production fluctuation and raise in the production level is yet another objective of the study.

1.3 An Over-view on Literature on Rice and Irrigation :

Literature on rice and irrigation are numerous. Most of them are technical in nature and written by specialist agronomists and irrigation engineers. However, social scientists in recent years have analysed the trend in rice production and the regional variation in rice yield. Special attention is drawn to the few literatures which bring out the inter-relationship between weather parameters and yield of rice. Likewise the irrigation development has been studied by social scientists. An over-view of some of the important literature, pertaining to the objective of the study is presented in this section.

Elaborate treatment on rice as a cereal crops and the technicallity of its cultivation is given by Grist, D.H. (1965)[2] and by the Central Food Technological Research Institute.[3] An interesting study by Singh, L.R. (1974)[4] describes the historical, archeological and botanical

---

2. D.H., Grist (1966) - "Rice" Longmans, Gree & Co. Ltd.

3. A. Techno-Eco. review: '*Rice in India*', Central Food and Technological Research Institute (Mysore) 1965.

4. L.R.Singh (1971) - 'Agricultural origin and Dispersal of Rice', *National Geographical Journal of India*, 17 (2 & 3), pp. 113-119.

widenses which point out the Indian Origin of rice and its global dispersal with the passage of time. The importance of rice in the economy of Asia is precisely brought out by Ishikawa (1976).[5] The important role that plays in the crop rotation and cropping pattern is brought out by Vachani, M.V. (et. al.) (1963).[6]

The most important review on weather and rice is done by Robertson, G.W. (1976).[7] Rice cultivation, growth and development of rice plant, environmental factors determining the growth of rice, forecasting of rice yield based on weather factors, and the climatic zonation and bioclimatic conditions in rice producing areas are all well reviewed by Robertson. Nikhilesh Das (1968)[8] describes the agro-climatic factors of rice production in West Bengal. The work of Malik, A.K. (1964)[9] focussed on the

---

5. S. Ishikawa (1974): '*Economic development in Asian Perspective*' (Tokyo, Kinokieniya Book Store Co. Ltd.)

6. M.V., Vachani (et. al.) (1963), - 'Crop rotation, double Cropping and Cropping pattern in rice areas in India', *News letter International Rice Comm.*

7. G.W. Robertson (1976)- '*Rice and Weather*' Tech. note No.144 (Geneva, World Met. Org.).

8. Nikhilesh, Das (1968)- 'Agro-climatic factors of rice production', *International Geographical Congress*, Selected papers, gol.1.

9. A.K. Malik (1964): 'Climatology, of the crop seasons of India - Rice', *Indian Journal Met. and Geo-physics*', vol.15, no.4.

normal growth features and the yield of rice crop in India. He has pointed out that sowing and transplanting of rice crop mainly depend upon the rainfall regime wherever irrigation facilities are not available. According to Abraham and Rakeja (1967)[10] weather has tremendous impact on the rice cultivation. The study of the problem of water supply for agriculture has also received some attention. Bagchi and Bhattacharya (1969)[11] have analysed rainfall for the past 60 to 70 years in order to assess the water availability and rainfall periodicity for agricultural operation and the cropping patterns in lower West Bengal. The work done by Abraham (1966)[12] reveals that the combined effect of all the weather factors occuring in particular season over a specified area needs to be assessed. It is not necessary to estimate the effect of individual weather factors.

---

10. T.P. Abraham & S.K. Rakheja (1967) - 'An analysis of growth of production of rice and wheat crops in India', Indian Journal of Agricultural Eco., vol.22, no.1.

11. A.K. Bagchi & R. Bhattacharya (1969) - 'Problems of water supply for agricultural operations in lower West Bengal', Geographical Outlook, vol.6.

12. T.P. Abraham (1966) - 'Isolation of effect of weather on productivity including other risks such as damages', Journal of Indian Society and Agri. Statistics, vol.17, no.2.

There are few studies dealing with the problems of rice cultivation on problems of soils. Bhattacharya (1971)[13] has tried to collect information on the cultivation and improvement of rice in saline soils of India. Patnaik (1971)[14] has studied the results of the application of fertilizers in submerged rice soils and shown the ways and means of improving soil conditions and the application of fertilizers on a rational basis for getting higher yield of rice. Abichandani (1971)[15] has suggested that the saline underground water potential of west Rajasthan can be utilized for irrigation with intelligent and proper soil water management practice.

According Panse, V.G. (1969)[16] irrigation can be introduce in some rice areas as a positive measure for

---

13. B.K.Bhattacharya (1971); 'Rice cultivation of saline soils', Proc. Symp. Sc. & India's Food Problems, ICAR, New Delhi.

14. S. Patnaik (1971): 'Soil Amelioration and Fertilizer use for maximising Rice yield', Proc. Symp. Sc. & India's Food Problem, ICAR, New Delhi.

15. C.T. Abichandani (1971): 'Management of Saline Water Irrigated Soils for increased crop production' Proc. Symp., Sc. & India's Food Problem, ICAR, New Delhi

16. V.G.Panse (1969) - 'Recent trends in yield of rice and wheat in India', Indian Journal of Agricultural Eco., vol.14, no.1.

increasing yield by supplementing the normal rainfall of the area and not merely as a protection against the vagaries of rainfall. He discussed the trend of yield in rice and wheat in India by attempting the regression analysis. The work by Mitra, T. (et. al) (1964)[17] deals with variation of rice yield, area and production and factor affecting the variations. And the article of Rao (1971)[18] questions about the factors responsible for inter-regional differentials in the growth of crop out put. It argues that the most important proximate cause of the disparities in growth of crop- output during 1952-53 to 1964-65 is the differences in growth of irrigation. The paper by Sharma (1975)[19] examines the regional achievements in the production of rice in this context; variations in area are accompanied by variations in production. The analysis has identified some of the promising districts which can be developed into potential supplies of rice. Govinda (1977)[20] has discussed about the inter-district

---

17. T.Mitra (et. al., 1964) - 'Regional variation in yield per acre in major crops in India', Indian Journal of Agricultural Eco., vol.19.

18. G.K.Rao (1971): 'Inter-regional variations in Agricultural Growth', 1952-53 to 1964-65, A Tentative analysis in relation to Irrigation, Economic and Political Weekly, July 3, vol.6.

19. O.S.Sharma (1975),'Regional variation in Rice economy of India', Indian Journal of Regional Sc., vol.2.

20. Nalini, Govinda (1977), 'Variation in wheat and Rice responses - A Case Study in their production and productivity in Punjab and Haryana', occasional papers, 4 CSRD, JNU.

variations in the cultivation and productivity of wheat and rice in the Punjab-Haryana region. The yield rates can be stablised and increased to a considerable extent with provision of irrigation facilities in area depending entirely on rainfall for crop production, Bashir and Thingalaya (1965)[21] have discussed in their research note.

Aiyasamy and Subramaniam (1979)[22] stated in his article that the production of rice in Tamil Nadu has been almost stagnant in the pre-Green revolution period and the marginal increase of 1.8 per cent in production was contributed by extension of area under rice. The degree of relationship between production and productivity lend quantitative support to the observation.

Hussain (1963)[23] has mentioned some of the geographical factors which are helpful in the drilling of tube-wells. He has also ascertained the influence of tubewells and land use, cropping patterns, yield per acre and agricultural activities in Upper Ganga Yamuna Doab.

---

21. A Bashir Desai ' Thingalaya (1966), 'Irrigation factor and yield variability of rice growing districts in India', Indian Journal of Agricultural Economic, vol.20, no.3.

22. P.K.Aiyasamy & V.Subramaniam (1979), 'Growth rates in Area, Production & Productivity of rice in Tamil Nadu', Agricultural situation in India, vol.33, no.12, March

23. M.Hussain (1963), 'Agricultural Adages of the Upper Ganga-Yamuna Doab', The Geographer, no.16.

Raychowdhari (1969)[24] outlined the extent of utilization of underground water in irrigation in the arid and semi-arid states of north and north-western India. He has also drawn up water suitability maps for the states of Punjab, Rajasthan and Gujarat which atonce depict the effect of good and bad water on the soils and thus help the adoption of suitable cropping and irrigation pattern.

The paper by Sadhu Khan (1974)[24] attempts to highlight the relationship between the progress of small irrigation and the expansion of cultivated area. Canals and wells are important sources of irrigation in Haryana, whereas Gupta (1970)[25] has observed, nearly 38 per cent of the net sown area was irrigated in 1966-67. Future irrigation programmes as persued by the state government, when completed, will raise the irrigation potential of Haryana. Whereas, it is suggested in the paper of Singh (1977)[26] that for a National Development of Irrigation, diff erent parts of the states should be treated separately, keeping in view their specific problems.

---

24. G.K.Sadhu Khan (1974), 'A Quantitative analysis of an Agro-Irrigational Facet of West Bengal', Geographical Rev. of India, vol.36, no.3.

25. S.L.Gupta (1970) - 'The Geography of irrigation in Haryana', Geographical Rev. of India, vol.32 (1), pp. 28-40.

26. J.Singh (1977) - 'Development of Irrigation in Punjab during 1961-74', Geographical Rev. of India, vol.39, no.3.

One pertinent question that needs to be looked into is whether irrigation planning is oriented to the objective of reducing inter-regional disparities and, if so, to what extent, this was achieved, the paper by Rao (1978)[27] is to briefly discuss this aspect. The source-wise growth of irrigation over the 12 years (1960-61 to 1971-72), which is mainly based on compound growth rates and linear rates of increase was discussed by Khare (1979)[28].

An edited book in five volumes by Noor Mohamad (1981)[29] is a compendium of knowledge in this all important field and provides a veritable mine of information regarding the concepts, theories, models, the latest techniques and tools, and infact, everything the geographer and researcher might seek to know about this field of study.

There is a text book on Bihar written by Ahmad (1965)[30] is the first work on the geography of Bihar. The book entitled 'Bihar' deals with physical background,

---

27. T. V.S.Rao (1978) - 'Inter-district variation in Irrigation Development in Andhra Pradesh', Agricultural situation in India, October, vol.33, no.7.

28. M.P.Khare (1979) - 'Growth of Irrigation in Maharashtra', Artha Vijnana, July, vol.21, no.2.

29. Noor Mohamad (ed. 1981), Perspectives in Agricultural Geography, Concept Publication Co., New Delhi.

30. E.Ahmad (1965) - Bihar, Ranchi University Press, Ranchi.

economy, population, agriculture and the detailed study of the regions of Bihar. Another book on Bihar by Singh and Kumar (1970)[31] come in a atlas form dealing with a geographical study of its own type. It combines the assets of the stydy of a state in maps and an analysis of state-geography in its varied spheres.

There were no studies relating irrigation with rice in Bihar. The approach and methodology of the authors listed above utilized some extent, with suitable modification in the present study.

1.4 Hypothesis :

The present study has attempted to examine and test the following hypothesis :

(a) Increase in irrigated area leads to increase in the total cropped area under rice, particularly in the districts having low irrigated area and in plain regions.

(b) With more development of irrigation, particularly canal irrigation, the area under winter rice tend to decrease.

(c) Irrigation development might have comparitively greater positive impact on summer and autumn crops in

---

31. R.P.Singh & A.Kumar (1970) - Monograph of Bihar, Bharati Bhavan, Patna .

terms of area and yield.

(d) In districts which have relatively high percentage of net irrigated area crops other than rice might be cultivated.

(e) Increase in irrigated area would reduce the year to year flustuation in the production and also rise the overall level of productivity.

(f) Sources of irrigation affect the yield rate.

1.8 Source of Data :

The present study is mainly based on data published by different government and quasi-government organisations.

(a) Annual Season and Crop Repor, Bihar (1961-62 to 1972-73).
(b) Agricultural situation in India (1972-73).
(c) Indian Agricultural Statistics
(d) Bihar Statistical Hand book (1971)
(e) Selected Plan on Statistics, Government of Bihar (1976)
(f) Report on Agricultural census, Bihar (1970-71)
(g) Report of National Commission on Agricultural, Bihar, vol. III, (1976)
(h) Climatogical Tables of Observatories IMD, Poona.

Care has been taken to ensure the accuracy, reliability and homogeneity of the statistical information.

1.6 Sources of Maps :

The following maps were available and have been used in this investigation:

(i) 1" = 15.78 Miles (Million Map) Map of Bihar Published by the Survey of India.

(ii) 1 cm. = 25 Kilometres National Atlas Map, Calcutta plate No. 33 (Physical) prepared under the direction of Prof. S.P.Chatterjee, Published in Calcutta.

(iii) 1:6,00,000 million map of Slope & Relief, National Atlas Map, Calcutta.

(iv) 1 cm = 16 kilometres, a map prepared National Commission on Agriculture 1976 entitled Bihar: Rainfall pattern (Ministry of Agriculture and Irrigation.

(v) 1 cm = 30 kilometres Map of Soil types in Bihar prepared by Souvenier 1972. The Directorate of Rice Development, Government of India, Patna.

1.7 Method of Analysis :

In the present study, district has been selected as the unit analysis. Although there are 31 districts in Bihar at present, the existing number of districts before 1972-73 were seventeen. So only the old seventeen districts have been taken into account in order to avoid the problem of splitting data. For a comparative study of this kind it was not possible to make a study of a new district that have come into existence, since no data is yet available for them.

For the present study twelve years data have been taken, viz; 1961-62 to 1972-73. In order to study the spatial temporal variation of different crops of rice (irrigated and unirrigated) Gross and Net cropped area, Irrigated area (source-wise) Yield and production of different crops of rice the annual compound growth rate per cent per annum and linear rate of increased in hundred hectare per annum* has been calculated. The district-wise percentage share of above mentioned variables in the state was also calculated.

---

* The compound growth rates reflect the strength of any movement, the linear rates of increase which are in actual (rather than percentage) terms, show us the impact of such a movement, free from the magnitude of a given series. Besides, the linear rates are additive and are less sensitive to terminal values. In written expression, it takes the form as:

$$r = \left[\left(\frac{X_t}{X_o} \right)^{1/t} - 1 \right] \times 100$$

where ;

r = annual compound growth rate (percentage)

X_t = variable in terminal year

X_o = variables in initial year

t = time interval

For the correlation matrix, step-wise Multiple Regression of all the data is given in percentage form (See appendice 4 to 9). There is one independent variable water availability index* has been worked out.

To analyse the impact of irrigation on production or rice, a model has been developed taking the production of each individual year (for each district) to total average production of the district (for the period of 12 years). And taking the maximum and minimum production ratio, ranges are calculated. Thus, an attempt has bee n made to establish the flustuation in production.

Multiple regression** and correlation models*** have been used widely in geographic research.[32] Step-wise is

---

* Formula for calculating the water availability index is :

$$WI = \frac{I\,(P_E - E_r) + E_r}{GSA}$$

where;

I = % of area irrigated
P_E = Potential Evapotranspiration
E_r = Effective rainfall
GSA = Gross sown area

** In a written expression, it takes the form as :

$$Y_1 = a + b_1 X_1 i + b_2 X_2 i + b_3 X_3 i \ldots b_n X_n, \; i=1, 2 \ldots n$$

where;

Y = dependent variable
X_1 to X_9 = independent variables
a = intercept

*** Correlation coefficient has been calculated on Karl Pearson's formula; which is given in Chapter V.

32. S.P. Gupta (1971) - <u>Statistical Method</u>, Sultan Chand & Sons, Dariaganj, New Delhi, p. B 11.1

a powerful variation of multiple regression which provides a means of choosing independent variables and provides the best prediction possible with the fewest independent variables. Thus, to analyse the impact of irrigation (different sources of irrigation), rainfall and water availability index on area and yield of different crops of rice (autumn, winter and summer), the multiple step-wise regression technique has been used in the present study.

The results of the analysis are represented with appropriate cartographic techniques and a production model has been developed.

1.8 The Format of the Study :

The present study consists of a detailed analysis of secondary sources of data and available literatures. The entire work has been divided into six chapters for the sake of convenience. The Chapter One introduces the subjects, its objectives, over-view of literature, hypothesis, data base, methodology etc. The Chapter Second deals with the factors determining the rice cultivation, physiography, climatic conditions, soils etc. prevail in Bihar are described in detailed. The Chapter Third gives a detailed description of irrigation - its importance, development, potentiality, sources of irrigation and its growth, spatial and temporal variation of irrigation in the State of Bihar. While the Chapter Fourth deals with Rice - its place in agricultural sector; its varieties grown in Bihar, its production and procurement, its growth and spatial variation over the period under study etc. in Bihar State.

The Chapter Fifth analyses a vivid account of Inter-relationship between rice and irrigation such as - growth of irrigation and increase in the acreage of rice, growth or irrigation and growth of rice in both area as well as in yield per hectare improvements in irrigation, measures and its impact on rice cultivation, relationship with water availability index and rainfall etc. The Chapter Sixth concludes the subject by giving some major findings and suitable suggestions for further study.

C H A P T E R - II

FACTORS DETERMINING THE RICE CULTIVATION IN BIHAR

CHAPTER - II

FACTORS DETERMINING RICE CULTIVATION IN BIHAR

Rice is indegenous to the humid areas of tropical and subtropical regions and shows very wide adaptability to different soil and climatic conditions. However, most varieties grow best under flooded conditions, in coastal lowlands, flood plains, and river deltas. Rice is also grown extensively in plain regions with assured irrigation facilities and in terraced fields in the mountainous areas, where spring and cut channels provide continuous supply of water to the fields.

Although rice is grown in variety of soils, heavier clay with 50-60 per cent finer fractions of silt and clay are preferred.[1] In order to retain water in the paddy it is essential that an impervious layer of fine-textured soil(clay) exist within two to five feet of the surface. According to Robertson (1975) rice will tolerate a wide range of soil acidity from pH 4.5 to 8.7, best yields are obtained on neutral to slight acidic soils.

Being a tropical or subtropical plant, rice generally requires high temperatures above 20°C but not above 35° to 40°C. The optimum appears to be near 30°C for the day maximum

---

1. G.W. Robertson, (1975) - 'Rice and Weather' ....O. p.1

and near 20°C for the night minimum.[2]

The most important environmental requirement for the cultivation of rice is water. The optimum water requirement is just to cover the soil. Since rice can grow well under flooded conditions, the water requirement approaches the potential rate. When this water requirement is met, rice can be grown under any type of soil.

Solar radiation is important during the last 30 to 45 days of ripening period of paddy. If the sunshine is inadequate during this period, there is reduced considerably.

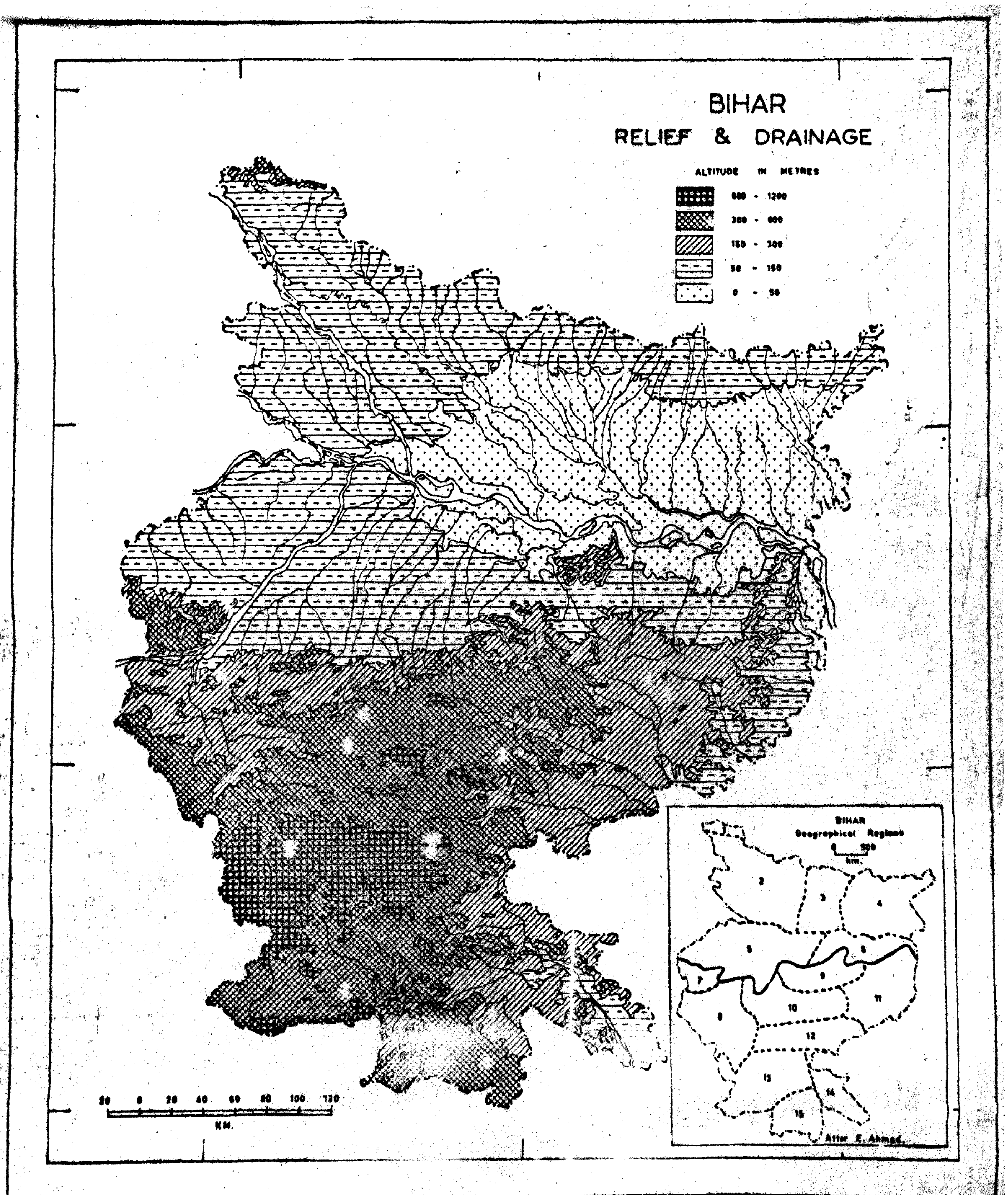
These factors as they prevail in Bihar are described in detail in the succeeding paragraphs.

2.1 Physiographic Conditions :

Large area of Bihar is plain. The river Ganga divides the plain into two halfs North Bihar Plain and South Bihar Plain to the northwestern part of the Ganga Plain occurs small fragment of the Siwalik range of the Himalayan piedmount, covering approximately 940 sq. km. Chotanagpur plateau occur in the south of Bihar plains. The plain and plateau are further divided into micro regions are given in fig.2.[3]

---

2. Robertson - Op. Cit., p.11.
3. E.Ahmad, (1961) - 'Bihar', Ranchi University Press, Ranchi, p.311.



BIHAR
RELIEF & DRAINAGE
ALTITUDE IN METRES
600 - 1200
300 - 600
150 - 300
50 - 150
0 - 50
20 0 20 40 60 80 100 120
KM.
BIHAR
Geographical Regions
km.
After E. Ahmad.

Fig. 2

Thus as regards physiography Bihar is divisible into three unequal parts. These are :

(i) Himalayan foot hills
(ii) Bihar Plain, and
(iii) South Bihar Plateau

(i) Himalayan Foot Hills : Himalayan foot hills region occurs in the north western part of Bihar in Champaran District. The altitude of this region varies from 500 to 1600 ft. The region consists of two different ranges of hills and intervening valleys, all parallel to the Nepal border in a north-west to south-west direction. It consists of relatively young sedimentary rocks of late Tertiary times. Being young they are ill-compacted and relatively soft, so that under a tropical humid climate they have been broken into an area of very rugged relief consisting of a maze of ravines and ridges.[4] Rice is grown in the terraced field of this region.

(ii) Ganga Plain : The major relief unit of Bihar is the Ganga plain, which covers about 72,600 sq. kms. or 42 per cent of the total area of Bihar. There are some differences in the relief features of North Ganga Plain and South Ganga Plain.

---

4. E. Ahmad, (1961) - Op. Cit., p.312.

(a) North Ganga Plain : This region covers an area of about 56,980 sq. kms. And the optimum conditions for the cultivation of rice are present in the North Ganga Plain where alluvial cones or fans spread and unite to form interfluves of rivers that run from the Himalaya to the plain.

The following districts, Saran, Champaran, Muzaffarpur, Darbhanga, Saharsa, Purnea, north of Bhagalpur and north Monghyr constitute the region. Broadly speaking, the topography of the North Bihar plain consists of the following features: a narrow tarai belt in Champaran, a sub-tarai belt of marshy land in the north with intervening tracts of uplands along rivers, a wide belt of marshy lowlands notably devoid of uplands, characterised by permanent depressions and lakes.

(b) South Ganga Plain : This lowlands of Bihar covers about 33,670 sq. kms., and also intersected by streams and marshes is subjected to floods leading to the spread of fertile soil.

The lowlying tract holding water seldom requires an aid of irrigation. Low earthen dams or bunds constructed around paddy plots are the devices for retaining water for winter rice.

The districts of Patna, Gaya, Shahabad, Monghyr and central Bhagalpur constitute the region. This region is roughly divisible into, a narrow belt of highland along the

Ganga and the rest of the plain. In the second part behind the Ganga levee is a treeless low-lying region called 'Tal' lying in Patna district. As the high Ganga levee impedes the entry into the Ganga, of the streams coming from the south, these streams (Punpun, Phalgu and Paimar) flow parallel to the ganga for several kilometres. They combine as a vast sheet of flood water during rains supplemented by the spill water of the Ganga itself and thus cause the inundation of the 'Tal' which mark an old bed of the Son.

(iii) South Bihar Plateau : Covering an area of about 79,476 sq. kms., the region includes the districts of Palamau, Ranchi, Hazaribagh, Singhbhum and Dhanbad. The rice lands are invariably terraced in south Bihar plateau and the upper land are given to autumn rice, the lower one being reserved for winter rice.

The North Koel, eastern part of the Damodar, the lower Subarnarekha valleys in Bihar, mica schist peneplain, reticulating dykelands of Singhbhum, alternating valleys or dons amidst uplands over Ranchi-Hazaribagh plateaus are good rice lands.[5] Don of the first order is the best paddy land, occupying the primary valley bottom, don of second order sets the paddy fields along the natural slopes of rivers and don of third order consists of artificial terraces. The paddy

5. R.P.Singh and A.Kumar (1970) - 'Monograph of Bihar' Bharat Bhavan, Patna, p.41.

becomes coarser and quick maturing from wet don of the first order to artificial terraces where water tables quickly retire after rainy season.

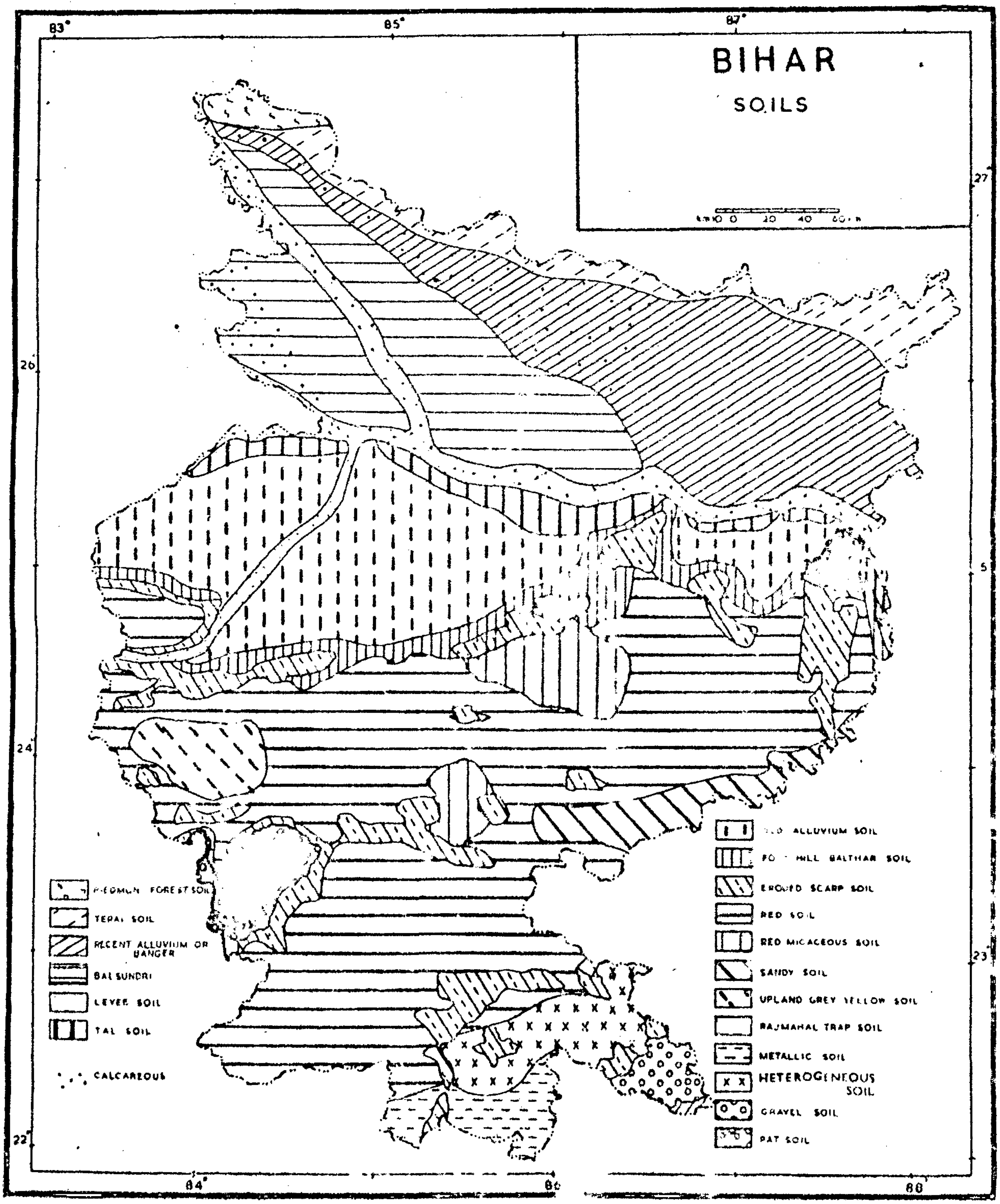
2.2 Soil Types :

Fig. 3 shows the distribution of different types of soils in Bihar. It incorporates some of the recent studies made by the Directorate of Agricultural Research, Bihar.

There are four major soil types in North Ganga Plain:

(i) Piedmont Forest Soil : This type of soil found in the Sumeshwar and Dun hills forest tract of Champaran district. The soil has been derived from the parent rocks of sand stones, limestone etc. The soils are shallow to medium deep over bed rocks and pebbles. Their sandy texture changes to loamy sand. The soils vary in productivity from medium to good.

(ii) Tarai Soil : It is distributed in a narrow belt varying in width from 3 to 8 kilometres along the border of Nepal in the northern fringe of the districts of Champaran, Muzaffarpur and Darbhanga and north-eastern part of Purnea district. The Tarai soils are heavy textured. They show neutral to moderately acidic reaction, their colour varying from grey to yellow. The low land of tarai soils are very fertile and produce bhadai and aghani crops.



BIHAR
SOILS
83°
85°
87°
27
26
24
23
22
84°
88
TERAI SOIL
RECENT ALLUVIUM OR BANGER
BALSUNDRI
LEVEE SOIL
TAL SOIL
CALCAREOUS
ALLUVIUM SOIL
HILL BALTHAR SOIL
ERODED SCARP SOIL
RED SOIL
RED MICACEOUS SOIL
SANDY SOIL
UPLAND GREY YELLOW SOIL
RAJMAHAL TRAP SOIL
METALLIC SOIL
HETEROGENEOUS SOIL
GRAVEL SOIL
PAT SOIL

Fig. 3

(iii) Recent Alluvium or Bangar :

Bordering the Tarai soil belt stretches the belt of recent alluvium soil. It has maximum extent in Purnea and Saharsa but it has been reduced to a narrow strip in the north-western part of Champaran district. The soil is non-calcareous and non-saline but the stipled part of this belt is young alluvium and the remaining eastern broad belt is recent alluvium. The soil is of low to medium productivity where creals are the primary crops.

(iv) Balsundri : It forms a distinct belt between the Burhi Gandak and the western border of Bihar in Saran and Champaran. They are young alluviums but differ in texture, colour, physical and chemical properties from east to west. Their fertility varies from medium to high.

There are three major types of soils in the South Ganga Plain:

(i) Tal Soil : Tal soils are found in the backwater belt of the Ganga from Buxar in the west to Palur in the east where rain water remains collected in the rainy season. Their textures differ from medium to heavy. They vary from loamy to Kewal and they are very fertile.

(ii) Old Alluvium Soils : It correspond to clay loam and Kewal soils of south Ganga plain. They occur from the western border of Bihar and stretch through Shahabad, Gaya, Monghyr, Bhagalpur and Sahebganj plains. The grey tinged neutral to slightly alkaline soils with medium to heavy texture develop wide and deep polygonal cracks and attain medium productivity status.

(iii) Foot Hills Balthar Soils : Foot hill balthar soil form a continuous narrow belt between the plain and the dissected plateau fringe from the western end of Kaimur plateau to the Rajmahal highlands. The soils are deep and acidic, texture is light, poor in fertility.

(iv) Levee Soils : It belongs to North and South Ganga Plains. They are light in texture and attain medium high fertility status.

The soils of Chotanagpur Highlands differ in their physical, chemical and biological characteristics. They are:

(i) Eroded Scarp Soils : The eroded scarp soils are found all along the dissected, descending scarplands at various elevations. The soils are very shallow and stony with an average thickness of 3 to 30 inches. They have poor fertility.

(ii) Red Soils : Red soils are common soils found all over the granite and gneissic plateau surfaces of Chotanagpur but their texture and colour vary from the eastern to the western parts. The soils are light to medium in texture and are red to yellow and light grey in colour. The fertility vary from upland to low-land.

(iii) Red Micaceous Soils : The Mica-belt around Kodarma in Hazaribagh and the country around Mandu have this type of light pinkish soils on uplands and light yellow to yellow soils in the lowlands. Soils are loamy sand, sandy with high proportion of mica particles.

(iv) Sandy Soils : Sandy soils are found in Dhanbad, eastern Hazaribagh and southern Santhal Parganas. Soils vary from reddish yellow to greyish yellow in colour. They are moderately deep soils and their fertility level is the same as the major catenary soils.

(v) Upland Grey Yellow Soils : They have developed on shales, silts and low grade metamorphic rocks in Palamau district. Their texture is medium to heavy and their colour varies from grey to yellowish grey and fertile.

(vi) Rajmahal Trap Soils : The lava country of Rajmahal is covered with trap soils which are derived from the basalts. Their colour varies from Olive grey to black. These black soils are rich in fertility. The yellowish red soils found in this area are derived from the granite rocks.

(vii) Metallic Soils : The metallic soils are derived from rocks rich in iron content. The soils are shallow and poor in productivity. Their colour varies from red to yellow and dark reddish brown. These are found in south Singhbhum.

(viii) <u>Hetrogeneous Soils</u> : These soils are found in the central part of Singhbhum district. The soils are heavy admixture of different types of rocks. The red and yellowish soils are found on the uplands whereas black and dark grey soils are found in low land areas. The fertility varies from upland to low land.

(ix) <u>Gravel Soils</u> : Gravel soils are found in the tertiary gravel belt east of Dalbhumgarh and extend to the borders of West Bengal in the east and Baharagora village in the south where alluvial plain begins. Their colour varies from red to yellow. They are lateritic soils and their fertility is very poor.

(x) <u>Pat Soils</u> : The western higher plateau of Chotanagpur is capped by laterites which have developed under hot and humid conditions over the basalts. The typical red colour is due to high content of iron oxides. The pat soils are devoid of the plant constituents and hence are infertile.

2.3 Climatic Conditions

Rice is grown under damp warm climate. It is best suited to the regions which have high temperatures, high humidity, prolonged sunshine and an assured supply of water. 'It is generally estimated that weather as a single factor could be responsible for as much as 60 per cent of variation in the yield which occur from year to year'.[6]

2.3.1 Temperature :

The varieties of rice which are grown in Bihar require a temperature range of 20 to 37°C (68°F to 100°F) for the optimum growth.[7] And in Bihar this range of temperature occurs in eight months (except January-February and November-December). In the Table-1 normals of daily maximum and minimum and daily mean temperature for four respresentative observatory stations (two from the plains and two from the plateau) are given.

Daily maximum temperature is uniformally hight throughout the year above the threshold value of 20°C, while the minimum temperature falls down this value in four months (from November to February). This is the period when rice is not generally grown in Bihar.

2.3.3 Sunshine :

The effect of Sunshine is most pronounced when water, temperature and introgenous nutrients are not limiting. Some varieties are more responsive to Solar radiation than others. Low temperatures accompanied by light Sunshine are most

---

6. Report of the National Commission on Agriculture '<u>Climate and Agriculture</u>' Part IV (1976), p.23.

7. '<u>Rice</u>' - (1980) FAI, New Delhi, p.14.

Table - 1

Normal of Daily maximum, Daily minimum and Daily mean Temperature (^{o}C)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Patna													
Daily maximum	23.6	26.3	32.9	37.6	38.9	36.7	32.9	32.1	32.3	31.9	28.9	24.9	31.6
Daily minimum	11.0	13.4	18.6	23.3	26.0	27.1	26.7	26.6	26.3	23.0	16.1	11.7	20.8
Daily mean	17.3	19.9	25.8	30.5	32.5	31.9	29.8	29.3	29.3	27.[illegible]	22.5	18.3	26.2
Darbhanga													
Daily maximum	23.6	25.9	31.7	35.9	36.4	34.5	32.4	32.1	32.2	31.4	28.7	25.2	30.8
Daily minimum	10.0	11.6	16.3	21.3	24.7	23.0	26.2	26.2	25.8	22.3	15.2	10.8	19.7
Daily mean	16.8	18.8	24.0	28.6	30.6	30.3	29.3	29.2	29.0	26.9	22.0	18.0	25.3
Ranchi													
Daily maximum	23.6	25.9	31.2	35.9	37.9	34.2	29.1	28.9	29.2	28.6	25.7	23.7	29.6
Daily minimum	9.9	12.2	16.7	21.1	24.0	23.9	22.6	22.4	21.9	18.5	13.0	9.9	18.0
Daily mean	16.8	19.1	24.0	28.5	31.0	29.1	25.9	25.7	25.6	23.5	19.4	16.8	23.4
Chaibasa													
Daily maximum	26.5	29.2	34.7	38.9	40.5	36.7	31.7	31.4	31.7	31.0	28.5	26.6	32.3
Daily minimum	12.0	14.4	19.3	24.1	26.8	26.7	25.3	25.0	24.7	21.6	15.4	11.7	20.6
Daily mean	19.3	22.8	27.0	31.5	33.5	31.7	28.5	28.2	28.2	26.3	22.0	19.2	26.6

Source: National Commission on Agriculture (1976), Rainfall and Cropping pattern, Bihar, vol.III desirable since the ripening period is prolonged, resulting in a greater accumulation of total radiation.

Mostly rain-fed rice is grown during the rainy season solar energy is frequently limiting due to higher incidence of clouds resulting in minimum yields. Only where irrigation is possible can rice be planted at a date which will result in the ripening period coinciding with a period of high global solar radiation during the dry season.

Paddy plant is a lover of the heat and moisture and it mostly grows during June-July to November-December in Bihar. And if we look at the table 2 we find that the all cloud amount is very high during these months in all four representative stations of Bihar. The July and August cloud amount of all the stations (Gaya, Motihari, Darbhanga, and Chaibasa) is more than 6.1. Even in September and October when rice crops are more responsive to solar radiation, the cloud amount is more than 5.0 (in September) in all the four stations. So, we can conclude that solar energy is frequently limiting during the period of optimum growth of rice in Bihar, resulting in minimum yields of rice.

2.3.3 Wind

'A light wind is said to be beneficial as it stirs the air and transports Co_2 to the leaf canopy.'[8] There are

8. Robertson, Op. Cit., p.12.

Table - 2

CLOUD AMOUNT
Based on observation from 1931-1960

Months		Gaya (All clouds)	Motihari (All clouds)	Darbhanga (All clouds)	Chaibasa (All clouds)
Jan.	I	2.2	2.0	1.8	2.3
	II	2.0	1.9	2.0	2.6
Feb.	I	1.5	2.0	1.9	2.2
	II	1.8	1.4	1.7	2.8
Mar.	I	1.6	1.3	1.5	2.3
	II	1.7	1.1	1.3	2.8
Apr.	I	1.0	1.3	1.6	2.7
	II	1.8	1.2	1.4	4.0
May	I	1.5	1.7	2.5	3.6
	II	1.9	1.4	1.8	5.4
Jun.	I	4.3	4.8	5.3	6.4
	II	4.0	3.7	3.9	7.2
Jul.	I	6.1	6.2	6.7	7.3
	II	6.4	5.4	5.3	7.5
Aug.	I	6.2	6.3	6.5	7.3
	II	6.6	5.6	5.3	7.5
Sep	I	5.4	5.1	5.4	6.3
	II	5.7	4.4	5.3	7.0
Oct.	I	2.5	2.0	2.4	3.8
	II	2.7	1.5	2.0	4.6
Nov.	I	1.1	0.7	0.9	2.2
	II	1.3	0.6	0.7	2.6
Dec.	I	1.1	1.1	1.0	1.7
	II	1.3	0.9	1.0	2.2
Annual	I	2.6	2.9	3.1	4.0
	II	3.2	2.4	2.6	4.6

I = Taken at 8.30 A.M.
II = Taken at 5.30 P.M.

(Oktas of Sky)

so many demerits of strong winds for the growth of rice i.e. during pollination strong winds may induce sterlity and increase the number of abortive endosperms, ripening plants may suffer severe grain shattering, certain leaf diseases may be spread more rapidly etc.

On the whole wind is an unimportant factor in rice production.

2.3.4 Rainfall

The major limiting factor in growth and yield of rice is rainfall. The signal of rain is the signal for paddy cultivation, as the plant germinates in muddy watery fields and is transplanted under flooded conditions. Low-lying tracts which hold water till about October are admirably suitable for its cultivation. Rice is susceptible to the vagaries of the monsoon rainfall. The rainfall in the asterism of adra (mid June) and Hathia (early October) are inevitable for its transplantation in proper period and for development of juice and life in the paddy plant respectively. The failure of rain in adra denies the peasants of a good return whereas the failure of Hathia rains means death to the plant.

The total water requirements for rice crop are therefore quite high throughout the growing season ranging from 1,000 to 3,000 mm for wet season crops and from 700 to 2500mm for dry season crops requiring 120 days from transplanting to maturity.[9] The efficiency of water use in rice paddies varies widely from 30 per cent during the wet season to 70 per cent in well managed systems during the dry season.

Map No. 4 shows the mean annual distribution rainfall in Bihar. The annual total rainfall is 1,000 mm to 1,500 mm except for a pocket near Patna, which gets slightly less than 1,000 mm and in the extreme south-west and north-east, where the amounts exceeds 1,500 mm.

The normal monthly and annual rainfall along with CV are shown in the table 3. Plateau area is more rainy than the plains. July and August have practically the same averages, CV in August is less than that of July for plateau but practically the same for the plains. When the whole subdivision is considered the annual CV for plateau is only 11 per cent showing the small order of variability.

Rainfall of January-February is generally less than 5 per cent of annual rainfall. During March to May, rainfall is less than 5 per cent in the western districts of Patna, Gaya, Shahabad, Saran, Palamau and western part of Hazaribagh and 5 to 10 per cent in other areas. June to September are months of heaviest rainfall accounting for 80 to 85 per cent of annual rainfall. October-December is 5 to 10 per cent of annual average. Here, the main features of monthly, seasonal and annual rainfall are considered (fig.5).

---

9. Robertson, Op. Cit., p.9.

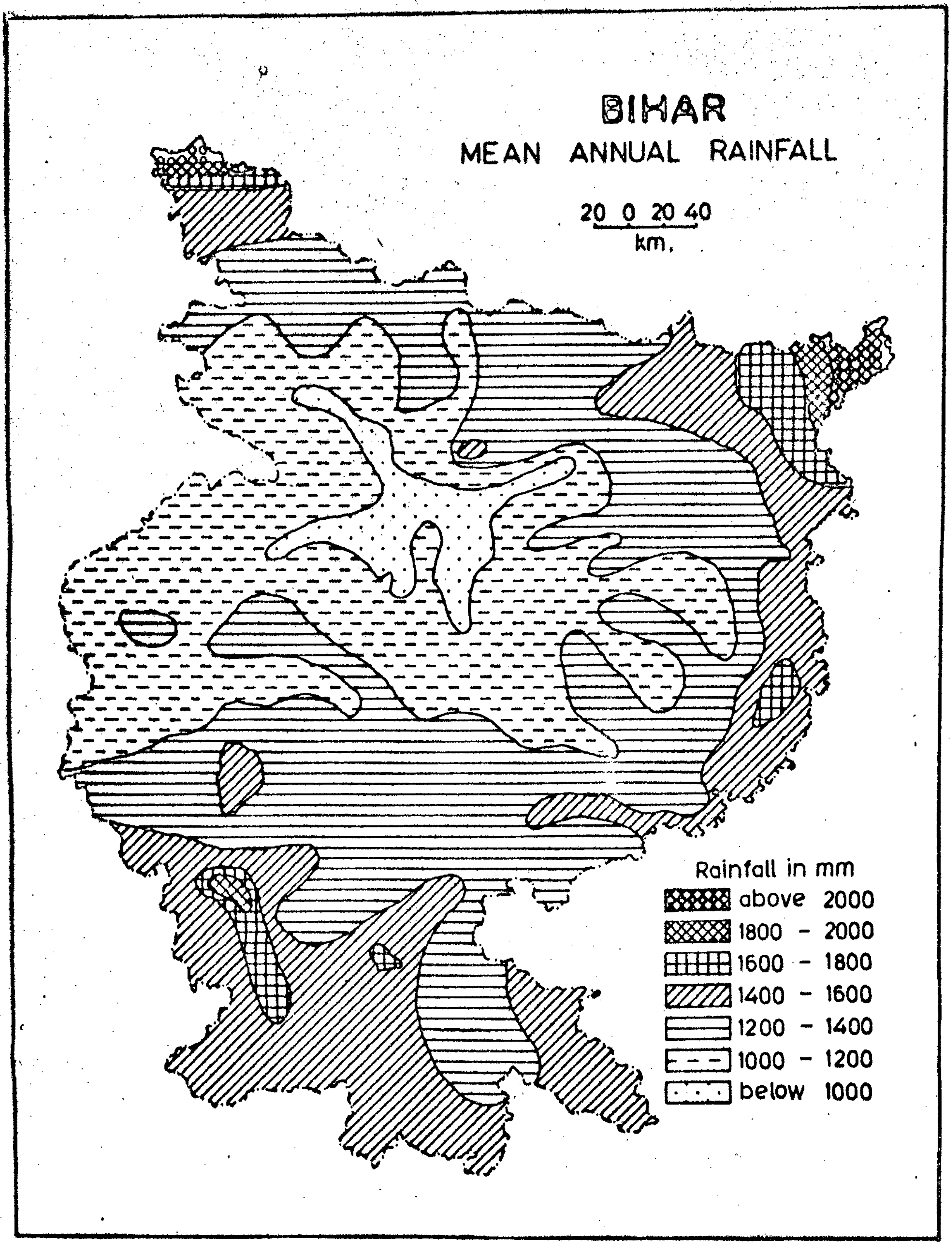

BIHAR
MEAN ANNUAL RAINFALL
20 0 20 40
km.
Rainfall in mm
above 2000
1800 - 2000
1600 - 1800
1400 - 1600
1200 - 1400
1000 - 1200
below 1000

Fig. 4

Table - 3

Normal Monthly and Annual Rainfall and Coefficient of Variation

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Plateau													
R.F.	2.1	3.1	2.0	1.9	5.1	19.6	35.8	34.4	21.8	8.3	1.6	0.5	137.2
C.V.	111	92	108	83	60	43	25	18	29	83	168	203	11
% of Annual R.F	1.5	2.3	1.6	1.4	3.7	14.3	26.1	25.8	15.9	6.0	1.2	0.4	
Plains													
R.F.	1.4	2.0	1.1	1.6	4.8	17.2	31.1	31.4	22.5	5.9	0.9	0.4	120.3
C.V.	106	90	120	103	55	49	27	26	35	91	196	241	14
% of Annual R.F.	1.2	1.7	0.9	1.3	4.0	14.3	25.9	26.1	18.7	4.9	0.7	0.3	

R.F. = Rainfall in cm.

C.V. = Coefficient of variation (%) of Rainfall

Source: Nat. Comm. on Agri., vol.III

June - September : July rainfall in most of the southern half of the plains is less than 30 cm. and it rises to 40-50 cm. south of Ranchi and in the north-east. August rainfall is similar with reduced areas of less than 30 cm. to a small belt to the north of Patna and higher than Patna 40 cm. in the south-west and north-west. Rainfall diminishes significantly in September (20-30 cm.).

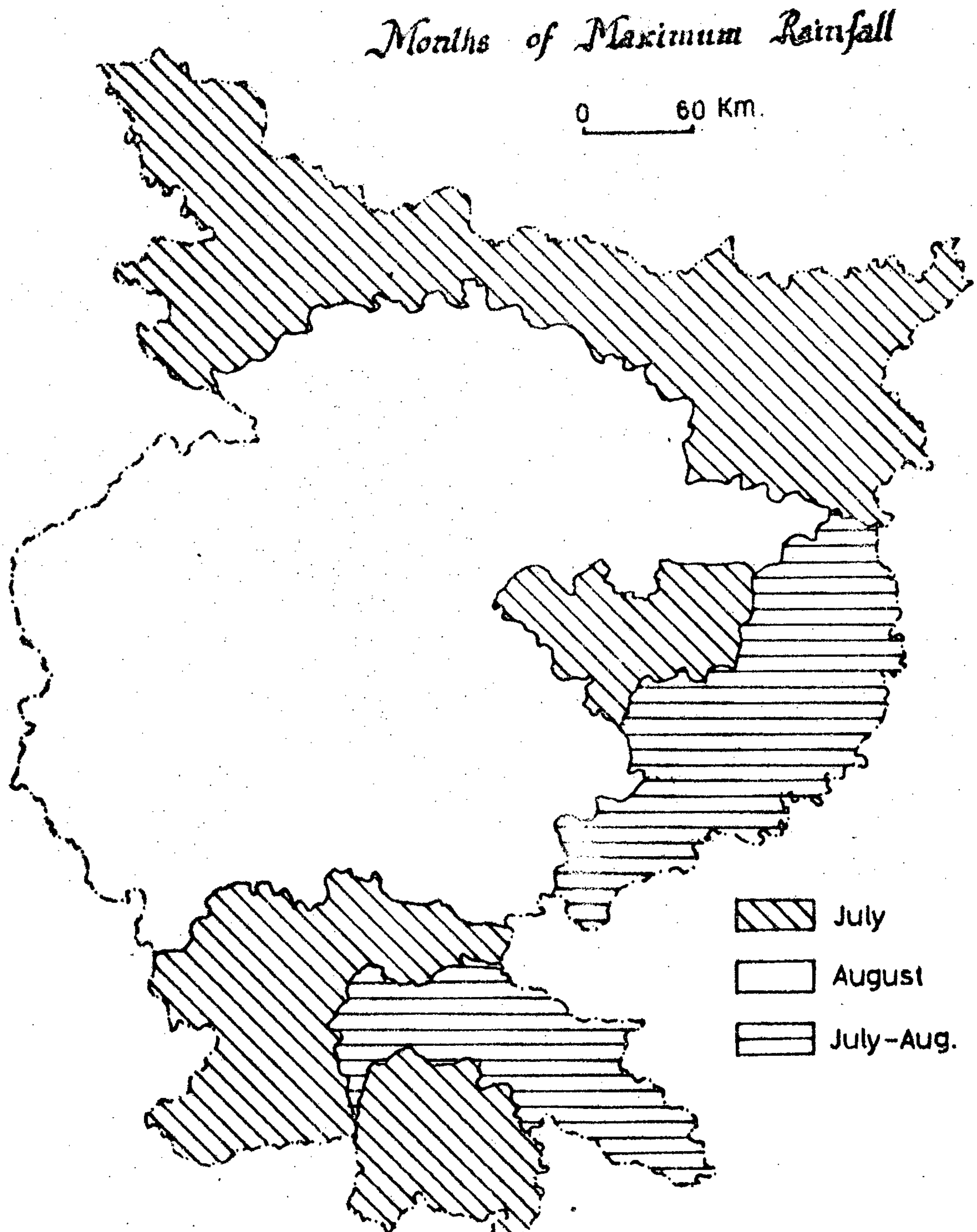
October - December : Rainfall in October is 5 to 10 cm. excepting a small area near Patna, which gets less than 5 cm. November rainfall is less than 1 cm. in the northern half of the plains and 1 to 2.5 cm. elsewhere. Rainfall in December is negligible. The seasonal total rainfall is mostly between 5 to 10 cm.

Rainfall Pattern : The National Commission on Agriculture[10] has identified on the basis of monthly rainfall zones in Bihar. Letter symbols are used to indicate the ranges of monthly rainfall and the sub-scripts to these refer to the number of months having these ranges of rainfall (fig.6).

Code for Rainfall data

Symbol	Monthly rainfall in cm. per month
A +	Greater than 30
B	20 - 30
C	10 - 20
D	5 - 10
E	Less than 5

10. National Commission on Agriculture (1976), 'Rainfall and Cropping Patterns', vol.III, Bihar, Government of India , Ministry of Agriculture & Irrigation, N.Delhi, p.2.



Source: National Comm. on Agri., Vol. III.

Fig. 5

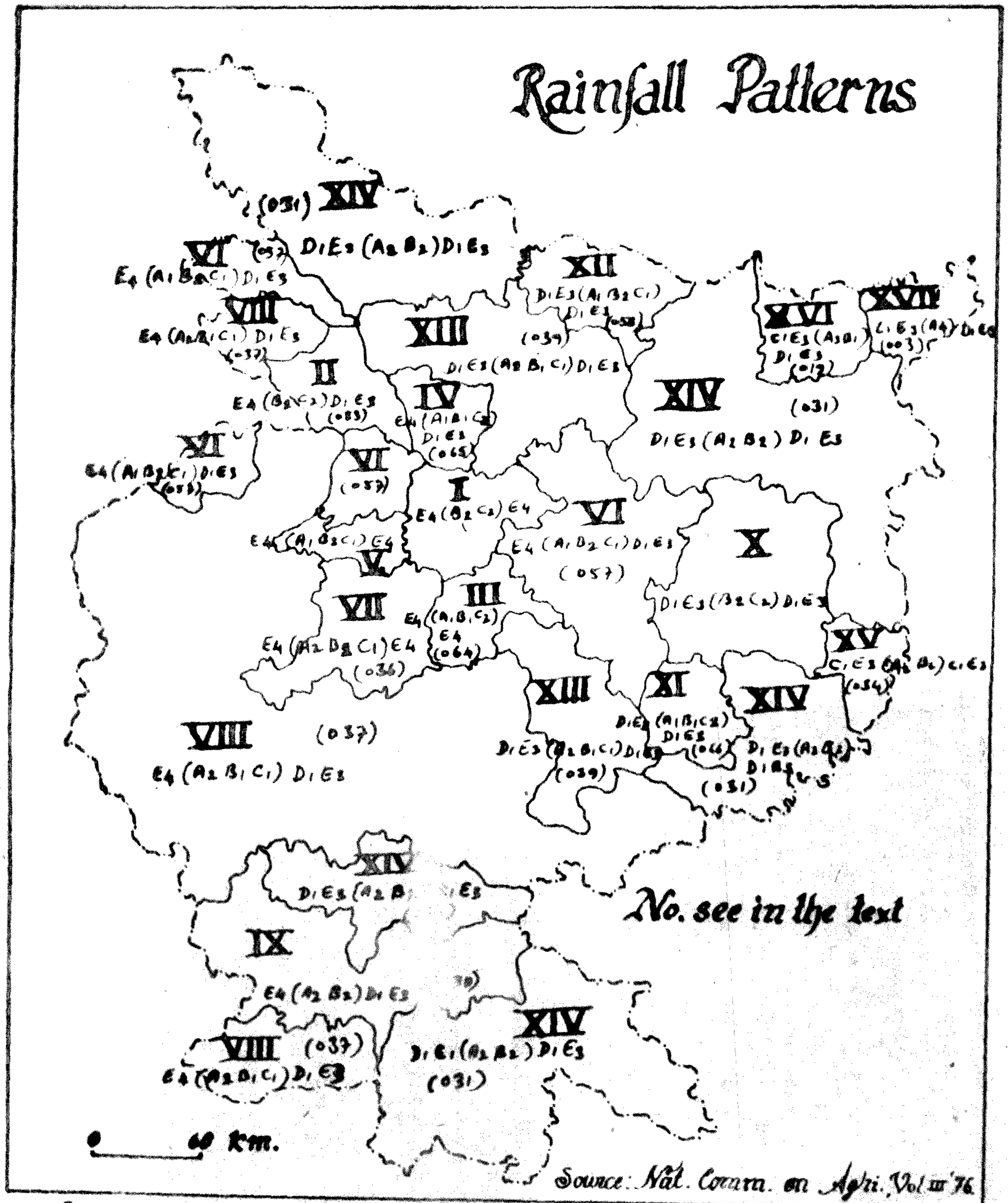

Rainfall Patterns
XIV
VI
VIII
XII
XIII
XVI
XVII
II
IV
I
V
VII
III
X
XV
XI
IX
No. see in the text
0 60 Km.
Source: Nat. Comm. on Agri. Vol III '76

Fig. 6

The rainfall zones are shown in fig.6. The National Commission on Agriculture further adds that rainfall greater than 30 cm. per month for atleast three consecutive months would be suitable for a crop like paddy, where water need is very high. This criteria is satisfied only in the Purnea district. Rest of Bihar according to this report, do not receive adequate rainfall for paddy cultivation, thereby necessiating the irrigation.

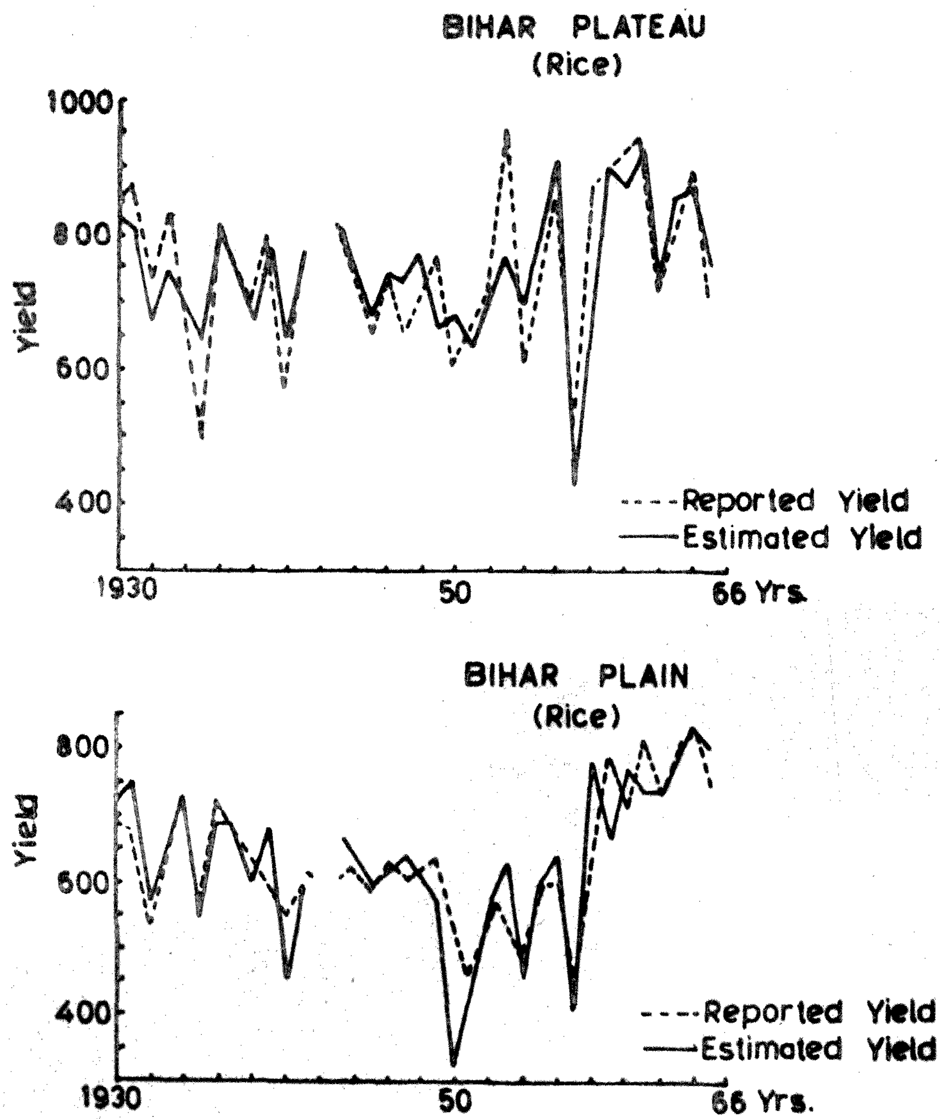
Models for Rice Yield on the basis of weather:

Studies were carried out in order to find out the characteristics of rainfall pattern which have greater influence on the paddy yield.

The study by Das and Mehara (1971) reveals that the fainfall during the period 16 September to 15 October is highly beneficial for rice crop in these areas and there is an increase of 10 to 28 lbs approximately in yield for each of rainy days during the period upto a maximum of 8 to 10 days. Absence of rain continuously for 10 days or more adversely affects the yield.[11] A long series of data from 1930 to 1966 was used to establish regression equations for Bihar plateau and Bihar plain (Das and Mehra 1971) (fig.7).

---

11. J.C.Das & A.K.Mehra (1971) - 'Forecasting the Yield of Principal Crops in India on the basis of Weather: Paddy/Rice (Gangetic, West Bengal & Bihar).' Meteorol. Monog. Agrimet. No.1, part.III, I.M.D., Poona, p.14.



Source: Meteorol. Monogr. Agrimet. No. 1, Part II, I.M.D. Poona, pp. 14-38.

Fig. 7

Total six districts viz. Hazaribagh, Ranchi, Palamau, Dhanbad, Singhbhum and Santhal Parganas constitutes the region Bihar Plateau, having the six observatory stations. And following four independent variables have been taken into consideration :

X_2 = Rainfall during the period 13th to 23rd June

X_3 = Rainfall during the period 5th to 15th July

X_4 = No. of occasions of drought* in July and August

X_5 = Rainy days during the period 16th September to 15th October.

Rest all the 11 districts of north and south of the Ganga have been taken in Bihar plain region being 10 representative stations. The independent variables are same as for plateau, but there is little difference in the period i.e.

X_2 = Rainfall during the 1st to 21st June

X_3 = Rainfall during the 7th to 13th July

X_4 and X_5 are same as for the Bihar plateau. And X_1 in both case is the dependent variable yield (estd.), whereas X_6 is the technological trend.

---

* When there is no day of rainfall more than 1.3 mm. within a continuous period of 7 to 10 days, it has been taken as an occasion of drought marked by dummy figure 1.

Before running the regression they have estimated the yield and a comparision of estimated and reported yields of rice in Bihar plain and plateau are given in fig. 7 which shows almost equal relationship.

Mean (748.5 for plateau and 830.2 for plain) and standard deviations (117.4 for plateau and 116.2 for plain) are same for both the regressions, but C.V. is high in plain (18 per cent).

The regression equation[12] of Bihar plateau for all the six independent variables are significant at 99 per cent level of confidence. And all in combination explaining 70 per cent contribution in the variation of estimated rice yield. Whereas in Bihar plain it is explaining 70.4 per cent contribution. And again in Bihar plain the regression equations[13] are significant at 99 per cent level of confidence, due to the

---

12. X_1 (Estd.) = $717.841 - 5.577\, X_2 + 19.187\, X_3 - 40.088\, X_4 +$
$\quad (2.12) \quad (2.39) \quad (2.79)$
$19.812\, X_5 + 12.003\, X_6$
$\quad (3.37) \quad (4.08)$
$\bar{R}^2 = 0.709$

13. X_1 (estd.) = $594.064 - 8.748\, X_2 + 12.187\, X_3 -$
$\quad (2.03) \quad (2.13)$
$39.201\, X_4 + 19.240\, X_5 + 20.574\, X_6$
$\quad (2.61) \quad (3.29) \quad (4.76)$
$\bar{R}^2 = 0.704$

high degree of freedom.

Finally, Das and Mehra (1971) have concluded on the basis of correlation coefficient result° that independent variable X_5 (rainfall during 16 September to 15 October) is highly beneficial for rice crop. And if we look the table 1 (where the coefficient of variation is given for Bihar plain and plateau) we find that C.V. is very high in these two months i.e.

	July	August	September	October
(a) Plateau	25	18	29	83
(b) Plain	27	26	35	90

In comparision of July and August the coefficient of variation is very high as well as in June. This high variation in rainfall at critical stages of crop growth necessitate irrigation not for a successfull crop but its more survival.

2.4 The Importance of Irrigation for the Rice Cultivation in Bihar

Rice attains an important place amongst the crops of the State in both acreages and production. It alone shares 62.2 per cent of total sown area of Bihar. But the yield of rice is very low. It is below the all India level in many

° Significant at 0.01 per cent level.

parts of the State. There appears to be very good scope to improve the yield of rice with better water management.

Since the crop like rice requires water throughout the year and the rain is uncertain, seasonal and irrigular, it is essential to improve irrigational facilities in Bihar. If we take the highly irrigated districts like Patna where the rainfall distribution is not adequate for growing rice but the crop is grown under fully irrigated conditions and the yield is 90 per cent of all India average yield.

On the other hand if we take the example of Purnea district where the rainfall is adequate for growing a crop like rice but the irrigation is available only 20 per cent of the total area under rice, which resultant to the low yield. It is only 45 per cent of all India average yield. So wherever assured water is available there the variation in the yield and production of rice will be low, and the yield rate will be also high.

Thus, we have seen in above examples that the most common means of increasing the yield and production of rice is irrigation. The technological inputs like fertilizer etc can not put without water. So, the irrigation frees the rice cultivation from the vagaries of rainfall and thereby increases the yield. It also helps to grow more than one crop of rice.

2.3 Conclusion :

Environmental conditions are very favourable for the cultivation of rice throughout Bihar. More than 50 per cent of the State area is highly productive alluvial plain, interspersed with numerous rivers. Even in the plateau level lands occur, where rice is grown extensively. Located in tropical latitudes, day temperatures are optimal for growth of rice throughout the year, while night temperature in four months from November to February may fall occasionally below the optimal requirement. Sunshine may be wanting sometimes in the months of July and August, but plenty in the rest of the year. Rainfall is adequate interms of quantity but unreliable in time. Occurrence of adequate rainfall from 13th to 23rd June, from 5th to 15th July and from 16th September to 15th October is very crucial for optimal growth of paddy. But in these periods the rainfails frequently. Irrigation is, therefore, a must for sustaining, leave alone increasing, the rice production.

C H A P T E R - III

IRRIGATION IN BIHAR

CHAPTER - III

IRRIGATION IN BIHAR

3.1 Importance of Irrigation in Bihar

Next to air, water is the most vital for plant and animal life. The critical role of water for intensive agricultural production hardly needs to be emphasized. Irrigation and drainage are processes which aim at the maintenance of soil moisture within the range required for optimum plant growth.[1] There are many parts of the world where the moisture available in the soil from rain, or from underground waters, is not sufficient for the requirement of plant life, either all the time, or in a particular crop season when it is necessary to provide extra water which enables the soil to keep the required moisture for plant growth. Such artificial application of water to land for growing crops or trees is called irrigation.[2]

The largest use of water in the world is for irrigating lands, as an agricultural input, specially for the

---

1. FAO/UNESCO - 'Irrigation Drainage and Salinity' An International Source Book, 1973, Hutchinson. p.1.

2. C.Gopinath (1976) - Problems and concepts in Irrigation Use Seminar on - 'Role of Irrigation in the development of India's Agriculture'. The Indian Society of Agricultural Economics, Bombay, p.6.

production of foodgrains. For the growth of plants, water must be available in the appropriate quantities and at the right time, depending on the species of plant and climatic conditions. Crops like rice need larger quantities than the crops like wheat and other cereals. Even dry farming technology depends upon the moisture retained in the soil by conserving the scanty rainfall through the construction of small bunds.

Agriculture is a gamble in most parts of Bihar due to the uncertainty of the rains, which even in normal times is inadequate.[3] Irrigation is, therefore, vital to stablise agriculture and augment production for all areas where the rainfall is seasonal and irregular.

The state needs irrigation, because the rainfall is varying periodical and irregular. It is also not uniformally distributed. A large part of the North Ganga Plain receives greater rainfall than the South and the overspill of rivers accounts for the maintenance of moisture. The districts of Saran and Champaran are comparatively dry. Rain is less and the rivers are embanked which necessitates irrigation in these areas.

The rain in the western part of the South Ganga is less and variation is also greater than in other parts of

---

3. E. Ahmad, - '<u>Bihar</u>' University Press Ranchi 1961, p.91.

Bihar. Overspill of rivers is nominal and the drainage is rapid. Irrigation therefore attains importance in the sphere of agriculture. Crops like rice and sugarcane require water throughout the year and the rabi or winter rain is variable. The Son canal system accounts for canal irrigation in Shahabad and Western Gaya and Patna. To meet the deficiency of moisture during unrhythmical behaviour of the monsoon, indigenous systems of irrigation works like ahars, pynes, tanks, wells are extensively practicised.

Highlands of Bihar are also not immune from the variability of the monsoon; and hence rivers on account of steep gradient drain off quickly. Contour irrigation and damming of small stream make up the water deficit due to vagaries of the monsoons.

One of the most common means of increasing the production or the yield, is irrigation. Irrigation frees the rice cultivation from the vagaries of rainfall and thereby increases the yield. It also helps to grow more than one crop of rice. Besides directly affecting the area and yield, irrigation also provides the base for putting more modern inputs, interms of fertilizer, high yielding variety.

3.2 Development of Irrigation in Bihar:

Bihar is endowed with good water resources and apart from the Ganga, it has a number of major rivers flowing through it, among these are the Kosi, the Gandak, the Ghaghra, the Son, the Damodar and the Subarnarekha.

During the period of control by the East India Company, little was done to improve irrigation facilities inspite of a number of famines. When India came under British Crown in 1858 a series of terrible famines occurred. The attempt to curb the high cost of combating such disasters led to the rapid expansion of irrigation.

There were only four pre-independence irrigation Project viz; the Son river project, the Tribeni canal project, the Dhaka canal project and the Tour or Tirhut canal project.

Work on the Son canals commenced only in 1869 and was completed in 1876 at a cost of Rs. 26.82 million to benefit an area of 347, 230 hectares in the district of Patna, Gaya and Shahabad.[4] The project comprised a weir across the Son at Dehri with a left bank and a right bank canal.

---

4. Report of the Irrigation Commission 1972, vol.II, Ministry of Irrigation and Power, New Delhi, p.57.

To protect a precarious tract in the Champaran district to the north of the Gandak, the Tribeni canal was taken up in 1897, to begin as a relief work. It was completed in 1914 at a cost of Rs. 8.16 million and benefited 48,160 hectares. Originally conceived as a single canal, 98 km. long taking off from the Gandak just below the boundary of India and Nepal. Like the Tribeni, the Dhaka canal from the Lalbakeya river was also taken up in 1897 as a relief work to irrigate about 6,420 hectares. The Tour or Trihut canal was constructed in 1878 to irrigate 1,620 hectares.

3.2.1 Development of Irrigation upto 1960-61 :

No significant major irrigation works were taken up till independence. Whatever increase in irrigated area was mainly due to tubewell. Hence at the time of independence barely 0.2 million hectares of cultivated area was irrigated. The increase in irrigated area was due to tubewell irrigation (16.08 per cent) and irrigation from other sources (35.80 per cent). On the other hand there was a marginal decrease (-0.84 per cent in area irrigated by canal and subsequently decrease (-18.41 per cent) in the case of area irrigated by tanks.

After Independence, ambitious ventures, with tremendous irrigation potential have been taken up, like the tamming up of the Kosi which has been called 'Bihar's river of sorrow', and the construction of a barrage at Valmikinagar on the Gandak etc. During the First Five Year Plan period, the total area of Bihar was 182 lakh hectares out of which the net area cultivated was 90 lakh hectares. The area under assured irrigation before the inception of the First Plan was approximately 2 lakh hectares, which works out to approximately 3.4 per cent of the total cropped areas as compared to 6.8 percent for all Part A States and the All India average of 5.3 per cent.[5]

According to the original plan 2 lakh hectares were expected to be brought under irrigation. Against this means of irrigation have been provided over an additional area of 2.26 lakh hectares, besides about 0.416 lakh hectares brought under irrigation by schemes out side the plan. The development of irrigation from tube-wells and emergency river pumping schemes has been rather slow in comparison with earlier expectations. This is partly due to irrigation schemes being in the earlier state of development, and partly because of favourable rainfall. On the other hand due to devastation caused by repeated and heavy floods, demand for

---

5. Planning Department - Report of First Five Year Plan, 1951-56, Government of Bihar, Patna, pp.78-88.

more and more flood control measures poured in and as a result, the activities of the department had to be accelerated on flood control schemes.

In the Second Plan a special drive was launched to accelerate the progress under irrigation. During the First Plan new irrigation potential of 1.86 lakh hectares was created through major and medium irrigation schemes. Out of which 1.07 lakh hectares actually utilised the available water by 1955-56. The Second Plan target was (i) to create a further potential of 3.45 lakh hectares hectares through the major and medium irrigation schemes (ii) to bring 2.45 lakh hectares (including 0.797 lakh hectares in respect of the unutilised potential of the First Plan) from the major and medium irrigation schemes. On the completion and full development the irrigation schemes of Second Plan was benefited about 4.91 lakh hectares.

Thus, if we look at fig.8 showing the trend of gross irrigated area (1940-41 to 1960-61), we can conclude that gross irrigated area over this 21 years an increased marginally. Beginning of the First Plan (1950-51) has responded maximum area (2264 thousand hectares) under irrigation. And the last year (1960-61) has shown increasing trend.

DEVELOPMENT OF IRRIGATION IN BIHAR

(From 1940-61)

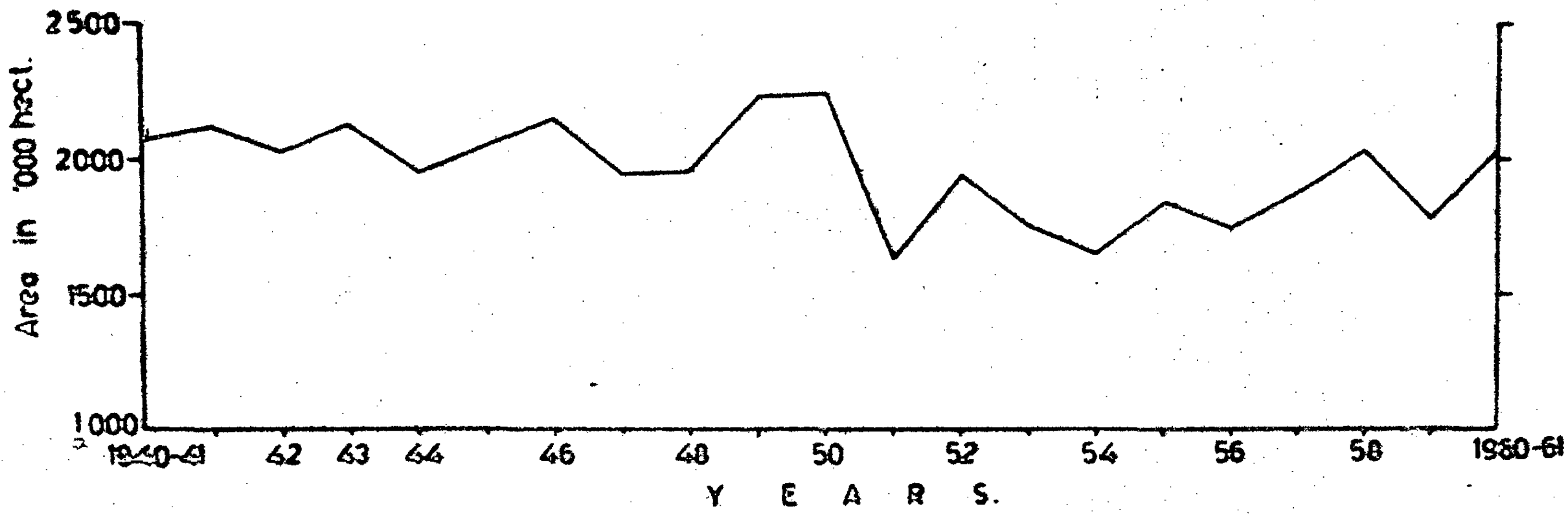


Fig. 0

3.2.2 Irrigation Development in Bihar during the Study Period (1961 to 1973) :

Our study period begins with the Third Plan and in the Third Plan, there was a definite shift of emphasis towards the major irrigation schemes. As a result, assured irrigation facilities have been extended to an additional area of about 2.42 lakh hectares. The irrigation potential created and utilised in major and medium irrigation schemes. By the end of the Third Plan 9.18 lakh hectares irrigation potential had been utilised. In the Annual Plan emphasis was given to the execution of medium and minor irrigation schemes. The total target during the Annual Plan was 4.50 lakh hectares but the assured irrigation facilities were extended to an area of 2.50 lakh hectares only. And at the end of the Fourth Plan irrigation potential through major and medium schemes was created in 15.79 lakh hectares. The potential, however, was utilised in 10.33 lakh hectares. The State's Fourth Plan accepted the need for providing irrigation facilities to a large area.

To have a clear grasp, it is essential to analyse GIA, NIA and different sources of irrigation. Fig.9 shows the Gross and Net irrigated sources of irrigation is based on that. Graph is showing the clear picture of the behaviour of irrigation during the study period. There is a clear-cut increasing trend in Gross irrigated area and Net irrigated

IRRIGATION DEVELOPMENT IN BIHAR

During Study Period

1961-73

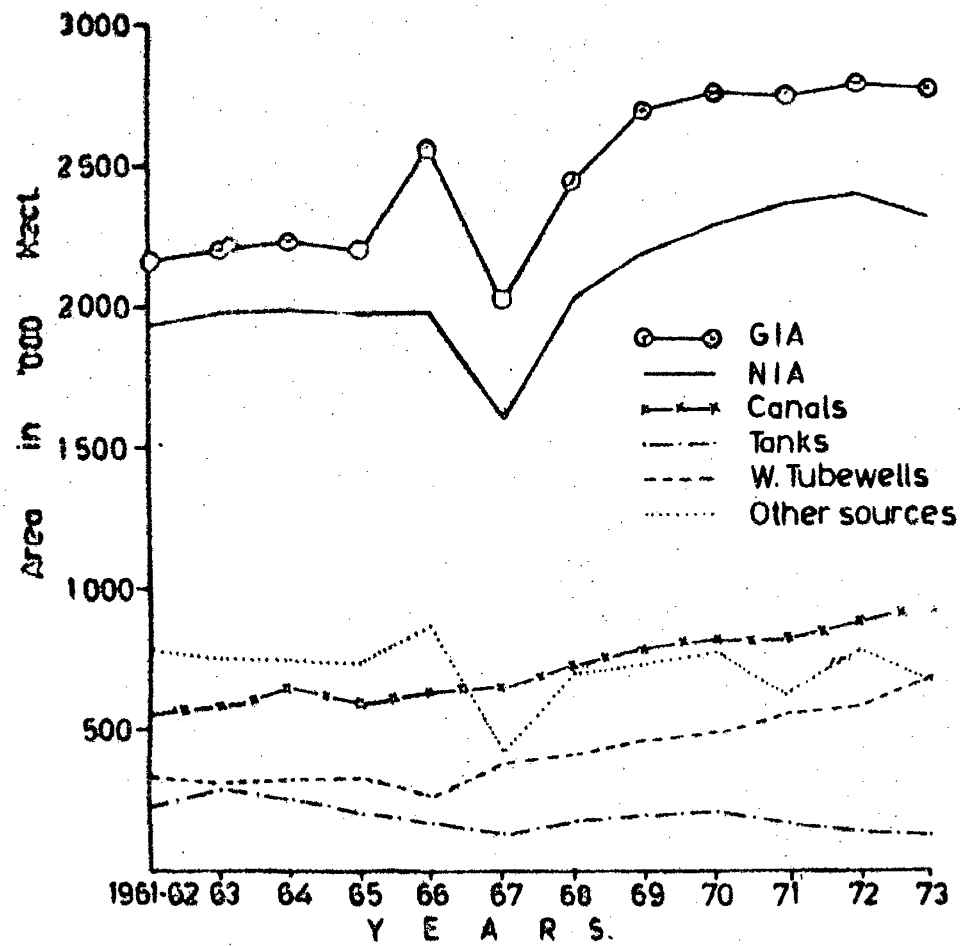


Fig. 9

area, except the year 1966-67 because in this year there was a severe drought in Bihar. The line of net irrigated is following the same trend. The gross irrigated area has shown the change of 582 thousand hectares over the period 1961-62 to 1972-73, whereas the NIA has shown 334 thousand hectares.

Among the sources of irrigation canal and well and tube-well irrigation have shown continuously increasing trend. Both the sources of irrigation (canal and well and tube well) have responded increasing trend even in the drought year, and it is obvious because these are the only sources which can be utilised during the drought period. Tank and other sources of irrigation have shown decreasing trend over this period.

The area irrigated by tank decreased by 1,13,000 hectares and by other sources by 2,58,000 hectares. Thus, it is essential to see the distribution and Growth of irrigation in the districts.

3.3 Growth of Irrigation in Bihar during the Study Period 1961-62 to 1972-73 :

It is a generally accepted fact that the benefits of the new agricultural strategy based mainly on the High Yielding Varieties and intensive use of fertilisers have not spread evenly across the country. This has even led to widening of gaps between the rich and the poor areas. Since the new technology in agriculture requires assured irrigation, it is safe to assume that a major part of State's investment in agriculture has gone into developing this important resource. The growth and utilization of this resource thus needs to be closely examined. In this chapter we will examine the growth of irrigated area, growth in different sources of irrigation. The analysis is undertaken for individual districts so that one can probe into the possible reasons for the resultant State behaviour.

The analysis is mainly based on the compound Growth rates and linear rates of increase, calculated by regression method. While the compound growth rates reflect the strength of any movement, the linear rates of increase which are in actual (rather than percentage) terms, show us the impact of such movement, free from the magnitude of a given series. Besides, the linear rates are additive (as we shall see later) and are less sensitive to terminal values. Indeed, with the district as the unit for analysis, for a given characteristic we get districtwise series of different magnitudes and if one were to rely only on the compound growth rates, comparison of such growth rates is likely to be misleading. For example, Saharsa district shows the highest compound growth rate of 70.0 per cent per annum for the gross irrigated area and a linear increase of over 101.60 hundred hectares per annum. On the other hand, Shahabad district has a very low growth rate of 2.9 per cent per annum but has the highest linear increase per annum in the state of 176.44 hundred hectares. Purnea district has a share of less than 4.0 per cent (in the state) while Shahabad district is 25.48 per cent. Thus although the growth rate would be relevant for a given district for the consideration of the impact of that movement on the state as a whole the linear rates are highly useful. The data for the state for the twelve year period are presented in table 4 along-with indices, compound growth rates and linear rates of increase. Here one can see that the compound growth rates for the gross and net sown area (GSA and NSA) are -0.28 and - 0.02 per cent per annum showing small decline or near stagnancy whereas gross irrigated area (GIA) and the net irrigated area (NIA) show positive growth rates of 2.8 and 2.1 per cent per annum respectively. Thus irrigated area shows a clear increase as against small decline (or stagnation) in total area. The stagnation in the net sown area (NSA) indicates that the frontiers of cultivation have more or less been reached.

From the last two columns one can see that 23 to 28 per cent of net sown area or 20 to 26 per cent of gross cropped area is irrigated. Though, these percentages are

Table - 4

Gross cropped area, Gross irrigated area and their break-up into Net for Bihar (1961-62 to 1972-73)

(in Hectare)

Year	Gross cropped area (GCA)	Net sown area (NSA)	Gross irrigated area (GIA)	Net irrigated (NIA)	NIA/NSA (%)	GIA/GCA (%)
1961-62	11133412 100.00	8350111 100.00	2080225 100.00	1942657 100.00	23.26	19.63
1962-63	1108297 99.53	8341517 99.92	2203917 105.94	1984555 102.15	23.78	19.88
1963-64	11049152 99.24	8546702 102.35	2226422 107.02	1999307 102.91	23.39	20.15
1964-65	10831647 97.28	8544719 102.33	2207628 106.12	1980135 101.92	23.27	20.38
1965-66	10759933 96.65	8338337 99.85	2251119 108.21	19991281 102.50	23.88	20.92
1966-67	9225060 82.85	7422399 88.88	2010431 96.64	1600783 82.40	21.56	21.79
1967-68	10895694 97.86	8284276 99.21	2464344 118.28	201132 10.35	24.27	22.58
1968-69	10933164 98.22	8324745 99.69	2697439 129.67	2174011 111.90	26.11	24.50
1969-70	11063347 99.37	8395694 99.45	2740851 131.75	2279018 117.31	27.14	24.77
1970-71	11026513 99.03	8454359 101.25	2732602 131.35	2331999 121.58	27.93	24.78
1971-72	10683931 95.96	8276462 99.11	2788033 134.02	2384090 122.72	28.80	26.09
1972-73	10391739 93.26	8053629 96.45	2768792 133.10	2277779 117.25	28.28	26.63
Compound Growth rate % per annum	-0.28	-0.02	2.8	2.1		
Linear rate of increase Hha/annum	301.78	-155.15	687.48	429.15		

smaller than the all India* level, but it shows that state is having a good irrigation facilities.

3.3.1 Spatial Distribution of Gross and Net Irrigated Areas: Important Irrigated Regions :

Before going into the growth aspect, let us examine the distribution of this important resource of irrigation over various districts and form important irrigation regions for a detailed analysis. In Table 5 percentage shares of different districts are presented for the first three years together and the last three years together in state NIA and GIA. The irrigation proportion for individual districts is also presented for the initial and end periods in the same table, proportion being based on district GIA/district GCA ratios. Similar district NIA/district NSA ratios are also presented but the ratios do not differ greatly from the gross level ratios and in any case, the ranking of top district does not change.

It is already seen that the irrigated area forms a small proportion of the state cropped area but from the present table we further see that it is distributed rather unevenly over the different districts. Looking at this table 5 and fig.10, one can form three important irrigated regions, viz;

---

* At the all India level this percentage for 1970-71 is as high as 38.60.

Table - 5

Percentage shares of different districts in the State Net Irrigated Area (NIA) State Gross Irrigated Area (GIA) (Average of first 3 years & last 3 years)

Districts	Dist GIA/ DIST GSA		Dist.NIA/StateNIA		Dist.GIA/State GIA		Dist.NIA/Dist.NIA	
	1961's	1971's	1961's	1971's	1961's	1971's	1961's	1971's
Bihar Plain								
Patna	44.23	51.67	13.26	10.85	13.93	11.18	63.92	64.47
Gaya	54.59	61.93	25.86	21.39	27.79	20.15	74.33	77.07
Shahabad	45.75	62.68	22.78	23.17	26.16	25.48	65.05	72.23
Saran	15.35	23.51	4.55	6.28	4.90	5.64	17.94	30.52
Champaran	15.00	23.78	5.23	7.51	5.64	7.69	16.64	29.90
Muzaffarpur	2.95	7.32	0.95	1.78	1.08	2.07	3.19	7.40
Darbhanga	1.42	9.99	0.46	2.68	0.52	2.84	1.53	10.31
Monghyr	21.97	25.28	6.89	5.49	7.66	5.42	24.51	28.78
Bhagalpur	35.32	32.26	5.77	4.54	6.34	5.27	36.63	36.42
Saharsa	0.21	18.58	0.03	2.55	0.03	3.19	0.28	17.75
Purnea	0.17	12.46	0.07	2.92	0.07	3.58	0.23	12.39
Bihar Plateau								
Santhal Parganas	12.78	9.66	4.17	2.23	4.29	2.10	16.11	9.96
Hazaribagh	7.47	6.85	1.05	0.87	1.63	0.83	5.45	6.06
Ranchi	1.67	3.52	0.60	1.03	0.66	0.93	1.77	3.36
Palamau	20.19	21.12	3.48	2.97	3.62	2.61	21.82	24.69
Dhanbad	7.30	3.19	0.32	0.10	0.38	0.10	6.88	3.04
Singhbhum	4.30	5.42	1.20	0.88	0.90	0.07	7.26	7.28

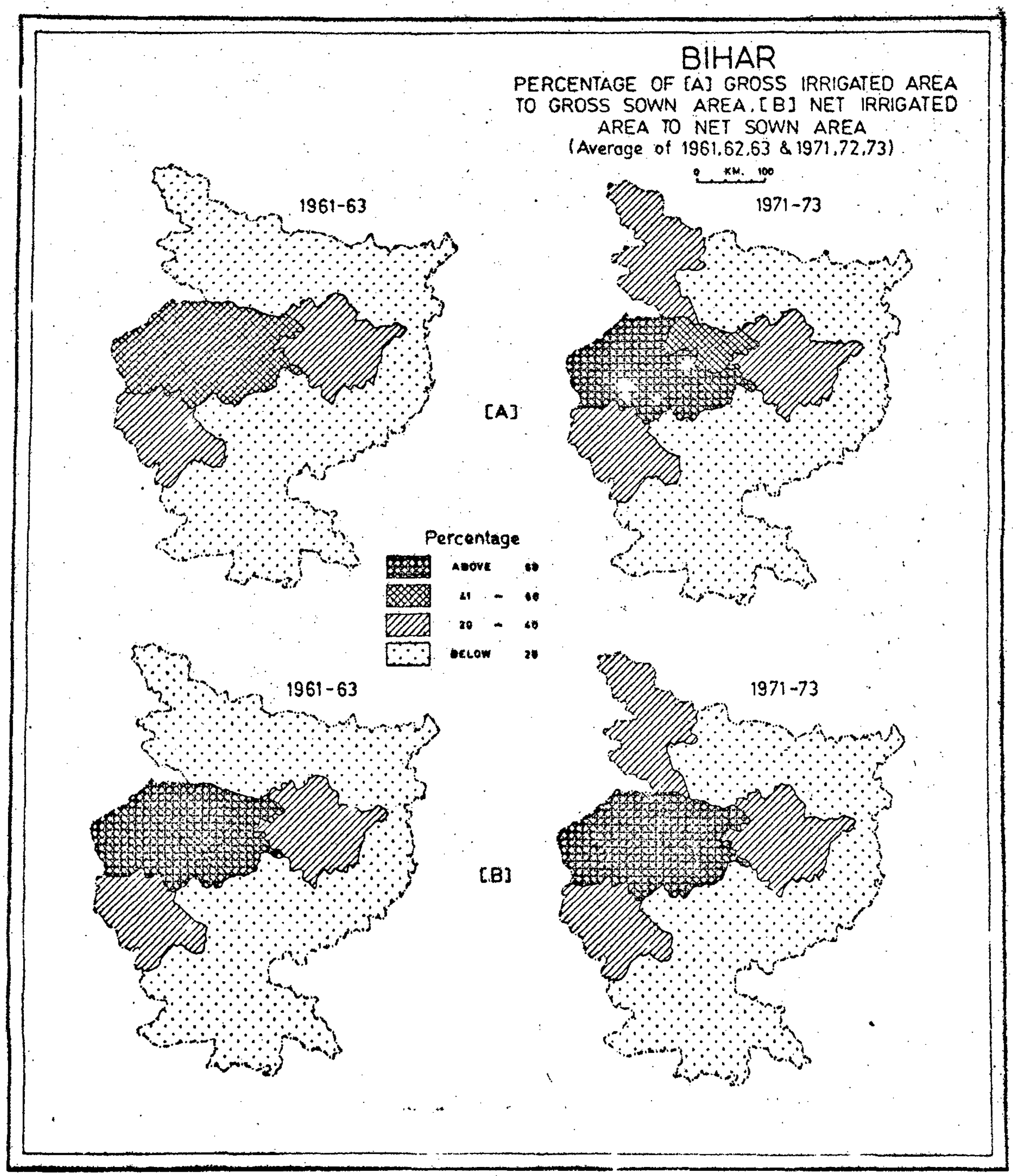

BIHAR
PERCENTAGE OF [A] GROSS IRRIGATED AREA TO GROSS SOWN AREA, [B] NET IRRIGATED AREA TO NET SOWN AREA
(Average of 1961,62,63 & 1971,72,73)
0 KM. 100
1961-63
1971-73
[A]
Percentage
ABOVE 60
41 – 60
20 – 40
BELOW 20
1961-63
1971-73
[B]

Fig. 10

Region I - Highly developed region - having more than 40 per cent of gross sown area irrigated considering the initial period share.

Region II - Moderately developed region - having more than 20 per cent of gross sown area irrigated.

Region III- Least developed region - having below 20 per cent of gross sown area irrigated.

If we look at the map we find three districts, Patna, Gaya and Shahabad (which is in South Bihar Plain) is highly developed region having more than 40 per cent gross irrigated area in initial period and more than 50 per cent in last period. This we denote as Region I. Further the five districts comprising the Saran, Champaran, Monghyr, Bhagalpur and Palamau are sharing about more then 15 per cent irrigated area of their Gross cropped area, and more than 4 per cent share in State Net irrigated area this is Region II. Next in importance are nine, districts of Muzaffarpur, Darbhanga, Saharsa, Purnea, Santhalpurs, Hazaribagh, Ranchi, Dhanbad and Singhbhum which is having less than 10 per cent irrigated area and less than 4 per cent in State share in not irrigated area. This we denote as Region III.

Though, the percentage of gross irrigated to state gross irrigated area has decreased from first three years to last but the districts which is in Region I (three districts only) have registered increase in the districts gross irrigated area. However, this increase is also marginal, due to which Region I has experienced loss in the state share.

Thus, having examined this table 5 we have come to the conclusion that in all respect these three districts Patna, Gaya and Shahabad is most developed region interms of irrigation facilities.

Irrigation in the districts shows wide variation. In the plateau districts except for Palamau, area irrigated is less than 10 per cent of net sown area.

3.3.2 <u>Districtwise Growth in Net and Gross Irrigated Area (1961 to 1973)</u>

A view of Table 6 and Map 11 gives a very clear picture of the district-wise compound growth rates and linear rates of increase in irrigated area for each individual districts. For the consideration of the distribution of increase, linear rates of increase are useful. Growth in Net irrigated area and gross irrigated area is presented in this table. At the state level, the growth rates for net irrigated area and gross irrigated area are 2.1 and 2.8 per cent per annum respectively while the linear rates of increase are 429.15 hundred hectares (Hha) and 637.48 respectively. Between the districts Shaharsa has highest growth rates for both net irrigated area

Table - 6

Compound growth rates* and Linear rates of increase (Hha/annum)** of the irrigated area (1961 to 1973)

Districts	N I A		G I A	
	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase
Bihar Plain				
Patna	0.30	10.47	0.10	29.76
Gaya	0.58	23.96	3.60	75.91
Shahabad	1.68	83.61	2.90	176.44
Saran	6.70	84.73	2.40	48.88
Champaran	6.20	81.31	7.40	110.04
Muzaffarpur	9.40	24.28	11.90	37.54
Darbhanga	28.50	101.93	26.90	78.52
Monghyr	-0.71	- 8.80	-0.44	- 6.22
Bhagalpur	2.00	17.33	1.80	17.91
Saharsa	66.40	68.90	70.00	101.60
Purnea	58.80	79.38	66.00	117.28
Bihar Plateau				
Santhal Parganas	5.52	37.47	5.01	36.58
Hazaribagh	0.10	0.22	1.96	12.43
Ranchi	8.60	14.45	6.10	15.62
Palamau	-0.12	- 1.08	-0.53	- 4.54
Dhanbad	-3.49	- 1.79	-10.44	- 5.58
Singhbhum	-9.67	-90.22	-1.42	- 3.28

* % per annum

NIA = Net Irrigated Area

GIA = Gross irrigated Area

** Hundred hectare/annum

COMPOUND GROWTH RATES

(1961-62 TO 1972-73)

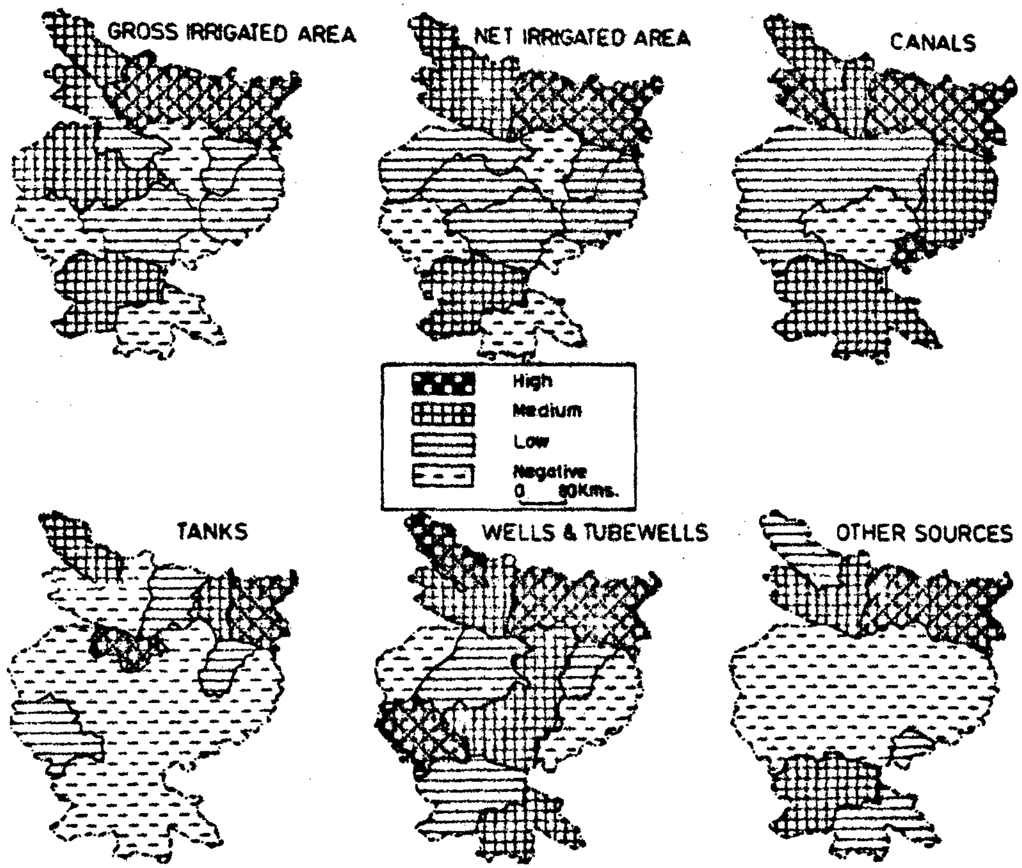


Fig. 11

and gross irrigated area but in linear terms, it ranks much lower (6th for NIA) and thus in terms of 'impact' on the state it is not significant. Same is the case with Purnea district. High compound as well as linear are noticeable for the three districts, Darbhanga (28.50 and 101.93), Saran (6.70 and 84.73) and Champaran (6.20 and 81.31). In fact in terms of linear increase these are mainly the top three districts for both net and gross irrigated area.

The districts of Patna and Gaya which cover more than 39.11 per cent of net irrigated area in the period 1961-63 (table 5) are having almost all stagnant in net and gross irrigated area. In fact these growth rates in net and gross irrigated area are much lower than the overall state rate of 2.8 percent. The districts of Monghyr (-0.71 & -8.80), Palamau (-0.12 & -1.08), Dhanbad (-3.49 & -1.79) and Singhbhum (-9.67 & -90.22) are having negative growth rates as well as negative linear rate in net irrigated area and same in the gross irrigated area. Out of 17 districts 13 districts are having positive growth as well as positive linear rates in both net and gross irrigated area.

One wonders whether the growth of irrigation facility is towards its more equitable distribution in Bihar and is of the order suggested by this reduced share for Region III. But this aspect needs to be examined in relation to the growth of 'means of irrigation' which we will consider subsequently.

3.4 Source-wise Irrigation :

Before proceeding further we will consider the percentage share of each sources of irrigation at state level.

The net irrigated area in the state in 1972-73 was 2.3 million hectare which accounts for 27 per cent of net sown area. Nearly 36 per cent of the areas are irrigated by canals followed by tubewells (13 per cent) and tanks (8 per cent). 70 per cent of the irrigation in Shahabad was by canals. Champaran, Monghyr, Ranchi and Singhbhum have 45 per cent area irrigated by canals. 75 per cent of the area irrigated in Santhal Parganas is by tanks. As far as well irrigation is concerned, Patna has 30 per cent and in Darbhanga and Palamau 25 per cent areas is irrigated by tubewells (fig. 12 & 13).

Table 7 (Map 12 & 13) comprises percentage of net area irrigated by different sources of irrigation for the initial and the end period, alongwith the similar percentage for the state. For the state as a whole it can be seen that over 39 per cent of net irrigated area is covered by canal irrigation (in the initial period) 29 per cent by canals, 16.58 per cent by tanks, 15.50 per cent by wells and Tubewells.

Among the districts Champaran and Shahabad are having more than 60 per cent canal irrigation. Darbhanga, Santhal Parganas, Dhanbad and Singhbhum are having more than 50 per

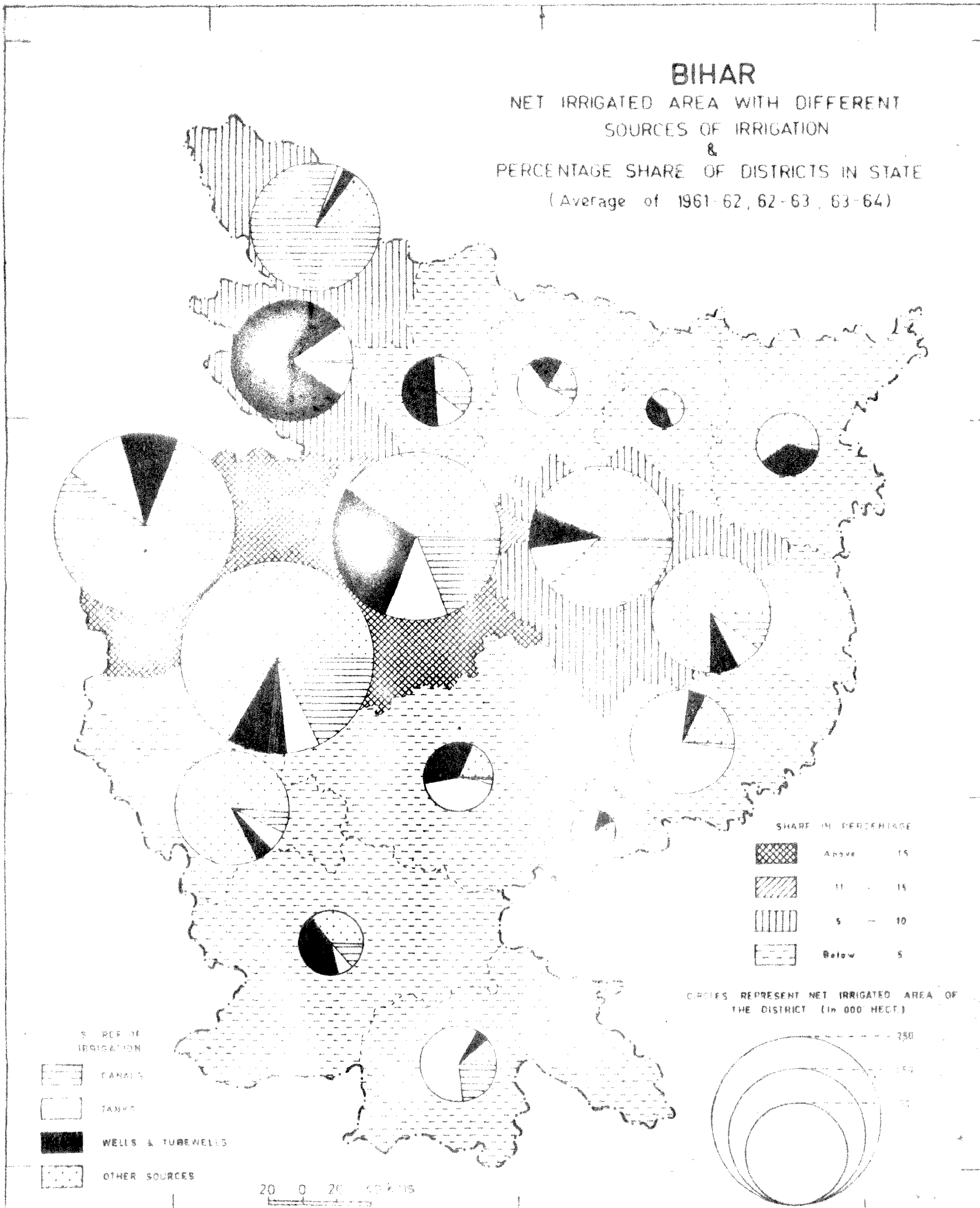

BIHAR
NET IRRIGATED AREA WITH DIFFERENT
SOURCES OF IRRIGATION
&
PERCENTAGE SHARE OF DISTRICTS IN STATE
(Average of 1961-62, 62-63, 63-64)
Above 15
11 - 15
5 - 10
Below 5
REPRESENT NET IRRIGATED AREA OF
THE DISTRICT (In 000 HECT.)
250
CANALS
WELLS & TUBEWELLS
OTHER SOURCES
20 0

Fig.12

Table - 7

Percentage of different sources of irrigation to net irrigated area (1961's & 1971's)

Districts	Canals		Tanks		Wells and Tube-wells		Other sources	
	Initial period	End period	Initial period	End period	Initial period	End period	Initial period	End period
Bihar Plain								
Patna	19.00	22.95	11.86	1.06	29.27	42.07	39.78	33.90
Gaya	19.18	22.53	5.55	2.35	9.89	14.63	64.67	60.48
Shahabad	59.65	67.73	12.34	7.05	9.50	16.28	18.63	8.92
Saran	0.05	0.20	9.51	5.78	83.84	83.84	7.10	10.17
Champaran	80.41	65.33	1.23	2.30	4.67	24.44	13.68	7.91
Muzaffarpur	10.09	0.66	13.93	7.33	49.78	74.65	26.14	17.14
Darbhanga	6.25	13.14	52.66	18.10	25.61	42.71	15.53	24.92
Monghyr	37.71	41.04	9.90	3.08	8.78	29.75	43.59	26.11
Bhagalpur	10.26	29.85	6.90	6.04	7.02	9.12	75.80	52.43
Saharsa	-	74.811	18.98	0.94	40.22	10.33	40.65	5.64
Purnea	-	71.57	3.95	0.35	27.44	19.24	66.94	8.82
Bihar Plateau								
Santhal Parganas	1.33	10.45	75.04	51.80	6.65	7.63	17.01	28.30
Hazaribagh	2.67	2.26	44.91	18.71	33.79	71.31	20.35	7.70
Ranchi	14.49	32.63	10.42	3.46	41.83	29.58	40.77	34.30
Palamau	5.87	5.77	6.36	15.04	4.12	16.08	81.74	63.09
Dhanbad	-	3.91	57.39	56.80	19.86	20.43	17.09	18.56
Singhbhum	23.86	48.56	52.52	33.55	5.40	2.71	12.46	15.19
State	29.40	37.15	16.58	6.03	15.50	25.70	39.20	28.22

cent tank irrigated area. Only Saran district is having more than 80 per cent well and Tube-wells irrigated area and rest are Muzaffarpur, Saharsa and Ranchi districts having more than 40 per cent. In other sources of irrigation Gaya, Bhagalpur and Purnea are having more than 60 per cent irrigated area.

Map 13 are pertaining to the same data (which is in Table 7) inferring the total irrigated area and their break-up according to sources of irrigation and share of each district in the state. While looking at the maps one can visualise that districts of Shahabad and Gaya share more than 15 per cent in the state total in both the period (initial and end). Next to these districts there is only one district Patna comes in second category (11 to 16 per cent). In the third category Saran, Champaran and Monghyr (5 to 10 per cent) stands, rest 11 districts are in fourth (below 5 per cent). About the sources of irrigation we have already discussed above.

The proportionate circles of the maps represent the net irrigated area of the districts in thousand hectares.

3.4.1 Source-wise Growth of Irrigation During 1961 to 1973 :

Table-8 shows the district-wise distribution of compound growth rates and linear rates of increase in net irrigated area

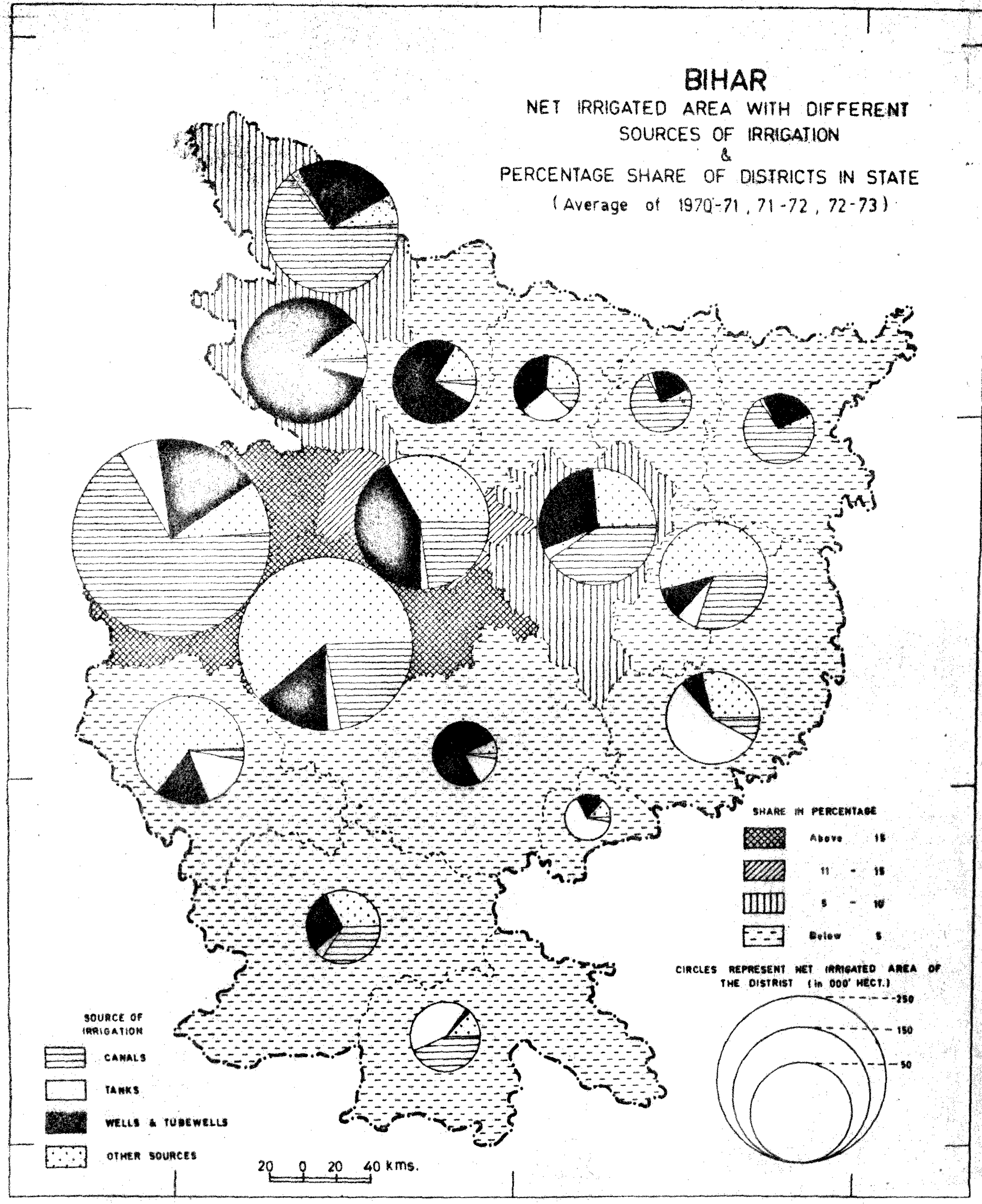

BIHAR
NET IRRIGATED AREA WITH DIFFERENT SOURCES OF IRRIGATION & PERCENTAGE SHARE OF DISTRICTS IN STATE
(Average of 1970-71, 71-72, 72-73)
SHARE IN PERCENTAGE
Above 15
11 - 15
5 - 10
Below 5
CIRCLES REPRESENT NET IRRIGATED AREA OF THE DISTRIST (in 000' HECT.)
250
150
50
SOURCE OF IRRIGATION
CANALS
TANKS
WELLS & TUBEWELLS
OTHER SOURCES
20 0 20 40 kms.

Fig.13

Table - 8

Compound growth rates and linear rates of increase of net area irrigated by different sources of irrigation (1961-62 to 1972-73)

Districts	Canals		Tanks		Wells & Tube-wells		Other Sources	
	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase
Bihar Plain								
Patna	1.7	9.56	136.8	-31.78	4.0	35.82	-2.21	-23.43
Gaya	1.0	10.63	- 12.1	-16.99	3.2	22.54	-1.41	-36.39
Shahabad	3.2	101.76	- 4.52	-22.97	10.5	71.87	-7.13	-48.39
Saran	35.4	0.48	- 1.5	- 1.9	5.4	52.73	11.7	11.82
Champaran	3.9	36.48	18.1	3.35	29.8	42.36	8.3	-0.89
Muzaffarpur	4.2	-1.24	- 1.62	- 0.46	14.2	23.71	7.6	2.20
Darbhanga	36.8	10.58	12.2	2.09	31.8	25.82	31.8	15.67
Monghyr	0.6	1.34	-12.1	- 8.81	14.7	28.87	-5.96	-30.21
Bhagalpur	13.1	27.76	0.8	- 1.40	3.3	2.41	-5.23	-34.90
Saharsa	225.0	52.48	19.9	0.56	42.0	6.87	33.0	3.29
Purnea	288.4	60.33	67.1	0.26	49.8	13.77	19.7	5.00
Bihar Plateau								
Santhal Parganas	28.9	5.33	- 5.83	-30.45	-2.82	- 3.14	-5.61	-9.90
Hazaribagh	- 1.69	-0.06	- 0.47	- 4.34	7.6	7.68	-8,13	-2.40
Ranchi	6.9	7.84	- 2.69	0.13	3.7	2.38	4.6	4.10
Palamau	0.8	0.28	13.0	8.57	19.2	9.39	-3.71	-18.54
Dhanbad	88.2	0.12	-14.24	- 5.12	-2.32	-0.09	1.9	0.04
Singhbhum	6.2	4.32	- 6.74	- 6.94	-8.99	-0.67	2.2	-0.38
State	4.6	325.62	- 5.72	-110.67	7.6	326.50	-2.21	-161.69

Compound growth rates in % per annum
Linear rates of increase in Hha per annum

per annum by different sources of irrigation. During the period under study, there exists a definite trend of positive growth of NIA under canals, wells and Tubewells irrigation in both the terms of compound and linear rates of increase. For example, at state level, the growth rates for canal irrigation is 4.6 per cent bringing 325.62 hundred hectares of land per annum under irrigation. Similarly, the growth rates of wells and Tube-wells irrigated areas are 7.6 per cent which brings 326.5 hundred hectares of NIA under this type of irrigation in each year. On the other hand NIA under Tanks and other sources of irrigation exhibit a negative trend, such as -5.72 and -2.21 per cent of growth rate and a loss of 110.62 and 101.69 hundred hectares of NIA respectively. Most of the districts of Bihar follows the same trend as it is established at state level. The only exception is found in Hazaribagh in the case of canal irrigation and in the district of Santhal Parganas, Dhanbad and Singhbhum in the case of wells and Tube-wells irrigation. The districts of Darbhanga, Saharsa and Purnea do not follow the established trend at all as they exhibit positive growth in all the sources of irrigation.

3.4.1.1 <u>Canal Irrigation</u> :

As mentioned earlier there has been a positive growth in canal irrigation throughout districts of Bihar, but a regional variation is found in the growth rates and linear rates of increase as discussed below:

(i) Regions of high growth rates:- There are three distinct regions of high growth rate i.e. more than 13.5 per cent. The first region is formed in Northern Bihar (Kosi Plain) comprising the districts of Darbhanga, Saharsa and Purnea. The later two districts show a very high growth rates as 225.0 and 288.4 per cent respectively. The second region of high growth rate is found in Southern Bihar comprising the districts of Dhanbad and Santhal Parganas. The third region constitutes of Saran plain between Gandak and Ghaghra rivers.

(ii) Regions of Medium Growth rate (3.5 - 13.5) : The region of high growth rates are followed by the region of medium growth on their flanks, such as Champaran and Muzaffarpur lies in between Eastern Gandak and Ghaghra plain and western Kosi plain. Another region of medium growth is formed in Southern Bihar constituting the districts of Ranchi and Singhbhum. Bhagalpur lies on the Southern and Western flanks of the region of high growth (see Map 11).

(iii) Regions of low growth below 3.5 per cent : Comprises the uplands of Southern Bihar and Southern part of Ganga plain comprising the districts of Shahabad, Patna, Gaya, Monghyr, Palamau, and Hazaribagh. The later district shows a negative rate of growth.

In the case of linear rates of increase per annum under canal irrigation, the districts of Muzaffarpur and Hazaribagh exhibit a decrease of 124 and 6 hectares of land. Other districts show increasing trends. The region of high rate of linear increase is formed on both northern and sides of the river Ganges comprising the districts of Shahabad, Champaran, Bhagalpur, Saharsa and Purnea. Among these only Saharsa and Purnea maintain their rank in both the compound and linear rates. The region formed with low growth rate exhibit a region of medium rate of linear increase excluding Shahabad and including Darbhanga. The region of lower rate of linear increase comprises the districts of Saran, Muzaffarpur in Northern Bihar and Monghyr, Hazaribagh, Palamau and Dhanbad in Southern Bihar.

3.4.1.2 Tank Irrigation :

Out of 17 districts only 7 districts shows a positive rate of compound growth and 6 districts in linear rates of increase. Most of the districts exhibit a negative trend in both compound and linear rate.

A region of high growth rate above 5 per cent tank irrigation is found in Kosi plains comprising the districts Darbhanga, Saharsa, and Purnea. Another region of high growth is found in north-western patches in the districts of Patna, Champaran and Palamau.

A region of medium compound growth rate in the range of 1-5 per cent is found in the plains of three rivers Son, Ganga and Gandak which comprises the districts of Shahabad, Saran and Muzaffarpur. Another region of medium rate of growth is found in South Bihar in the districts of Hazaribagh, Ranchi and Bhagalpur.

The region of low compound growth below .5 per cent comprises the districts of Southern Bihar such as Gaya, Muzaffarpur, Santhal Parganas and Singhbhum.

The linear rate of increase in terms of hundred hectares per annum forms two distinct region of medium and low rate of increase. Palamau is the only exception which shares an increase of 8.57 hectares of land under Tank irrigation. In the category of medium increase Saharsa and Purnea form one region of positive increase of 56 and 26 hectares of land under tank irrigation. Champaran is another exception to note where there is an increase of 335 hectares of land under tank irrigation. Other districts like Saran, Muzaffarpur and Darbhanga in medium region show a loss of 190, 46 and 209 hectares of land respectively from the tank irrigation. Ranchi in South Bihar shows a minor gain of 13 hectares under irrigation.

The region of low rate of increase mostly constitute the districts showing a loss of more than 500 hectares and tank irrigation such as Patna, Gaya, Shahabad and Monghyr of the South Ganga Plains and Singhbhum of the high lands of Bihar forms one distinct region of negative rate of linear increase per annum.

3.4.2.3 Well and Tubewell Irrigation :

Wells and Tube wells irrigation shows a positive rate of growth and linear increase in most of the districts of Bihar. A region of high growth rate more than 15 per cent is found in the districts of Champaran, Darbhanga, Saharsa and Purnea of North Bihar and Palamau of Southern Bihar. The districts of Shahabad, Saran, Muzaffarpur, Monghyr on both sides of Ganga form a region of medium growth rate in the range of 5 to 15 per cent of NIA under wells and Tube wells irrigation. Another patch of medium growth is found in South Bihar in districts of Hazaribagh, Patna, Gaya, Bhagalpur, Santhal Parganas and Dhanbad, Ranchi in south Bihar form three distinct regions of low growth rates below 5 per cent, whereas Santhal Parganas and Dhanbad show negative rate of growth.

Land under wells and tube-wells irrigation show a high linear increase of acreage in the districts of Patna, Gaya, Shahabad, Saran, Champaran, Muzaffarpur, Darbhanga and Monghyr which form a region where more than 2,000 hectares of NIA have been increased in each district per annum. Saharsa and Purnea of Northern Bihar and Hazaribagh and Palamau of Southern Bihar form a region of medium linear increase where 500 to 1500 hectares have increased per annum under wells and Tubewells irrigation. On the other hand Bhagalpur, Santhal Parganas, Dhanbad, Ranchi and Singhbhum form a region on the eastern flanks of Bihar which show a low rate of linear increase below 500 hectares of NIA under this irrigation. Ranchi and Singhbhum show a negative rate of linear increase.

3.4.2.4 Other Sources :

Everywhere in the districts the growth rate of NIA and other sources is lower than the well known sources of irrigation. The only exception is found in Saran where compound growth rate of NIA under other sources is greater than that of the Tanks, Wells and Tubewells irrigation. Both compound growth and linear rate of increase are high in the districts of Saran, Darbhanga and Purnea where compound growth rate of NIA is more than 5 per cent and linear rate of increase is more than 500 hectares. Similarly, the districts of Shahabad, Bhagalpur, Monghyr and Santhal Parganas form a region of low growth below 5 per cent of growth rates and a loss of more than 500 hectares of NIA per annum under this irrigation.

3.5 Irrigation Development After 1973 :

Before commencement of the Five Year Plan irrigation potential for 4.04 lakh hectares had been created through major and medium irrigation schemes. During the plan period additional potential for 18.98 lakh hectares was created upto the end of the fifth plan, i.e. 1977-78. Thus the total potential up to the end of the Fifth Plan was for 23.02 lakh hectares, which worked out to 20 per cent of the total cultivable area of the state (as against 37.7 per cent for the country as whole). In 1978-79, additional potential for 0.77 lakh hectares was created and in 1979-80 for 0.73 lakh hectares. Thus, upto 1979-80, irrigation potential for 24.52 lakh hectares was created which worked out to 21.32 per cent only of the total cultivable area of the state.

Cumulative area of utilisation of irrigation potential already created at the end of the Fifth Plan, was 15.55 lakh hectares which worked to utilisation of about 67.5 per cent of the potential of the 23.02 lakh hectares.

During 1978-79 and 1979-80, 0.85 and 0.80 lakh hectares respectively of additional land were brought under utilisation. Thus at the end of 1979-80, the utilisation was of 17.20 lakh hectates which accounted for 70.15 per cent of the total potential of 24.52 lakh hectares.

Following are the main objectives of this plan :

(a) to create 11.60 lakh hectares of additional irrigation potential, thereby increase the total cultivated area of the state; and

(b) to bring under utilisation additional 9.00 lakh hectares of land, making the total utilisation of 26.20 lakh hectares and taking the percentage of utilisation to 72.54 (of the total potential of 36.12 lakh hectares to be created). The strategy would be to complete expeditiously the ongoing schemes, maximise utilisation of the potential already created and endeavour specially provide adequate irrigation facilities to drought prone and tribal sub-plan areas.

3.6 Projection for Future Development of Irrigation Potential :

Although Bihar has made rapid progress in the development of irrigation potential for increased agricultural production, the continued shortage of food, frequent drought conditions, the rapid growth of population and increased standard of living have made it necessary to increase the irrigation potential to the maximum possible extent.

There are good sites for the location of storage reservoirs in most of the river basins and investigations are now being carried out to select the most favourable sites for dams. The State Government's plans comprise of : (i) construction of a network of small storage reservoirs on the tributaries of the main rivers to irrigate commands. These will also be helpful in controlling floods; (ii) the construction of a large number of new tanks and the deepening of existing tanks. It is also proposed to renovate 4 thousand private tanks and 2 thousand Government tanks; (iii) the construction of large diameter (8 to 10 m.) wells in the Don river lands; (iv) pumping the sub-surface flows of river-beds through 3 m. long horizontal strainers; (v) the construction of storage dams with pick-up wiers for irrigating the valley; (vi) the construction of medium and minor irrigation works.

In the Santhal Parganas, the Gumani and the Ajoy rivers have not been tapped. On both these rivers, good storage reservoir sites have been located. Large reservoir have been proposed on the South Koel and the Sankh rivers for hydro-power generation. It may be recommended that the possibility of irrigation and the development of fisheries from these reservoirs should be investigated.

The State Irrigation Commission has estimated that with the proper utilisation of surface water resources, Bihar has an additional potential irrigation capacity of 5.8 million hectare distributed as follows:[6]

North Bihar	3.1 million hectares
South Bihar	1.7 million hectares
Chotanagpur and Santhal Parganas	1.0 million hectares
Total	5.8 million hectares

There are also immense possibilities for the exploitation of the large reserves of ground water, which underlie about 50,400 sq.km. of its alluvium covered area. Only 13 per cent of this potential has so far been explored by tubewells. With the available credit facilities if the pace of rural electrification to energise tubewells could be accelerated, the immense ground water potential can be put into beneficial use.

The total number of pumps energized since 1973, is only 53,203. The Fourth Plan target for energizing pumps was 1,25,000 and by the end of the Fourth Plan, the total number of pumps electrified was expected to be 1,76,225.

---

6. Ministry of Irrigation & Power - 'Report of the Irrigation Commission 1972, vol.II, New Delhi, p.66.

Taking into account the irrigation potential of all types of future irrigation works, the State can irrigate an additional area of one million hectares which will bring the total area irrigated to about 7.6 million hectares. The works out of about 70 per cent of the gross cropped area.

3.7 Conclusion :

Irrigation development in Bihar dates back to the middle of 19th century. Initially canal irrigation was taken up. Later in thirties twentieth century well and tubewell irrigation were developed. But these efforts were small in scale and sporadic in nature. Thus at the time of independence Bihar State had only 0.2 million hectares of land ammounting only to a bare 3.4 per cent of cultivated land. Since independence rapid progress has been made in irrigation development.

During the study period the gross irrigated area in Bihar increased from 2.1 million hectares to 2.8 million hectares. The percentages of both net and gross irrigated area have increased by 5 per cent in the case of net irrigated area from 19.63 per cent to 26.6 per cent and by 5.02 per cent in the case of gross irrigated area, from 23.26 per cent to 28.28 per cent. The compound growth rates of gross and net irrigated area during the period 1961 to 1973 were respectively 2.8 and 2.1 per cent increase per annum.

The irrigated area is unevenly distributed. More than 55 per cent of the state irrigated area is distributed in three districts of south Bihar plain, viz; Patna, Gaya and Shahabad, were more than 40 per cent of the gross sown area is irrigated. The percentage share of other districts is low and varies from as low as 0.87 per cent in Hazaribagh to 7.5 per cent in Champaran. In the plateau districts, excluding Palamau less than 10 per cent of the gross sown area is irrigated.

The rate of irrigation in the districts of Bihar is also uneven. The compound growth rates in the net irrigated area are highest in Saharsa (69.47 per cent) and Purnea 53.8 per cent). In other districts the compound growth rates are not significant, rather in the districts of Monghyr in the plain and of Palamau, Dhanbad and Singhbhum in the plateau, they are negative.

The percentage of net sown area irrigated by canal and tubewell have increased considerably in this state, from 29 per cent to 37 per cent in case of canal and from 16 per cent to 27 per cent in the case of well and tubewell. The percentage of net sown area irrigated by tanks decreased from 17 per cent to 7 per cent and by other sources from 39 per cent to 29 per cent. The compound growth rates for the state of Bihar in area irrigated by canal, well and tubewell, tanks and other sources are respectively 4.9 per cent, 7.6 per cent

-5.7 per cent, -2.2 per cent per annum.

Highest compound growth rates in area irrigated by canal and well and tubewell have been registered in Saharsa (225 per cent and 42 per cent) and Purnea (288.4 per cent and 43.8 per cent). In the plateau region, the districts of Santhal Parganas and Dhanbad have registered higher compound growth rates, 28.9 per cent and 88.2 per cent respectively, in area irrigated by canal. Compared with area irrigated by canal, the compound rates of growth of area irrigated by well and tubewell are more uniform in the districts of Bihar. Shahabad in the plain and Santhal Parganas in the plateau, had the highest rate of decrease in area irrigated by tank and other sources.

CHAPTER - IV

RICE IN BIHAR

CHAPTER - IV

RICE IN BIHAR

4.1 Importance of Rice in Bihar's Agriculture :

Bihar is essentially an agricultural State where more than nine-tenths of the total population depends on agriculture directly or otherwise. The percentage of cultivated land (NSA) to the total geographical area is uniformally high in all the districts of Bihar. In the year 1972-73 it ranged from 67 to 73 per cent in North Bihar plain and 62 to 73 per cent in South Bihar Plain and less than 40 per cent in Chotanagpur plateau. There has been marginal increase or decrease in the cultivated area in the districts of Bihar during the period 1961-73. Table 4 and the fig. show these variations.

Rice attains an important place amongst the crops of the state in both acreage and production. In acreage under rice, Bihar ranks first among the rice growing states in India. In the year 1971 the total area under rice in India was 36.02 million hectares, out of which 5.02 million hectares were in Bihar. Nearly 13 per cent of the total rice area in India thus occurs in Bihar.[1] 62.2 per cent of gross

---

1. G.S.Bhall & Y.K.Alag (1979) - Performance of Indian Agriculture.

sown area was under rice in Bihar in the year 1972-73. Eleven of the Seventeen districts in Bihar share over 60 per cent of land under rice to net sown area whereas the remaining half a dozen districts share between 35-51 per cent (1972-73). In the triennial average (1971-73) the maximum percentage (88 per cent) of gross area under rice to gross sown area is found in Singhbhum district followed by Dhanbad (80 per cent) and Santhal Parganas (71 per cent). Less than 30 per cent of gross sown area is under rice in the districts of Saran (29.68 per cent) and Monghyr (24.08 per cent).

In general in many districts of Bihar, there have been no significant change in the percentage of gross area under rice to the gross sown area. However, marked increase is noticed in Purnea, where percentage of gross area under rice to gross sown area in 1961's was 47.10 and in 1971's 63.67 per cent. In Singhbhum district it increased from 81.20 per cent in 1961's to 88.04 per cent in 1971's. Only in Monghyr district the percentage share of rice area increased from 33.05 in 1961's to 24.08 in 1971's.

The significance of production depends upon acreage given to rice and yield of rice per hectare. Since the acreage is very high in Bihar, the production or rice is also high. Bihar accounts for 11.19 per cent of the total rice production in India. In the year 1972-73 the total production of rice in Bihar was 53.52 per cent of the total agricultural production and 59.20 per cent of the total cereals production.

However, the yield of rice in Bihar is the lowest. In the year 1972-73 the all India average yield of rice was 1,145 kg/hectare whereas in Bihar it was only 958 kg/hectare. The yield of rice in Bihar is less than half of the best yield obtained as in Tamil Nadu (2,007 kg/hectare).

The increase in the yield of rice and the corresponding rise in the rice production might pave way for reduction of more profitable crops, in the irrigated area.

4.2 Rice Varieties in Bihar :

Rice belongs to the genus Oryza in the family Gramineal. The genus Oryza includes 25 species of which only two are cultivated namely, Oryza Sativa and Oryza glaberrima. All the rice varieties of Asia, Europe and America belong to the species Oryza Sativa. Oryza glaberrima is confined to small areas in west Africa where it is grown as an upland crop.[2]

There are two main rice varieties and well over 2,000 strains of these have developed by natural plant selection over centuries of cultivation. These strains have subtle

---

2. The Fertilizer Association of India - 'Rice', July '80, New Delhi, p.21.

differences in characteristics which make each desirable in the area where it is grown matching the seasonal weather trends; being resistant to local disease; meeting the local requirements for planting and harvesting traditions. Indian varieties are grown mainly in tropical countries. Characteristically they are tall (over 150 cm.), leafy profuse tillering and photo periodically sensitive, making the period of maturity variable, depending on the planting date.[3] These varieties are generally low yielding but reliable year after year. Their main disadvantage is their susceptibility to lodging, often before flowering. This leads to low yields, harvesting difficulties, and low quality grain.

The Japanica varieties are common in subtropical and low temperate latitudes. They are short and usually early and high yielding. Some varieties have thick, tough leaves which can withstand strong winds. Others have tolerance to cold, a desirable characteristic in high latitudes and in high elevations in the tropics.[4] However, their ability to tiller is limited, they are susceptible to many disease, they have weak stand and their eating quality is not acceptable to many people in tropical areas.

---

3. Robertson (1975), Op. Cit., p.3.

4. Ibid.

The rice varieties in India are generally classified as early, medium and late maturing. In some states these are grouped as Autumn, Winter and Summer or first second and third crop varieties. As a result of the breeding and selection programme carried out by different central and state agencies, a larger number of indegeneously improved varieties have been avolved.

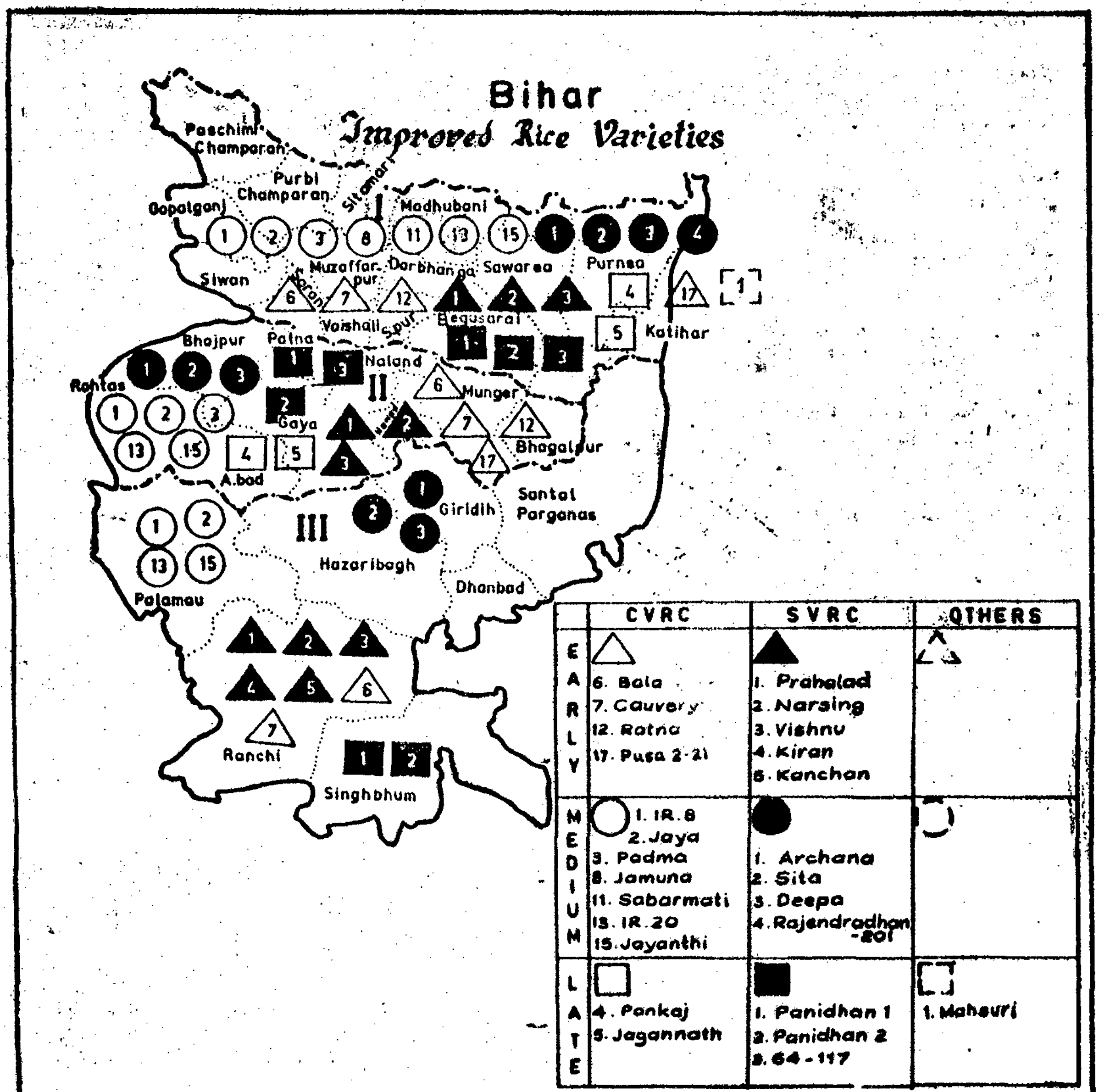
In Bihar, 14 improved strains have been released, of these five are aus varieties, five are aman varieties, two are floating rices, and two purple pigmented varieties suitable for cultivation in fields infested with wild rice.[5] Besides these there are other eight aus (Chinese introductions) and six aman strains which are reported to be very promising.

State Government has also released high yielding varieties to meet the requirements of the specific agroclimatic and soil zones. A list of high yielding varieties released for cultivation is given in the appendix 6 and are shown in fig. 14.

Apart from the list given, few more promising high yielding strains have also been developed and are at present undergoing pre-release multiplication and trail.[6]

---

5. R.H.Richaria & S.Govindaswami (1966) - Rice in India, Scientific Book Company, Patna, p.93.
6. Souvenir (1976) - Rice Farming, The Directorate of Rice Development, Government of India, Patna, p.5.



CVRC = Central Variety Release Committee
SVRC = State " " "

Source: Ministry of Agri. & Irrigation.

Fig. 14

The acreage under high yielding variety is low in Bihar. HYV coverage is only 23.3 per cent.[7] The remaining area grows only rainfed rice.

Rainfed rice is subjected moisture stress at one time or the other during the growing period. Therefore, the choice of the variety, particularly under rainfed "upland" conditions (Highlands of South Bihar) the main condition, should be the duration crop. The kind of rice grown in Highlands of Bihar is coarser and more quick-maturing as we move from the moisture retaining lowlands to the less moist and more precarious higher terraces.

4.3 Cultural Practices of Rice Cultivation :

Rice culture includes the method of cultivation, method of sowing, weeding, irrigation harvesting, threshing fertilizer use, control of diseases and choice of varieties. Seedling are usually prepared in a nursery and latter transplanted in the paddy field. A nursery of 300 to 500 m^2 and planted with 40 kg. of seeds will produce sufficient plants for a one-hectare field.[8] Before planting the seeds are soaked and pregerminated in warmth for 36 to 48 hours. The

---

7. Ministry of Agriculture & Irrigation (1976): Improved Rice varieties for different regions of India. Directorate of Extension, Government of India, p.11.

8. Robertson (1975) - Op. Cit., p.3.

seedlings remains under flooded conditions in the nursery for 20 to 30 days and reach the fifth-leaf stage with a height of 15 to 20 cm. when they are ready for transplanting.

After the land becomes flooded it is ploughed and harrowed several times until the soil is thoroughly puddled. The puddling not only helps in killing weeds and incorpora-ting organic material into the soil but also makes it easy to transplant seedlings. The preparation of the soil and nursery plants requires careful timining in relation to the begining of the wet season. Seedings are transplanted by hand, either randomly or in rows. Plant spacing varies with the variety but ranges from 20x20 to 35 x 35 cm.

There are three seasons for rice cultivation. The summer rice (garma) cultivated during March/April to July/August is concentrated in the canal irrigated regions of Sone, Kosi and Gandak Projects. The area under summer rice is 1.46 (1972-73) and early maturing varieties are mostly grown in this season. The autumn rice is sown broadcast in the undulating upland areas (Tanr lands) of Chotanagpur and Santhal Parganas and in the 'unbunded fields of North Bihar Plains. Autumn rice is grown as rainfed crop during June to October with early varieties. About 9.74 per cent of the rice crop is grown over in this season. The most important is winter rice (Kharif crop) occupying the largest acreage grown during June/July to November/December. The early varieties are harvested by mid November, the medium group by the end of November and the late by December. 'The early and the medium duration groups are raised in medium lands while the late maturing varieties are grown in the lowlying and ill-drained areas'.[9] A little over 88.79 per cent (1972-73) of Bihar's rice crop is grown in this season.

Rice follows a definite pattern of growth and development regardless of the method of planting and watering and of the variety used.[10] The period from seed germination to seed maturity, the life cycle of the plant can be divided into three distinct phase of development. First phase is vegetative, includes the interval from seed germination to panicle initiation and includes three period - (a) the seedling period is from the time of germination until the fifth leaf stage. During this period young plants develop seminal and lateral roots while absorbing nutrients from the endosperm of the seed. (b) The transplanting period covers the interval from the fifth-leaf stage to full recovery following transplanting. This usually takes about three weeks. (c) The period of tillering follows closely after the fifth-leaf stage and recovery from transplanting.

Near the end of the tillering period or sometimes before the end, the initiation of the panicle primordia in

---

9. Improved Rice Varieties; Op. Cit., p.11.
10. Robertson, G.W. (1975), Op. Cit., p.5.

in the tillers takes place. This makes the beginning of the second phase which called reproductive. The panicle initiation period may be very short ; following coinciding with or starting shortly before the stage of maximum tèllering in varieties insensitive to photo period. The period of internode elongation or booting begins immediately after initiation of the primordia. During this period the expanding primordia is pushed upward. The emergence of the panicle from the flag-leaf sheath marks the beginning of the third period followed almost immediately by the flowering period.

The ripening phase consists of three periods: (a) The milk period occurs when the starchy portion of the grain develops from a watery to a milky consistency. (b) During the dough period the caryopsis loses its milky consistency and becomes gummy (soft dough), then hardens to the hard-dough stage. The total time from germination to full maturity ranges from 90 to 200 days depending on the variety and its response to photo period and temperature.

4.4 <u>Harvesting</u> :

The right stage for harvesting is when the ears are nearly ripe and the straw slightly green. It delayed till the crop is dead ripe, grain may be lost due to shedding, lodging and by bird damage. Delayed harvesting may also lead to Sun-cracks which in turn would affect the milling recovery. The crop is generally cut with a sickle by mannual labour, dried in the field for 3-4 days and then threshed by sticks or bullocks. The pedal threshar is economical, time saving and may be used.

After removing husk through threshing, rice is milled and polished to remove the bran layer in order to improve the keeping and cooking quality of rice and to make it attractive for selling.

4.5 <u>Gross Area Under Rice in Bihar</u> :

During the period under study, the area under rice in Bihar has marginally decreased. It was 5.22 million hectares in the triennial average for 1961-63 and 5.15 million hectares during the period 1971-73. However, there are districts where there was a significant increase in area under rice during the same period. The districts were Champaran (3,97,006 hectare, 1961-63 and 4,78,146 hectares, 1971-73) followed by Bhagalpur (1,61,854 to 1,66,442 hectares), Saharsa (4,27,274 to 5,01,578 hectares) and Purnea (4,27,274 to 5,01,578 hectares) Table - 9. On the other hand the districts having more than 50 per cent gross irrigated area of gross sown area have registered a decrease in the gross area under rice. In these districts irrigation might have had led to the introduction of more profitable

Table - 9

Gross area under rice and % to GSA and Gross area under irrigated rice and % to gross area under rice (Average of 1961-63 to 1971-73)

Districts	1961 - 63		1971 - 73		1961 - 63		1971 - 73	
	GAR (in hectare)	% of GAR to GSA	GAR (in Hectare)	% of GAR to GSA	GIA under rice (in hec.)	% of GIAR to GAR	GIA under rice (in hec.)	% of GIAR TO GAR
<u>**Bihar Plain**</u>	255304							
Patna	255304	38.98	213336	36.02	248475	95.63	214465	99.14
Gaya	496470	46.89	505851	51.19	489654	95.07	453298	99.58
Sahabad	500651	42.10	503068	44.94	538032	86.23	441179	88.22
Saran	203763	30.69	195147	29.68	3522	1.61	3935	2.01
Champaran	397006	49.90	478147	53.97	105296	27.73	116035	25.99
Muzaffarpur	324572	42.50	319869	41.34	9146	9.92	7957	2.48
Darbhanga	380580	49.80	376381	48.26	6997	1.58	22612	6.00
Munghyr	239817	33.05	141606	24.08	135686	64.99	89785	63.45
Bhagalpur	151854	40.65	156442	40.37	122964	80.49	127227	81.39
Saharsa	121417	31.92	191242	40.69	324	0.37	38726	20.16
Purnea	427274	47.10	501578	63.67	569	0.17	52163	10.39
<u>**Bihar Plateau**</u>								
Santhal Parganas	440954	63.20	451585	70.71	77649	18.89	45913	10.89
Hazaribagh	283294	60.41	225406	57.61	15558	6.28	4888	2.17
Ranchi	450527	61.19	370434	48.45	5844	1.45	12985	2.72
Palamau	110781	29.69	116023	31.33	67356	61.61	59191	56.82
Dhanbad	84109	82.00	69407	79.76	15496	7.44	1151	1.65
Singhbhum	356048	81.20	356634	88.04	18825	1.63	17899	5.04
State	5224514		5152654		1773143	36.54	1709380	33.17

GSA = Gross Sown Area
GAR = Gross Area Under Rice
GIAR = Gross Irrigated Area Under Rice

crop than rice.

When we analyse the percentage share of gross area under rice to gross sown area (Table-9 and fig. 15); we find that all the 17 districts grouped into four categories :

1st category - Having 80% or more GSA under rice
2nd category - Having 60% to 80% GSA under rice
3rd category - Having 40% to 60% GSA under rice
4th category - Having 40% and below GSA under rice

A close perusal (Table-10) shows that entire districts can be grouped as :

(a) districts having the same category in both the periods viz. 1961-62-63 and 1971-72-73.

(b) districts gained percentage area under rice and jumping in the next category from 1961-62-63 to 1971-72-73 and

(c) districts lost percentage area under rice and going down in the next category from 1961-62-63 to 1971-72-73.

Considering the first group of districts, we find that there is only one district i.e. Singhbhum which remained in the first category having 81.20% and 88.04% GSA under rice during 1961-62-63 and 1971-72-73 respectively. However, it enjoyed more area in 1971-72-73 than in 1961-62-63. In

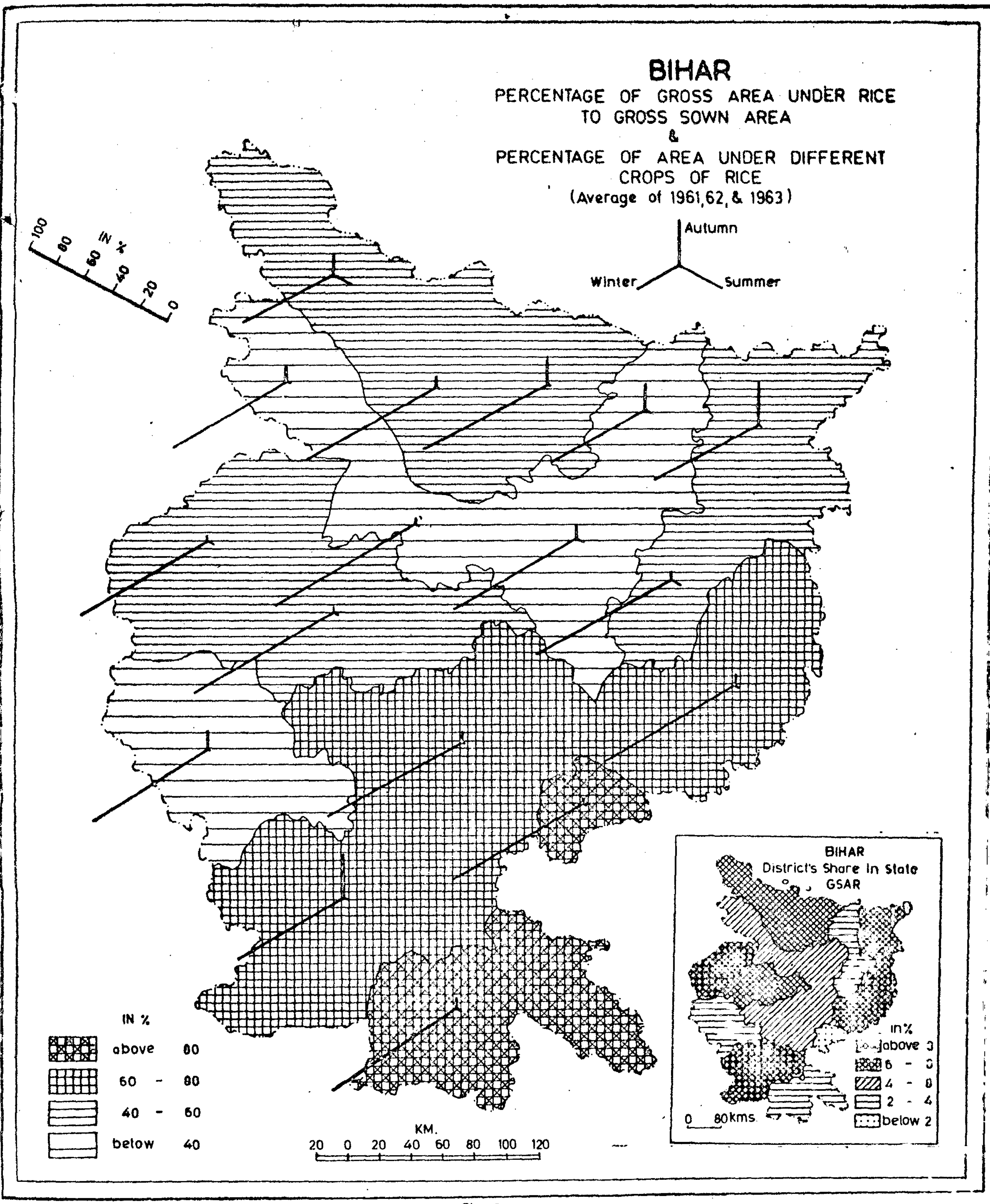

BIHAR
PERCENTAGE OF GROSS AREA UNDER RICE TO GROSS SOWN AREA
&
PERCENTAGE OF AREA UNDER DIFFERENT CROPS OF RICE
(Average of 1961, 62, & 1963)
Autumn
Winter
Summer
100 80 60 40 20 0
IN %
IN %
above 80
60 - 80
40 - 60
below 40
KM.
20 0 20 40 60 80 100 120
BIHAR
District's Share in State GSAR
in%
above 8
6 - 8
4 - 6
2 - 4
below 2
0 80kms.

Fig. 15

Table - 10

Distribution of districts in different percentage groups of GAR* to GSA**
(Average of 1961-62-63 and 1971-72-73)

1971 Group \ 1961 Group	Below 40 %	40 - 60 %	60 - 80 %	Above 80 %
Below 40 %	Patna Saran Monghyr Palamau			
40 - 60 %	Saharsa	Gaya Shahabad Champaran Muzaffarpur Darbhanga Bhagalpur	Hazaribagh Ranchi	
60 - 80 %		Purnea	Santhal- Parganas	Dhanbad
Above 80 %				Singhbhum

* GAR = Gross Area Under Rice
** GSA = Gross Sown Area

the second category, again there is only one district i.e. Santhal Parganas which had 63.20 per cent area under rice in 1961-62-63 as against 70-71 per cent during 1971-72-73. This district also remained in the same category but enjoyed more percentage of area during 1971-73 over 1961-63. The third category of districts in this group are Gaya, Shahabad, Champaran, Muzaffarpur, Darbhanga and Bhagalpur and Purnea. When we look at percentage share of area under rice to gross sown area (Table-9); we find that of these 6 districts, although they remained in the same (3rd) category; 3 districts viz. Gaya, Shahabad and Champaran gained percentage area under rice during 1971-73 over 1961-63 where as the remaining 3 districts viz Muzaffarpur, Darbhanga and Bhagalpur experience a decline in their percentage area under rice during 1971-73 as compared to 1961-63. However, the gain or loss of these districts was not such which would have changed their category. The last (4th) category of districts of this group are Patna, Saran, Monghyr and Palamau. Of these 4 districts, only the district of Palamau experienced gain in percentage area under rice during 1971-73 over 1961-63 while the rest 3 districts experienced a decline in its area under rice.

In the second group of districts which experienced a gain in its area under rice in 1971-73 over 1961-63 are only two viz. Saharsa and Purnea. The district of Saharsa jumped from 4th category (31.92 per cent in 1961-63) to 3rd category (40.69 per cent in 1971-73) whereas Purnea jumped to 2nd category (63.67 per cent in 71-73) from 3rd category (47.10 per cent in 1961-63).

The third group of districts which experienced a decline in its area in 1971-73 over 1961-63 are three viz. Dhanbad, Hazaribagh and Ranchi. The district of Dhanbad went down to 2nd category during 1971-73 from 1st category in 1961-63 whereas the districts of Hazaribagh and Ranchi went down to 3rd category in 1971-73. from 2nd category during 1961-63.

It is further evidenced that the districts which experienced loss are mostly in plateau region. They are totally dependent on rainfall. However, these plateau districts show highest percentage of area under rice. This also implies that in these districts, rice is the only staple crop and also the wheat cultivation is not practiced on a large scale. It is all due to rough topography of these districts together with the lack of irrigational facilities.

When we consider the districts individual percentage share of total area under rice to state total (appendix 8); district can be put into three categories;

1st category - districts having 5 to 10% of the state area under rice

Table - 11

Percentage share of districts to the total area under rice in the state during 1961-63 and 1971-73.

1961 Group / 1971 Group	Below 5 %	5-10 %	Above 10 %
Below 5 %	Saran Monghyr Bhagalpur Saharsa Palamau Dhanbad	Patna Hazaribagh	
5 - 10 %	Singhbhum	Gaya Champaran Muzaffarpur Darbhanga Purnea Santhal Parganas Ranchi	Shahabad
Above 10 %			

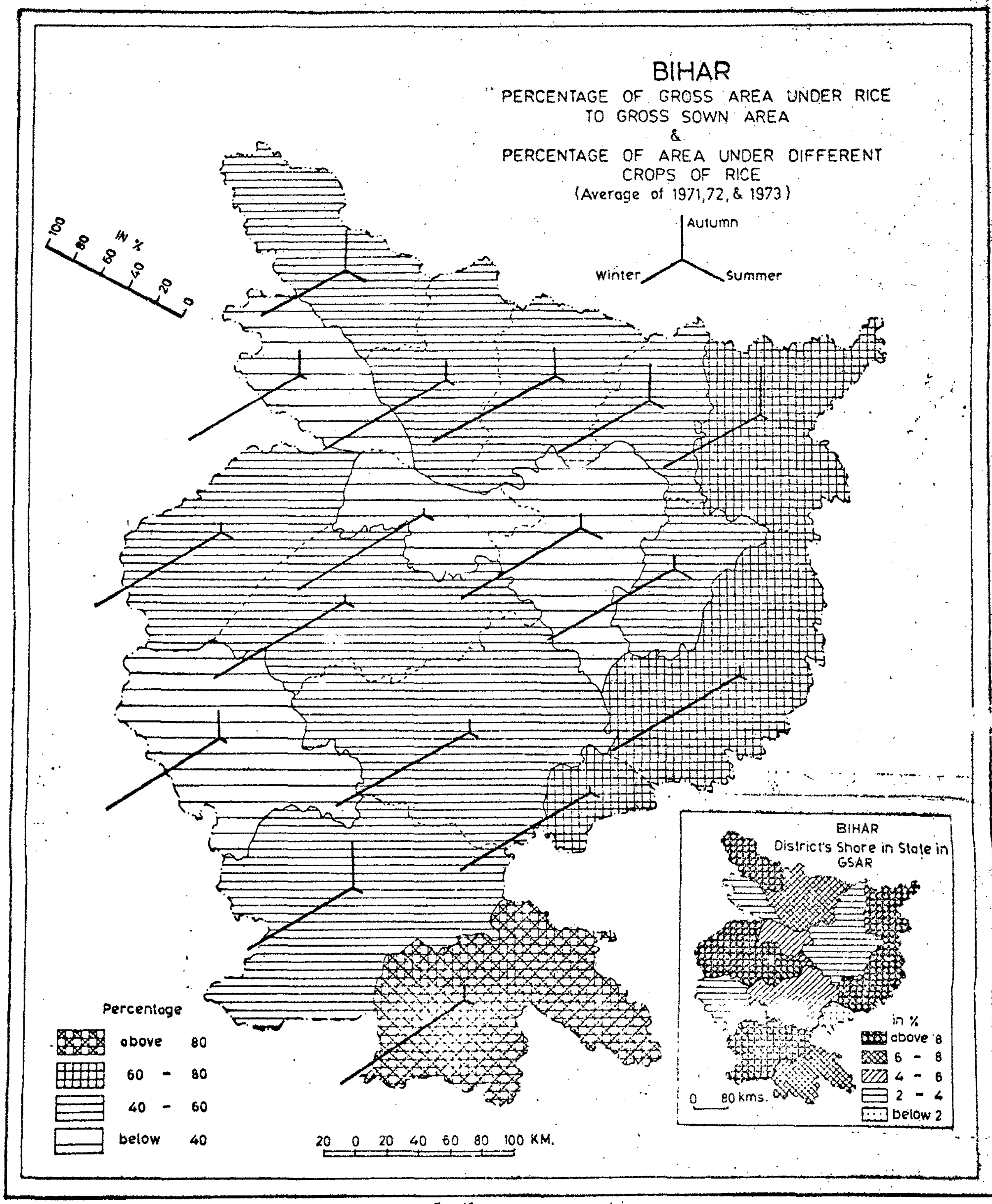

BIHAR
PERCENTAGE OF GROSS AREA UNDER RICE TO GROSS SOWN AREA
&
PERCENTAGE OF AREA UNDER DIFFERENT CROPS OF RICE
(Average of 1971,72, & 1973)
Autumn
Winter
Summer
100 80 60 40 20 0
IN %
Percentage
above 80
60 - 80
40 - 60
below 40
20 0 20 40 60 80 100 KM.
BIHAR
District's Share in State in GSAR
in %
above 8
6 - 8
4 - 6
2 - 4
below 2
0 80 kms.

Fig. 16

2nd category - districts having 5 to 10% of the state area under rice

3rd category - districts having below 5% of the state area under rice.

From the table; it is quite clear that there is no district which shares more than 10% of the state area under rice during 1971-73. However, one district i.e. Shahabad was in the first category (10.10 per cent) during 1961-63 which experienced a loss in its share and thereby went down to 2nd category during 1971-73 (9.70 per cent). When we look at Table - 11 and fig. 14 & 15, we find that the districts of Gaya, Champaran, Muzaffarpur, Darbhanga, Purnea, Santhal Parganas and Ranchi remained in the 2nd category in both the periods viz. 1961-63 and 1971-73. However, the districts of Muzaffarpur, Darbhanga and Santhal Parganas experienced a loss in its percentage share whereas the remaining districts of their category experienced a gain during 1971-73 over 1961-63. But this loss or gain was so marginal that it prevented them jumping down or going up to any other category. However 2 districts viz. Patna and Hazaribagh which were in the 2nd category during 1961-63 lost a considerable share in its area under rice which forced them to go down the last category (3rd) during 1971-73. When we consider the last category (3rd) of districts, we find that there were seven districts during 1961-73 viz. Saran, Monghyr, Bhagalpur, Saharsa, Palamau, Dhanbad and Singhbhum. Out of these 7 districts, 2 districts experienced an increase in its percentage share which causes one of these two i.e. Singhbhum going up in the next category (2nd) during 1971-73; whereas Saharsa remained in the same category (3rd) alongwith other 5 districts which experienced a decline in its share during 1971-73 over 1961-63.

Having examined the individual share of each district, it implies that as much as 11 districts experienced a loss in their percentage area under rice during 1971-73 as against 1961-63. It means that there would have been a general decline in the area under rice in the state during this period. Therefore, it is essential to analyse the relative changes in the area among the districts in Bihar. The relative changes has been analysed by computing the compound growth rates and linear rates in increase.

4.5.1 <u>Growth in Gross Area Under Rice</u> :

When we glance at Table-12 and fig.17 the compound growth rates (from 1961-62 to 1972-73) in gross area under rice, we find that in all 11 districts have experienced a positive growth. The maximum compound growth in gross area under rice is found in the district of Gaya (6.20 per cent). It is followed by Saharsa (5.90 per cent; Santhal Parganas (3.10 per cent); Purnea (2.10 per cent); Ranchi

Table - 12

Compound growth rates and linear rates of increase of Gross area under rice and gross irrigated area under rice during 1961 - 73.

Districts	Gross area under Rice		Gross irrigated under Rice	
	Compound Growth rate (%) per annum	Linear rates of increase ('00 hect/ annum)	Compound Growth rates (%/annum)	Linear rates of increase ('00 hect/ annum)
Bihar Plain				
Patna	-1.42	-33.19	1.0	22.70
Gaya	6.2	89.18	1.03	42.23
Shahabad	0.00	2.54	0.20	7.98
Saran	0.32	6.66	4.00	1.65
Champaran	1.6	69.80	1.00	10.82
Muzaffarpur	0.1	2.69	0.76	3.19
Darbhanga	0.25	4.05	18.20	21.02
Monghyr	-3.69	-64.25	-5.77	-37.72
Bhagalpur	0.30	4.85	0.60	2.73
Saharsa	5.9	85.06	7.7	37.72
Purnea	2.1	97.38	69.6	67.51
Bihar Plateau				
Santhal Parganas	3.1	40.36	-6.74	-42.66
Hazaribagh	-2.68	-66.23	-12.16	-12.82
Ranchi	1.84	19.31	9.60	8.46
Palamau	-0.28	- 5.96	-1.53	10.36
Dhanbad	-0.43	-17.32	-17.92	- 6.00
Singhbhum	-6.99	- 3.87	-0.62	- 2.83
State	0.30	186.43	-0.48	-83.43

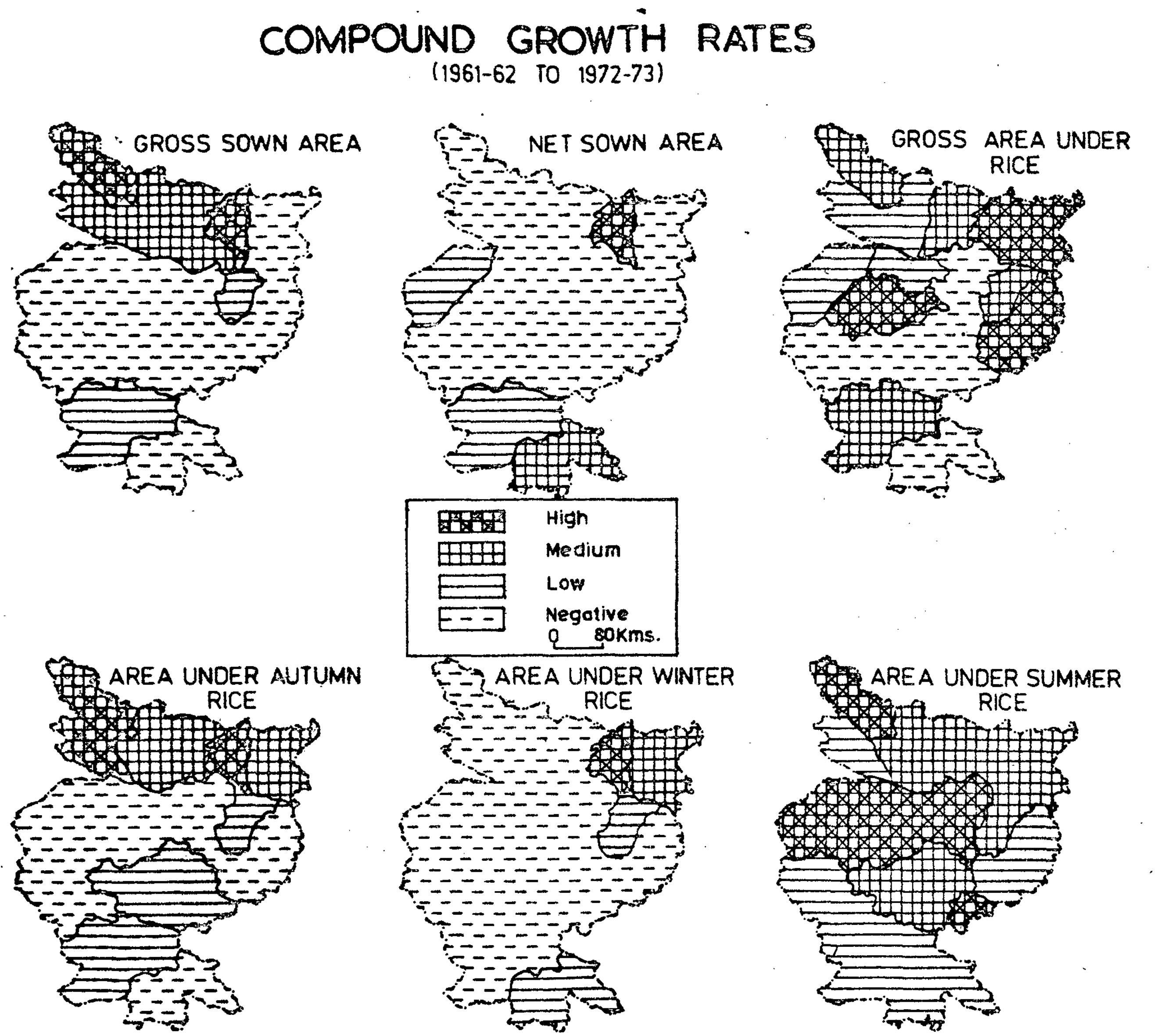

COMPOUND GROWTH RATES
(1961-62 TO 1972-73)
GROSS SOWN AREA
NET SOWN AREA
GROSS AREA UNDER RICE
High
Medium
Low
Negative
0 80Kms.
AREA UNDER AUTUMN RICE
AREA UNDER WINTER RICE
AREA UNDER SUMMER RICE

Fig. 17

(1.84 per cent); Champaran (1.60 per cent); Bhagalpur (0.30 per cent); Darbhanga (0.25 per cent); Saran (0.32 per cent); Muzaffarpur (0.10 per cent); and Shahabad (0.00 per cent) districts. All these districts have also experienced a positive increase in '100 hectare per annum' (linear rate of increase). The maximum has been experienced by Gaya itself where it is 89.18 as compared to Shahabad district (2.54) which experienced minimum linear rate of increase. Among the districts which have experienced a negative compound growth rate, are Singhbhum (-6.99 per cent) followed by Monghyr (-3.69 per cent); Hazaribagh (-2.58 per cent); Patna (-1.42 per cent); Dhanbad (-0.43 per cent) and Palamau (0.28 per cent) districts. Regarding linear rate of decrease also, Ranchi tops the list with -1036.87 leaving rest 8 districts far behind as Hazaribagh (-66.28) comes at second position followed by Monghyr (-64.25); Patna (-33.19); Dhanbad (-17.32); and Palamau (-8.96).

The compound growth rate indicates marginal increase in the acreage in few districts of the plain and while decrease in noticed particularly in the plateau districts. The trend seems continuity with the recommendation of the national Comm. on Agn.[11] It also reflects that majority of districts which have negative growth are plateau districts

---

11. National Commission on Agri. - '<u>Rainfall & Cropping Pattern</u>', vol.III, Bihar. Ministry of Agri. & Irri., 1976, p.76.

devoid of any developed means of irrigation or do not have assured water sources. Because, the 4 districts viz. Gaya, Saharsa, Purnea and Santhal Parganas which have shown a positive growth alongwith many others of 7 other districts, do enjoy better irrigational facilities or have assured water resources which is required for rice cultivation. However, it becomes more clear, rather a great variation is found when we analyse 'gross area under rice' in different seasons.

4.5.2 <u>Gross Irrigated area under Rice: During the Period 1961 - 73</u> :

During the period under study, the area under total irrigated rice in Bihar has marginally decreased. It was 18,11,611 hectares in the triennial average for 1961-63 and 17,09,380 hectares taking the period 1971-73. However, there are districts where area of irrigated rice increased during this period. The districts were, Saharsa (451 to 38,726 hectares) and Shahabad (4,31,748 to 4,41,178 hectares). While considering the total irrigated rice to gross area under rice, we find that 4 districts out to 17 have registered more than 80 per cent rice area was irrigated in both years. The districts were, Patna (99.63 and 99.14 per cent), Gaya (95.07 and 99.58 per cent), Shahabad (86.23 and 88.22 per cent) and Bhagalpur (80.49 and 81.39 per cent). The districts of Monghyr and Palamau have also experienced more than 60 per cent area under irrigated rice to gross area under rice. Rest of the districts have recorded below 30 per cent irrigated area under rice to gross area under rice in the years 1961's and 1971's Table-9 and fig. 18 & 19).

Looking at the regional pattern of growth it can be said that the districts of Saran, Darbhanga, Purnea and Ranchi have a high growth rates of total irrigated rice. While the linear rate of increase is highest in the districts of Shahabad, Champaran, Darbhanga, Purnea, Ranchi and Palamau where there is an incfease of more than 5 hundred hectares of NIA per annum under this cropping. Similarly, the districts of Patna, Gaya, Shahabad, Champaran, Muzaffarpur, Bhagalpur and in a discrete patch of Singhbhum form a region of medium growth rate in the range of -1.5 to +1.5 per cent, whereas the districts of Saran, Muzaffarpur, Bhagalpur and Singhbhum reveal a region of medium rate of linear decrease in range of -5 to +5 hundred hectares of NIA under rice cropping (Table-12 and fig. 20).

On the contrary, the districts of South Bihar like Santhal Parganas, Hazaribagh, and Dhanbad reveal a lower growth rate below -1 per cent and a lower rate of increase below -5 hundred hectares of NIA under rice cropping. This region also includes the districts of Monghyr, Saharsa and Palamau in the case of growth rate while in the case of

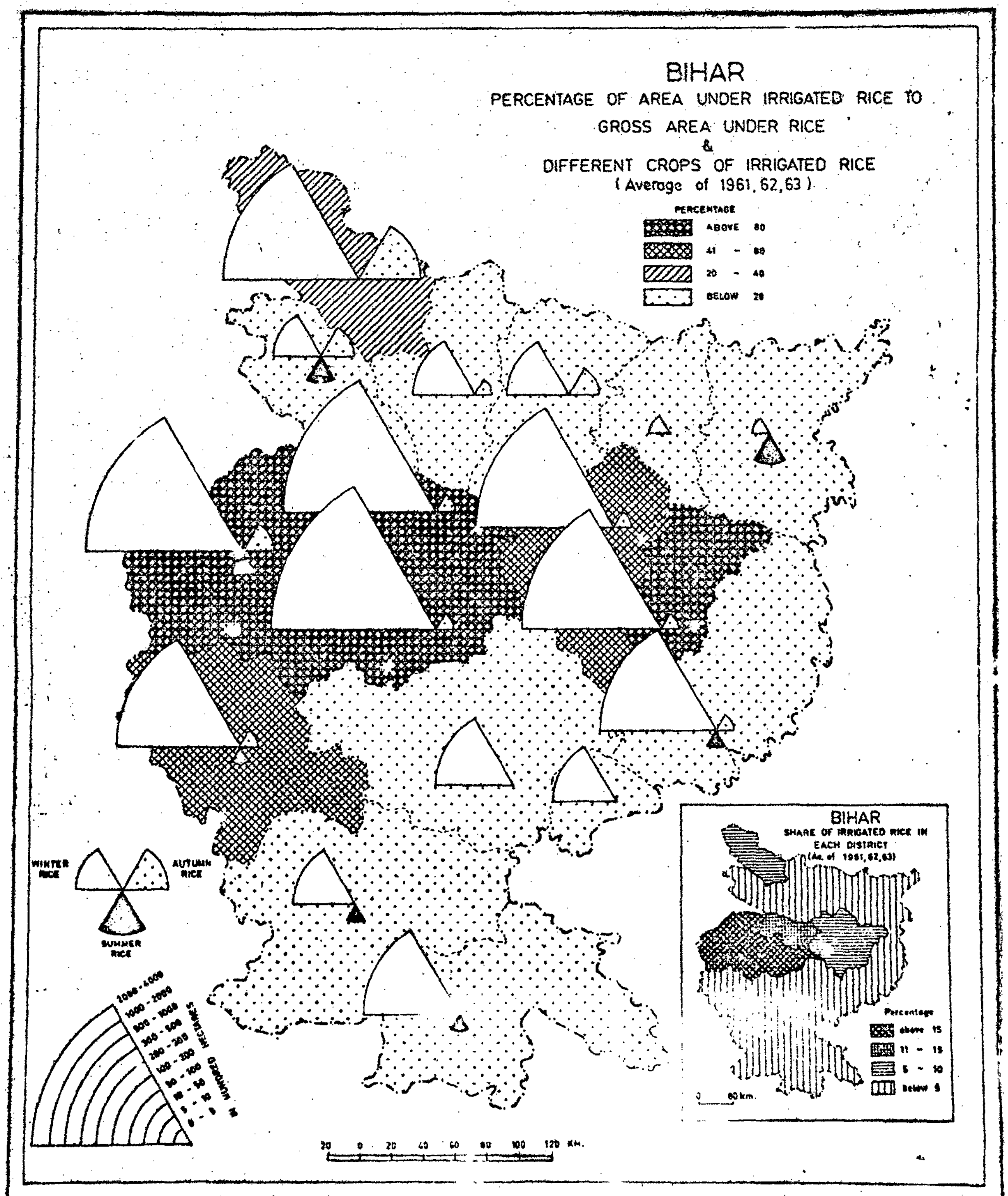
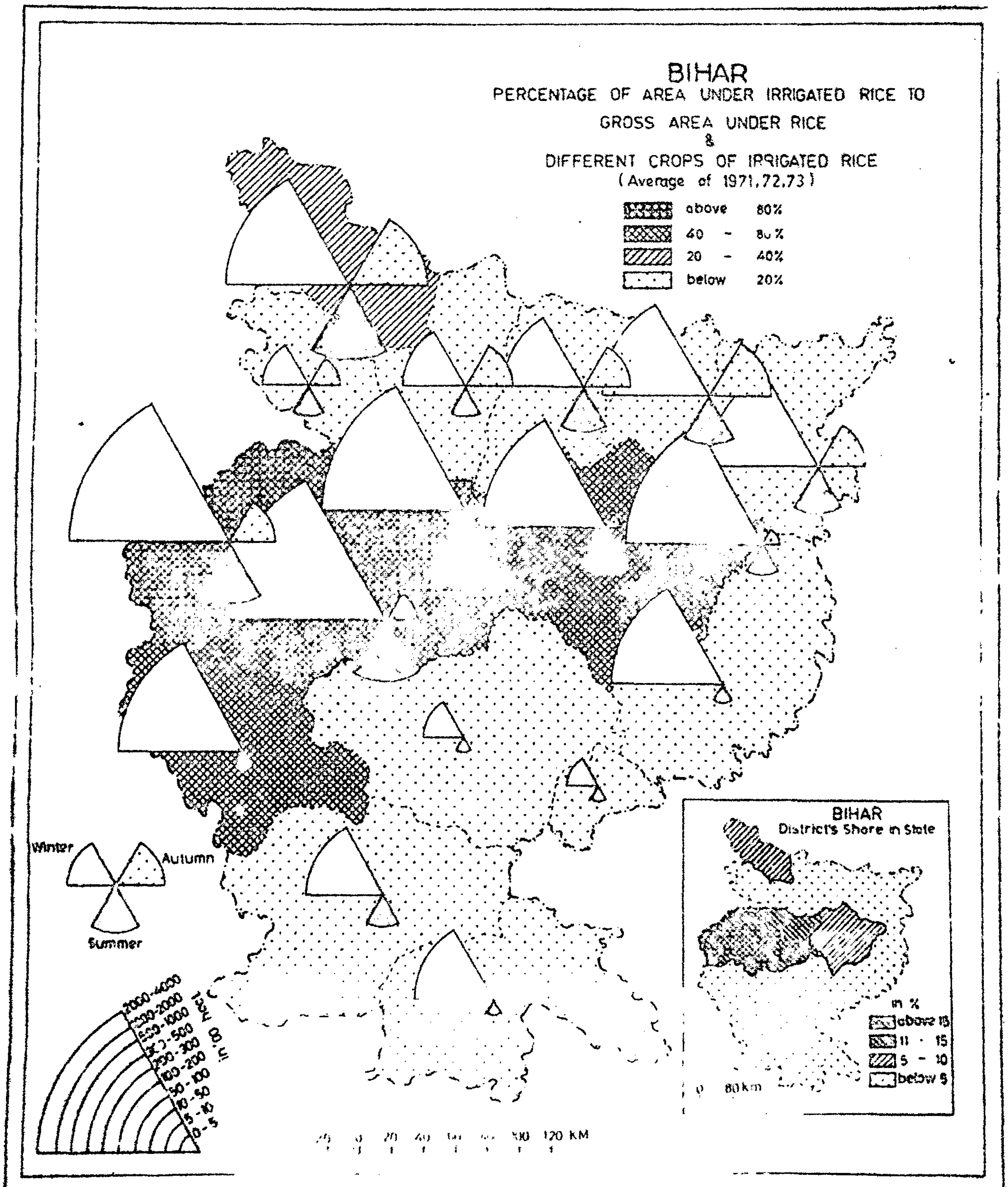

BIHAR
PERCENTAGE OF AREA UNDER IRRIGATED RICE TO
GROSS AREA UNDER RICE
&
DIFFERENT CROPS OF IRRIGATED RICE
(Average of 1961, 62, 63)
PERCENTAGE
ABOVE 60
41 - 60
20 - 40
BELOW 20
WINTER RICE
AUTUMN RICE
SUMMER RICE
1000 - 2000
IN HUNDRED HECTARES
20 0 20 40 60 80 100 120 KM.
BIHAR
SHARE OF IRRIGATED RICE IN EACH DISTRICT
(Av. of 1961, 62, 63)
Percentage
above 15
11 - 15
5 - 10
below 5
0 80 km.

Fig 18



BIHAR
PERCENTAGE OF AREA UNDER IRRIGATED RICE TO
GROSS AREA UNDER RICE
&
DIFFERENT CROPS OF IRRIGATED RICE
(Average of 1971,72,73)
above 80%
40 - 80%
20 - 40%
below 20%
Winter
Autumn
Summer
in 00 hect
BIHAR
District's Share in State
in %
above 15
11 - 15
5 - 10
below 5
0 80 km
120 KM

Fig 19

linear increase Palamau falls in the high linear rate of increase as discussed above.

4.6 Area Under different Crops of Rice :

In Bihar normally three crops of rice are sown autumn, winter and summer. Among these winter rice is the most important, covering more than 90 per cent of area under total rice in most of the districts.

4.6.1 Area under Autumn Rice :

The normal area given to autumn in Bihar is 4,88,037 hectares (1971-73) whereas its area in 1961-63 was only 3,83,453 hectares. It implies that the area under autumn rice is increasing. However, there are some districts where there was a significant increase in the area under autumn rice during this study period (Table-13). The districts were Champaran (66,438 to 1,03,461 hectares), followed by Darbhanga (16,925 to 22,748 hectares). It is interesting to note that most of the districts of Bihar plateau experienced decrease in the area under autumn rice and it is due to lack of irrigational facilities.

In general autumn rice occupies very less area. The largest percentage of area under autumn to total rice is found in the North Bihar plain. The districts in the North Bihar plain have also gained in autumn rice in 1971-73 over

Table - 13

Area under Autumn Rice and % to GAR and area under irrigation Autumn Rice and % to AAR (Av. of 1961-62-63 & 1971-72-73)

Districts	1961 - 63		1971 - 73		1961 - 63		1971 - 73	
	AAR (in hec.)	% of AAR to GAR	AAR (in hect.)	% of AAR to GAR	AIAR (in hec.)	% of AIAR to AAR	AIAR (in hec.)	% of AIAR to AAR
Bihar Plain								
Patna	296	0.11	237	0.11	84	19.38	177	74.68
Gaya	2034	0.40	2069	0.45	445	22.60	882	42.62
Sahabad	9062	1.81	4597	0.91	824	10.54	1456	31.89
Saran	22882	11.22	36128	18.51	629	4.16	611	1.69
Champaran	66428	16.74	103461	21.63	9875	13.82	17357	16.77
Muzaffarpur	13884	4.27	17159	5.33	361	3.49	1168	6.74
Darbhanga	16925	4.44	22748	6.04	444	3.18	2055	9.03
Munghyr	2535	1.22	1104	0.78	215	12.82	269	24.36
Bhagalpur	556	0.36	684	0.43	103	22.04	56	8.10
Saharsa	13026	10.72	21011	10.98	-	-	2251	10.71
Purnea	80036	18.73	102817	20.49	9	-	2768	2.23
Bihar Plateau								
Santhal Parganas	12815	2.90	8067	1.91	170	1.90	6	2.10
Hazaribagh	8485	2.93	8987	3.93	18	-	23	4.02
Ranchi	104321	23.15	85758	23.15	-	-	12	3.01
Palamau	16297	9.71	14645	13.81	135	1.01	6	2.11
Dhanbad	386	0.45	241	0.34	-	-	-	-
Singhbhum	23822	6.69	20415	5.75	19	-	4	1.20
State	383453		488037		13991	6.01	39075	5.95

AAR = Area Under Autumn Rice
GAR = Gross Area Under Rice
AIAR = Area Under Irrigated Autumn Rice

1961-63. But if we look at compound growth rates we find that most of the important districts (Patna, Gaya, and Shahabad etc) have recorded negative growth rate. It strikes that these districts have reduced their area under rice between two points of time. Therefore, to see the behaviour of autumn rice it is essential to analyse the compound growth rates and linear rates of increase.

4.6.1.1 Growth in area under Autumn Rice :

There are only 9 districts which have experienced a positive growth so far as area under autumn rice is concerned (Table-14). These districts, in order of their compound growth rates are Saharsa (10.60 per cent); Champaran (5.80 per cent); Saran (5.40 per cent); Dhanbad (1.40 per cent); Bhagalpur and Hazaribagh (0.20 per cent each) districts. The last 3 districts of this group fall below the state average figure of 3 per cent. Where we examine the linear rate of increase of these districts, we find that it is negative only in the case of Dhanbad district (0.09). However, the remaining districts have also experienced a positive linear rate of increase. The maximum has been experienced in the case of Champaran district (46.93) while the minimum is experienced by Bhagalpur (0.06). A total of 8 districts have experienced negative compound growth rate. The maximum can be witnessed (Table-9) in Monghyr (-8.59 per cent) districts where as the minimum is experienced by Gaya

Table - 14

Compound growth rates and linear rates of increase of area under autumn rice and area under irrigated autumn rice (1961-73)

District	Area under Autumn rice		Area under irrigated autumn rice	
	Compound growth rates (%/annum)	Linear rates of increase ('00 hect/annum)	Compound growth rates (%/annum)	Linear rates of increase ('00 hect/annum).
Bihar Plain				
Patna	-2.12	-0.08	9.80	0.11
Gaya	-0.07	-0.17	7.50	0.48
Shahabad	-7.66	-5.05	2.40	0.36
Saran	5.40	15.53	0.67	0.32
Champaran	5.80	46.93	9.00	9.46
Muzaffarpur	3.30	4.67	15.80	0.91
Darbhanga	4.00	7.77	18.00	1.83
Monghyr	-2.59	-1.61	3.20	0.04
Bhagalpur	0.20	0.06	-7.06	-0.05
Saharsa	10.6	12.64	158.30	2.85
Purnea	3.6	32.18	-15.30	-3.33
Bihar Plateau				
Santhal Parganas	-5.94	-6.13	-36.02	0.18
Hazaribagh	0.20	0.25	-19.91	-0.008
Ranchi	-3.39	-7.08	6.7	0.001
Palamau	-1.43	-2.29	31.42	0.26
Dhanbad	1.4	-0.09	-0.80	-0.00
Singhbhum	-1.32	-3.16	20.71	0.02
State	3.00	132.01	9.7	19.27

(-0.07 per cent). However, all these districts have also registered a negative linear rate of increase. The maximum is in Ranchi (-0.08).

Therefore, we can say that autumn rice area is increasing only in the districts where assured water is not available. Thus, it is quite interesting to note that autumn rice is wholly dependent on rainfall. It may also have a positive correlation with rainfall as we would be examining in Chapter V.

4.6.1.2 <u>Area under Autumn Irrigated Rice</u> :

The autumn crop of rice in Bihar is normally unirrigated as it is sown during the rainy season. The normal area under autumn irrigated rice in Bihar is 29,075 hectares (1971-73) whereas its area in 1961-63 was 55,501 hectares. In the year 1971-73, 5.95 per cent of the total area under autumn rice was irrigated in Bihar. However, the canal irrigated districts of Bihar plain have responded a significant change in the percentage of area under autumn irrigated rice to total area under autumn rice in the year 1971's over 1961's. The districts were, Patna (19.33 to 74.68 per cent), Gaya (32.63 to 42.62 per cent) and Shahabad (10.84 to 31.89 per cent) followed by Champaran (13.82 to 16.77 per cent) and Monghyr (12.82 to 24.36 per cent). But as discussed earlier, that there is no change in the area under autumn rice in those districts. And if we take the absolute figures of autumn irrigated rice we found that the districts of Champaran (7,700 hectate), Purnea (2,800 hectare), Saharsa (2,300 hectare) and Darbhanga (1,500 hectare) have got more than the double area under autumn irrigated rice in the years 1971's over 1961's.

During the period of 12 years autumn irrigated rice shows a high growth in the region of North Bihar comprising the districts of Muzaffarpur, Darbhanga, ans Saharsa. Where growth is noticed for more than 10 per cent of NIA under autumn rice. Among them Saharsa has highest rate of growth about 158 per cent. The plain regions of Patna, Gaya, Shahabad exhibit medium growth rate in the range of 1 to 10 per cent of NIA under autumn rice cropping. Another discrete regions of medium growth occurs in Champaran of the Northern Bihar and in Monghyr and Ranchi of Southern Bihar. The districts of Southern Bihar such as Bhagalpur, Santhal Parganas, Dhanbad, Hazaribagh and Palamau form a region of low growth rate below 1 per cent. It also includes the district of Saran in Northern Bihar.

The linear rate of increase of the NIA under autumn rice cropping form two distinct region of positive and negative increment in the districts of Northern and Southern Bihar except Purnea and Bhagalpur, all the districts show a positive rate of increase. Among these Champaran makes highest, 946 hectares per annum irrigated area under autumn rice. In South Bihar Hazaribagh and Dhanbad have shown negative growth.

4.6.2 <u>Area Under Winter Rice</u> :

As discussed earlier that among all three crops of rice winter rice covers in most of the districts having more than 90 per cent share of total area under rice. The normal area given to winter rice in Bihar is 4.69 million hectares (1971-73) but it was 4.83 million hectates in (1961-63). And there is a decrease in area under winter rice in almost all the districts, except Bhagalpur, Saharsa, Purnea and Singhbhum. In three districts Purnea has maximum area under winter rice in both years (1961's and 1971's) the area was 3,45,982 and 3,94,517 hectares whereas Bhagalpur recorded minimum i.e. 1,51,269 and 1,54,878 respectively (Table-15). These districts have responded positive growth in the winter irrigated rice and more over, these are highly rainfed districts. But overall area under winter rice is decreasing which can be clearly observed in the analysis of compound growth and percentage of area under winter rice to total rice.

While considering the percentage share of winter rice to total rice, we find that except four districts viz.

Table - 15

Area winter rice and % to GAR and Area under irrigated winter rice and % to Area under winter rice (Average of 1961-62-63 and 1971-72-73)

Districts	1961-63		1971-73		1961-63		1971-73	
	AWR (in hec.)	% of AWR TO GAR	AWR (in hec.)	% of AWR to GAR	AIWR (in hec.)	% of AIWR to AWR	AIWR (in hec.)	% of AIWR TO AWR
Bihar Plain								
Patna	255007	99.88	205399	96.27	246390	94.69	203892	99.20
Gaya	494435	99.59	445809	97.79	480425	97.90	444447	99.60
Sahabad	491427	98.15	483643	96.71	438636	87.00	427923	88.40
Saran	180440	88.55	157729	80.82	2436	1.38	2345	1.48
Champaran	330085	83.14	296689	62.04	95411	30.75	83360	28.00
Muzaffarpur	310691	95.69	301743	94.33	8784	6.19	5932	1.96
Darbhanga	363163	95.42	352058	93.53	6549	2.71	19420	5.60
Munghyr	237234	98.92	137374	97.07	135448	65.61	86896	63.20
Bhagalpur	151269	99.61	154875	99.99	122856	75.91	126334	81.57
Saharsa	108065	89.00	164706	89.12	472	0.77	35316	21.44
Purnea	345982	80.97	394517	88.65	119	0.03	46948	11.90
Bihar Plateau								
Santhal Pragana	427555	93.98	412766	96.90	77423	21.19	45504	11.02
Hazaribagh	274776	93.96	215667	95.67	16532	7.12	4641	2.10
Ranchi	345661	76.72	283826	76.61	5377	2.06	12233	4.30
Palamau	101172	91.32	91241	86.05	22183	73.26	59048	64.70
Dhanbad	84396	99.64	69040	99.47	5163	4.48	1026	1.48
Singhbhum	332001	93.24	333613	94.07	23568	7.47	17413	5.21
State	4833340		4594989		1758119	37.11	1622873	36.30

GAR = Gross Area Under Rice
AWR = Area Under Winter Rice
AIWR = Area Under Irrigated Winter Rice

Bhagalpur (99.61 to 99.9 per cent), Shaharsa (89.00 to 89.12 per cent), Purnea (80.97 to 88.66 per cent) and Singhbhum (93.24 to 94.07 per cent) all the districts of Bihar have experienced loss in the area under winter rice during the period 1971-73 over 1961-63.

4.6.2.1 Growth in area under Winter Rice :

The analysis shows (Table-16) that almost all the districts except 4 have experienced negative growth in area under winter rice. The districts which have experienced positive rate of growth are Saharsa (6.30 per cent); Purnea (1.70 per cent); Bhagalpur and Singhbhum (each 0.20 per cent). They have also experienced a positive linear rate of increase. The maximum is found in the case of Saharsa (67.83) while the minimum has been registered in Bhagalpur district where it is 3.90 only. Among the districts where there has been a negative growth and negative linear rate of increase, the district of Monghyr tops the list with highest negative growth of -5.41 per cent and linear rate of decrease of -97.16 while Muzaffarpur experienced a minimum of both i.e. a compound growth rate of -0.12 per cent and a linear rate of decrease of -3.03.

Table - 16

Compound growth rates and linear rates of increase of area under winter rice and area under irrigated winter rice (1961-73)

Districts	Area under winter rice		Area under irrigated winter rice	
	Compound growth rates (%/annum)	Linear rates of increase ('00 hect/annum)	Compound growth rates (%/annum)	Linear rates of increase ('00 hect/annum)
Bihar Plain				
Patna	-1.96	-45.42	1.55	34.84
Gaya	-0.96	-48.97	0.80	52.99
Shahabad	-0.23	-11.46	-0.16	- 6.98
Saran	-0.90	-23.06	1.70	- 2.16
Champaran	-2.93	-20.03	-2.93	-25.85
Muzaffarpur	-0.12	- 3.03	-3.13	- 3.82
Darbhanga	-0.51	-12.30	20.5	-17.98
Monghyr	-5.41	-97.16	- 4.32	-47.13
Bhagalpur	0.20	3.90	0.40	5.09
Saharsa	5.30	67.83	66.20	43.50
Purnea	1.70	61.87	-10.0	-56.98
Bihar Plateau				
Santhal Parganas	-0.83	-30.85	-5.94	-40.47
Hazaribagh	-2.69	-66.75	-12.64	-13.03
Ranchi	-2.03	-48.46	9.20	7.47
Palamau	-0.98	-10.12	- 0.09	- 9.65
Dhanbad	-2.32	-17.85	-19.74	- 6.29
Singhbhum	0.20	6.12	- 2.91	- 5.76
State	-0.44	-197.79	- 0.64	-107.43

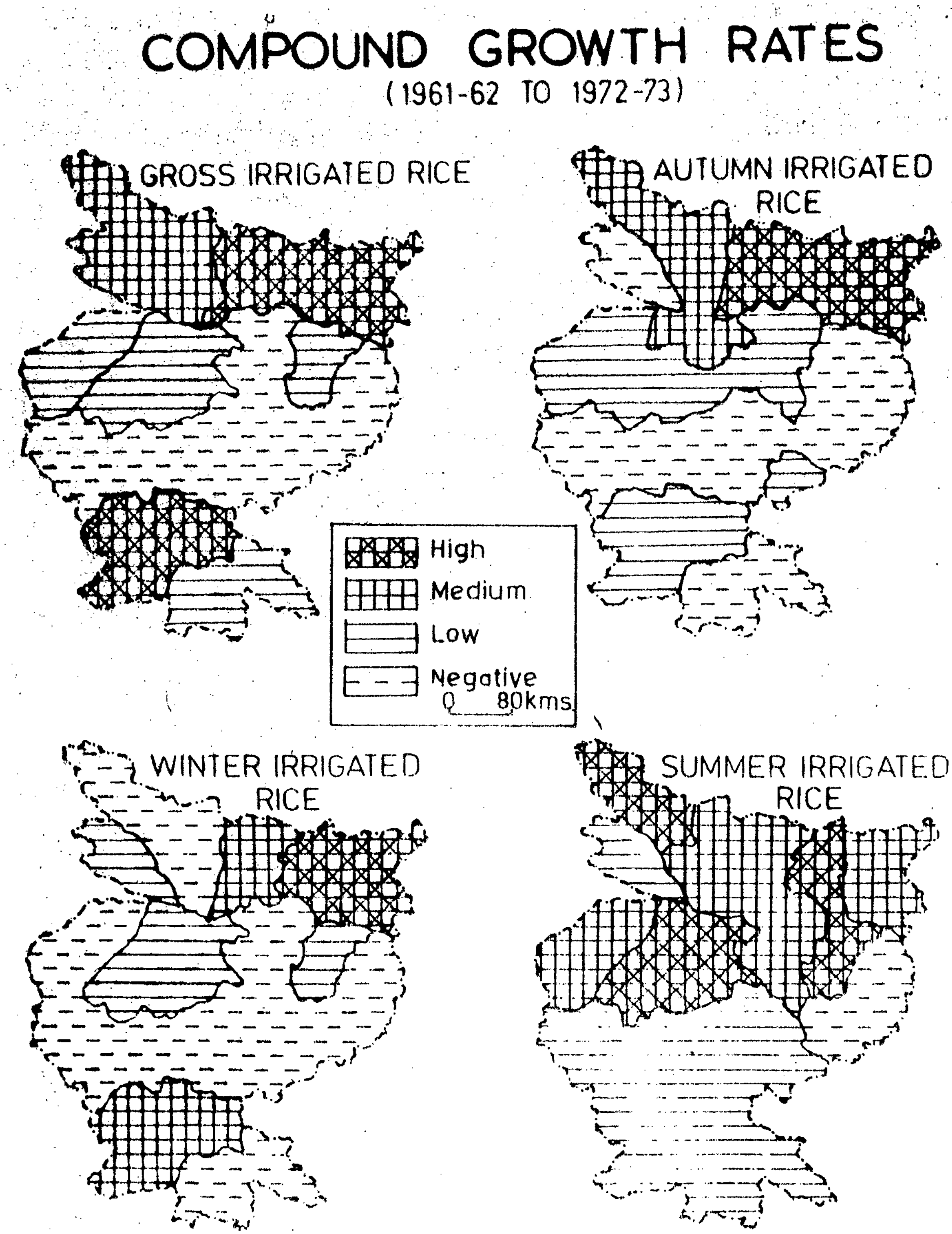

COMPOUND GROWTH RATES
(1961-62 TO 1972-73)
GROSS IRRIGATED RICE
AUTUMN IRRIGATED RICE
WINTER IRRIGATED RICE
SUMMER IRRIGATED RICE
High
Medium
Low
Negative
0 80kms

Fig 20

4.6.2.8 Area under winter Irrigated Rice :

The area under irrigated rice in Bihar was 17,54,120 hectares (1971-73) but it was 16,22,701 hectares in 1961-63. There is a marginal decrease in the area under winter irrigated rice. In the year 1971-73, the percentage of area under winter irrigated rice to area under winter rice was 35.3 per cent in Bihar. However, there are districts where was an increase in the percentage of area under winter irrigated rice to area under winter rice during the same period (1971-72 over 1961-63). The districts were Patna (94.69 to 93.2 per cent), Gaya (97.9 to 99.6 per cent), Shahabad (87.0 to 88.4 per cent) and Bhagalpur (75.9 to to 81.57 per cent). While considering the area under winter irrigated rice to area under winter rice we find that the area under winter irrigated rice is below 10 per cent to area under winter rice in the South Bihar Plateau during the period under study.

Out of 17 districts, 10 districts show a negative trend of growth rate in both the regions of North and South Bihar comprising the districts of Shahabad, Muzaffarpur, Champaran, Monghyr, Santhal Parganas, Hazaribagh, Palamau, Dhanbad, Purnea and Singhbhum. Among the districts of which show positive rate of growth are Patna, Gaya, Saharsa, Saran and Ranchi make a record of high growth rates. Similarly is the case with the linear rate of increase of NIA under winter crops of rice, where about 11 districts show a negative rates of growth in both the regions of Bihar Plain and Bihar Plateau. The districts of Saharsa and Purnea exhibit a gain of 4,360 and 5,628 linear rate per annum under winter irrigated rice in the period under study (1961-73).

4.6.3 Area Under Summer Rice :

Though, among the different crops of rice summer occupies very less percentage (0.18) of area but its increasing trend is marked among the three crops. However, during the period under study, the area under summer rice in Bihar has jumped from 4,355 hectares (1961's) to 69,628 hectates in 1971-73. Although, almost all the districts have registered high increase, Champaran has registered the maximum (304 to 77,996 hectares) and Dhanbad minimum (1 to 126 hectares) Table-17. In percentage of area also (under summer rice to total rice) Champaran achieved highest (from 0.02 to 16.33) followed by Patna (0.02 to 3.62), Saharsa (0.01 to 2.90), Shahabad (0.03 to 2.38), Monghyr (0.06 to 2.15) and Gaya (0.01 to 1.76) in 1971-73 over 1961-63. The percentage of area under summer rice was negligible in 1961-63 but after introduction of canal and well and tubewell irrigation, summer rice has taken important position among the other cereals. Total 15 districts have gained out of 17 in the

Table - 17

Area under summer rice and % to GAR and area under irrigated summer rice and % to area under summer rice (Average of 1961-63 and 1971-73)

Districts	1961-63		1971-73		1961-63		1971-73	
	ASR (in hec.)	% of ASR to GAR	ASR (in hec.)	% of ASR to GAR	AISR (in hec.)	% of AISR to ASR	AISR (in hec.)	% of AISR to ASR
Bihar Plain								
Patna	6	0.02	7700	3.62	1	-	10396	95.07
Gaya	1	0.01	7973	1.76	1	-	7969	99.90
Shahabad	196	0.03	11828	2.38	185	91.66	11790	99.67
Saran	453	0.21	1290	0.67	181	33.90	979	77.89
Champaran	137	0.02	77996	16.33	13	-	15318	10.63
Muzaffarpur	57	0.03	964	0.31	1	-	867	89.60
Darbhanga	220	0.04	1576	0.43	3	-	1137	72.10
Munghyr	70	0.06	3028	2.15	5	-	2620	86.50
Bhagalpur	26	0.01	883	0.58	0	-	837	94.70
Saharsa	246	0.01	5525	3.90	133	-	1160	20.90
Purnea	1165	1.16	4244	0.86	235	57.99	2447	57.60
Bihar Plateau								
Santhal Parganas	596	0.02	752	0.19	2	55.22	403	53.50
Hazaribagh	25	0.01	229	0.35	24	-	224	97.80
Ranchi	586	1.12	851	0.24	467	91.01	740	86.90
Palamau	64	0.01	137	0.14	61	8.90	137	99.00
Dhanbad	1	0.01	126	0.19	2	-	126	99.00
Singhbhum	242	0.02	606	0.18	93	80.59	482	79.50
State	4001		69623		1707		57632	82.70

years 1971-73 over 1961-63. Only two districts have registered negative viz. Purnea and Ranchi. And the percentage of area under summer irrigated rice to total area under rice in both the districts has decreased in the same year and thereby it reduce the area under summer rice.

4.6.3.1 Growth in Area Under Summer Rice :

Almost all the districts have experienced growth in area under summer rice during the period 1961-73. However, the range of growth varies between 217.40 per cent (Gaya) and 3.30 per cent (Santhal Parganas). So far as linear rates of increase is concerned, only one district has experienced a negative growth i.e. Monghyr having -3.14 only. When we consider the compound growth rate of the state (44.1 per cent) as a whole we find that 8 districts have experienced a faster rate of growth than the state of Bihar's figure of 44.1 per cent. All these districts (Table-18) are comparatively better off in irrigational facilities. However, one exception is there i.e. the district of Dhanbad is also above the state average where irrigation is not so developed. It implies, in this case, that in the initial years viz. 1961-62--63, very small proportion of land was available for rice, especially of summer rice. Later on, more area came under summer rice which made this growth rate so high which brought this

Table - 18

Compound growth rates and linear rates of increase of area under summer rice and area under irrigated summer rice (1961-73)

Districts	Area under summer rice		Area under irrigated summer rice	
	Compound growth rates (%/annum)	Linear rates of increase ('00 hect/ annum)	Compound growth rates (%/annum)	Linear rates of increase ('00 hect/ annum)
Bihar Plain				
Patna	146.7	9.50	215.50	12.05
Gaya	217.4	20.16	209.70	10.27
Shahabad	66.60	143.86	67.70	14.81
Saran	10.90	0.92	20.90	0.93
Champaran	92.70	91.06	204.70	10.02
Muzaffarpur	42.30	1.00	112.20	0.97
Darbhanga	24.80	1.40	98.50	1.21
Monghyr	65.60	-3.14	132.90	2.73
Bhagalpur	59.00	0.99	153.60	0.98
Saharsa	49.70	6.02	150.00	1.18
Purnea	16.10	3.32	- 66.60	- 2.27
Bihar Plateau				
Santhal Parganas	3.30	0.17	0.25	0.03
Hazaribagh	26.90	0.21	28.20	0.22
Ranchi	5.00	0.32	5.30	0.27
Palamau	10.20	0.08	- 9.80	- 0.08
Dhanbad	70.00	0.13	-37.00	0.01
Singhbhum	9.90	0.40	21.90	0.40
State	44.10	137.53	51.60	67.52

district in this group. Only two districts have recorded loss in the area under irrigated rice viz. Purnea and Palamau.

4.6.3.2 <u>Area Under Irrigated Summer Rice</u> :

The normal area of summer rice irrigated in Bihar was 57,601 hectares (1971-73) but the area irrigated to it was only 2,010 hectares in 1961-63. There is a significant increase in the area under irrigated summer rice. In the year 1971-73 the percentage of area under irrigated summer rice was 82.7 per cent. Except 3 districts viz. Saharsa (20.9 per cent), Purnea (57.6 per cent) and Santhal Parganas (63.6 per cent) in all the districts of Bihar more than 70 per cent of summer rice area is irrigated.

The trend of growth rate and linear rate of increase is much encouraging in the case of summer rice cropping. All the districts show a positive rate of growth other than Santhal Parganas which is also positive when linear rate of increase per annum is considered for the period of 1961-62 to 1972-73.

The growth rate of NIA under summer rice cropping form some distinct regions of high, medium and low growth rate which is more related to the regions of irrigation from various sources. Patna, Gaya, Champaran, Bhagalpur and Saharsa reveals a high rate of growth of NIA under summer rice as these districts are well served with irrigation facilities of prennial rivers of Ganga, Gandak and Kosi. The growth rate of NIA under this cropping is more than 150 per cent.

The districts of Shahabad, Muzaffarpur, Darbhanga, Monghyr and Purnea around around same Ganga and tributaries of Kosi form a distinct region of medium growth rate of NIA in the range of 50 to 150 per cent. Among these Saharsa and Monghyr exhibit a region of medium high growth rate. The districts of Southern Bihar like Hazaribagh, Ranchi, Palamau, Dhanbad and Singhbhum which are poorly served with the perennial rivers irrigation reveals lower rate of growth below 50 per cent as compare to the Northern districts of Bihar. Saran is the only exception which show a linear rate growth.

Observing the trend of linear rate of increase we find Patna, Gaya, Shahabad and Champaran are on the highest rate of increase more than 1,000 hectares of NIA per annum under summer rice cultivation. The districts of Saran, Muzaffarpur, Darbhanga, Monghyr, Bhagalpur, Saharsa and Purnea form a region of medium rate of increase in the range of 50 to 550 hectare of NIA per annum under summer rice. The districts of Southern Bihar like Santhal Parganas, Hazaribagh, Ranchi, Palamau, Dhanbad and Singhbhum exhibit a lower rate of linear increase below 50 hectare of land per annum under this cropping.

4.7 **Yields of Rice :**

In append 9, fig.21 yields are given, taking initial three years (1961-63) average and last three years average (1971-73). Table reveals that there is an increasing trend in the yields of rice over this period, due to irrigation development in Bihar over this period.

The districts having average yield higher than the State's average 789 kg/hectare (1971-73) are Patna (999), Gaya (883), Shahabad (968), Saran (869), Champaran (892), Muzaffarpur (835), and Bhagalpur (874). When compared with the average yields of 1961-63, it was found that 13 districts out of 17 have increased their yields rates. But except the three highly irrigated districts viz. Patna (788 to 999 kg/hectare), Gaya (717 to 883 kg/hectare) and Shahabad (775 to 968 kg/hectare) all the 10 districts have not responded high change in their yield rates during 1961-63 and 1971-73.

The districts sharing yield of autumn state's average 651 kg/hect. (1971-73) are Parna, Gaya, Shahabad, Saran, Champaran, Muzaffarpur, and Santhal Parganas. Out of 17 distt.

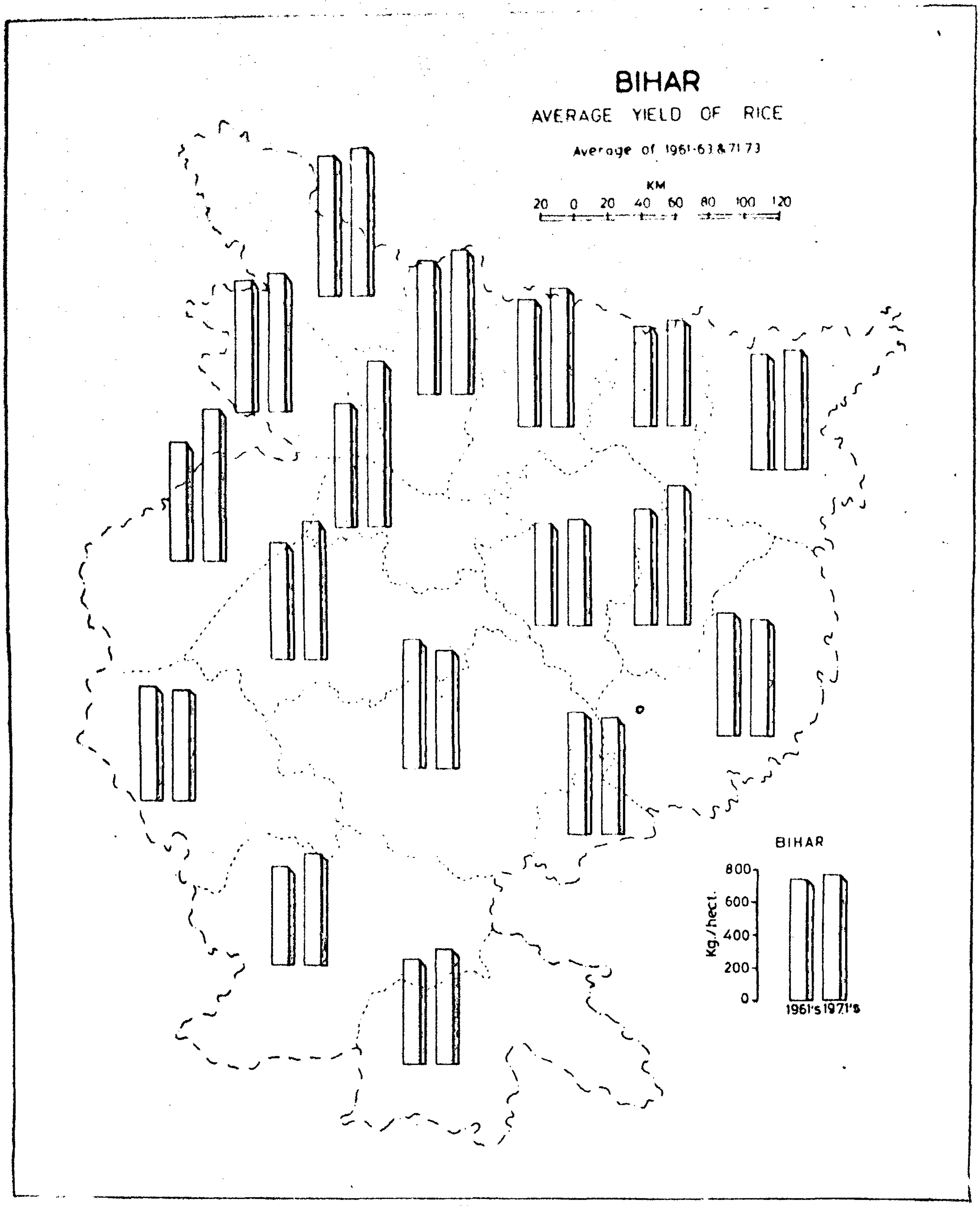
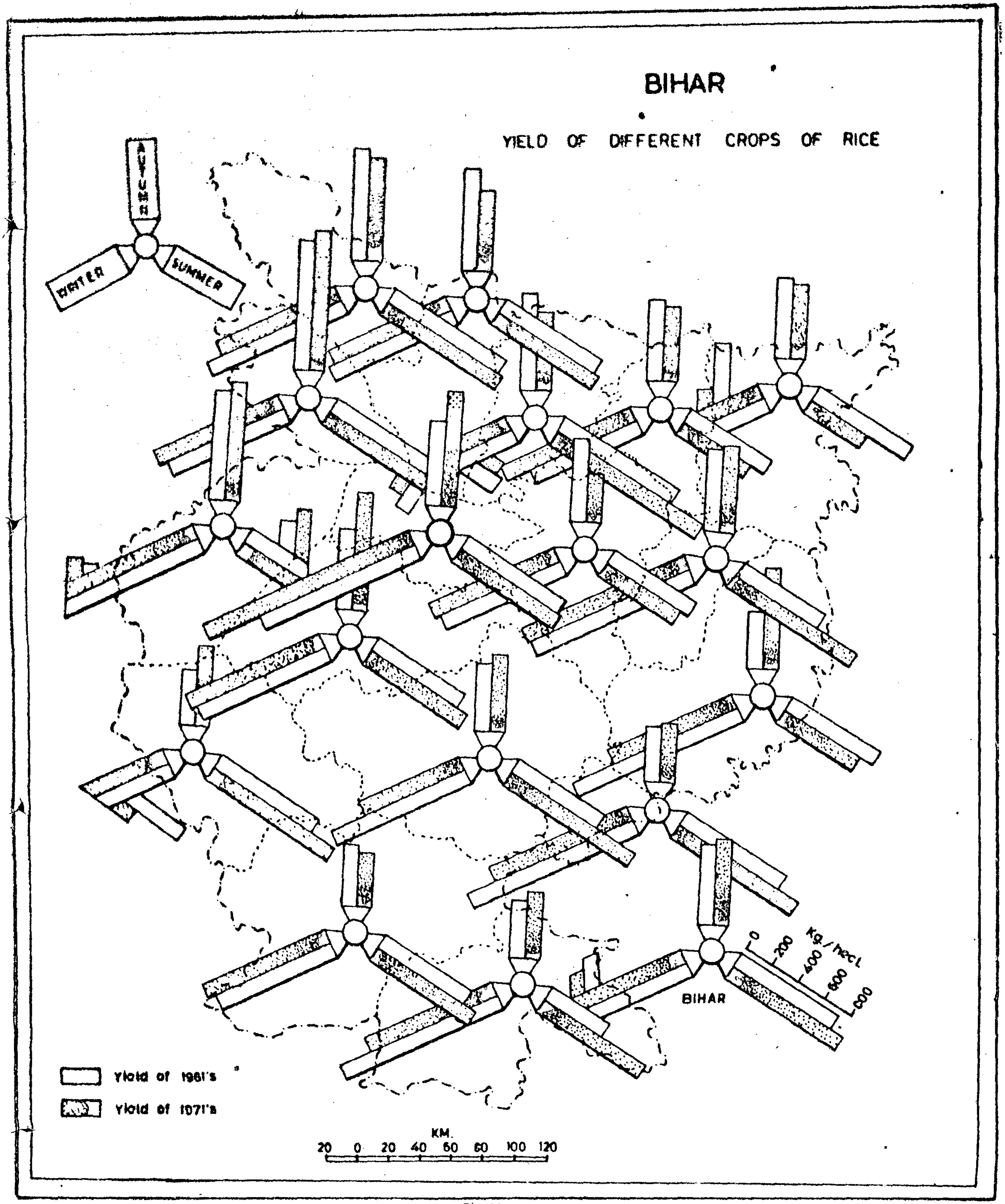

BIHAR
AVERAGE YIELD OF RICE
Average of 1961-63 & 71-73
KM
20 0 20 40 60 80 100 120
BIHAR
800
600
400
200
0
Kg./hect.
1961's
1971's

Fig. 21

districts 10 districts have registered increase in the yield of autumn rice in the year 1971's over 1961's. The districts which recorded decreased in the yield of Bhagalpur, Saharsa, Purnea and Ranchi. Rice grown in these districts, purely on rainfed conditions.

The districts with yield of winter rice higher than the state's average of 943 kg/hect. (1971-73) are; Patna (1437), Gaya (984), Shahabad (11 87), Bhagalpur (1143), Saharsa (961), and Dhanbad (987). Eight districts out of 17 have recorded increase in the yield of winter rice on this two point of time (1961's and 1971's), viz. Patna (1178 to 1437 kg/hect.), Gaya (1966 to 984 kg/hect.), Shahabad (1108 to 1187 kg/hect.), Saran (829 to 881 kg/hect), Monghyr (874 to 885 kg/hect.), Bhagalpur (1026 to 1143 kg/hect.), Saharsa (768 to 961 kg/hect.) and Ranchi (831 to 887 kg/hect.). Here if we compare with area of winter rice we find that these districts have registered lost in the area but in the yield they increasing the rate. It implies that irrigation development leads in the rate of yield fig.81.

The districts sharing the yield of summer rice higher than the State's average 867 kg/hectare (1971-73) are Gaya (881), Shahabad (932), Champaran (980), Muzaffarpur (986), Darbhanga (1106), Bhagalpur (965), Hazaribagh (956), Palamau (910), and Shanbad (929). Out of 17 districts 13 districts have shown increasing rate of yield they are Patna,



BIHAR
YIELD OF DIFFERENT CROPS OF RICE
AUTUMN
WINTER
SUMMER
Kg/hect
0
200
400
600
800
BIHAR
Yield of 1961's
Yield of 1971's
KM.
20 0 20 40 60 80 100 120

Fig 22

Gaya, Shahabad, Champaran, Muzaffarpur, Darbhanga, Bhagalpur, Hazaribagh, Ranchi, Palamau, Dhanbad and Singhbhum.

Having analysed the yield of rice we can conclude that whatever the irrigation development has taken place in Bihar, has lead to yields of rice also. The districts which have recorded loss in areas, they have increased their yield rate. For instance rice in Patna, Gaya and Shahabad, are grown under fully irrigated conditions and leads the highest yield in Bihar whereas in Purnea, Santhal Parganas and Singhbhum have the heaviest rainfall in the State but irrigation are negligible, the yield levels reached under these conditions are however low.

4.7.1 Changes in Yield of Rice between 1961 to 1973:

Having examined the growth area under rice, we now analyse the change yield of rice in general and rice yield in different seasons in particular (Table-19 and fig.23). First we consider the changes in average yield of rice, we find that the State of Bihar experienced an increase of 0.70 per cent (compound growth rate from 1961-62 to 1972-73). There are 11 districts which have also experienced a positive trend, but only 7 districts have experienced a growth which is more than the state average. The remaining 4 districts have recorded a growth below state average. The districts having significant change are Patna (2.70 per cent)

Table - 19

Compound growth rates and Linear rates of increase of average yield of Rice and different crops of Rice (1961-62 to 1972 - 73)

Districts	Average yield		Yield of Autumn Rice		Yield of Winter Rice		Yield of Summer Rice	
	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase
Bihar Plain								
Patna	2.70	0.04	5.30	0.05	1.40	0.03	50.50	0.13
Gaya	1.70	0.02	4.60	0.04	0.50	-0.005	24.40	0.07
Shahabad	1.70	0.02	4.50	0.05	-0.81	-0.005	2.40	0.04
Saran	0.80	0.0001	1.40	0.02	-0.85	00.001	1.53	0.005
Champaran	0.16	0.02	0.30	0.004	-2.93	-0.04	3.10	0.03
Muzaffarpur	0.69	0.01	2.19	0.02	-3.37	-0.03	2.60	0.03
Darbhanga	0.62	0.002	2.30	0.02	1.73	0.02	3.00	0.04
Monghyr	-1.90	-0.02	2.50	0.01	-0.10	-0.002	2.10	0.06
Bhagalpur	2.30	0.03	0.00	-0.01	1.20	0.02	5.70	0.08
Saharsa	1.03	0.006	3.42	0.02	0.60	0.02	3.97	0.01
Purnea	2.04	0.02	-1.46	-0.02	-8.59	-0.06	-2.86	-0.002
Bihar Plateau								
Santhal Parganas	-0.62	-0.003	1.50	0.01	-2.30	-0.03	0.10	0.01
Hazaribagh	-0.55	-0.22	-0.02	-0.007	-2.40	-0.04	2.60	0.07
Ranchi	0.05	0.0004	1.32	0.007	0.70	-0.008	0.69	0.009
Palamau	-0.14	-0.01	1.42	0.01	-4.52	-0.04	-0.67	-0.006
Dhanbad	-0.64	-0.005	-0.28	-0.0009	-1.62	-0.03	0.00	0.01
Singhbhum	-0.10	-0.0009	0.40	0.002	-2.37	-0.04	3.30	0.03
State	0.70	0.012	0.80	0.0007	-0.90	-0.012	3.50	0.051

COMPOUND GROWTH RATES
(1961-62 TO 1972-73)

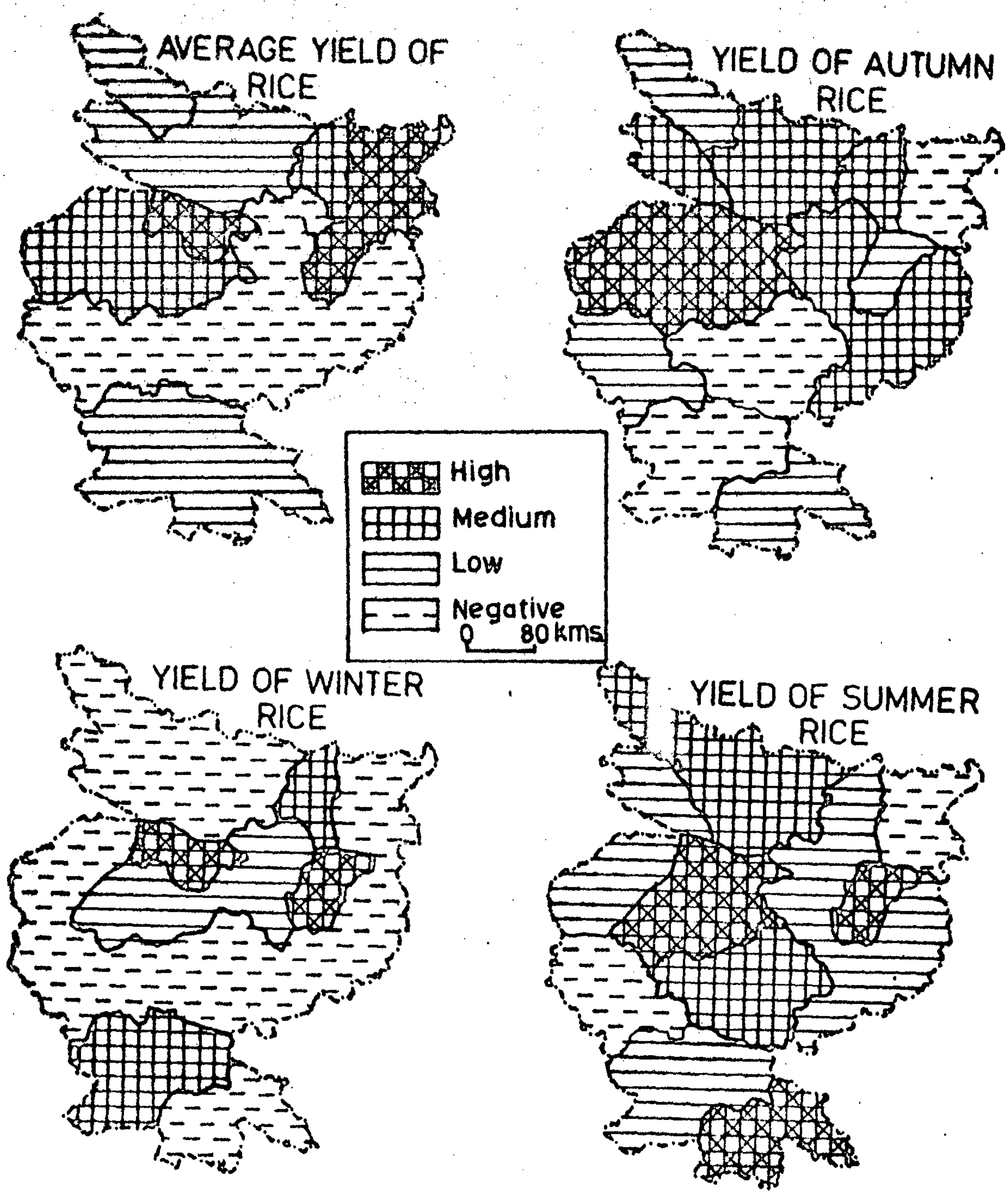


Fig. 23

followed by Purnea (2.74 per cent), Bhagalpur (2.30 per cent), Gaya and Shahabad (1.70 per cent), and Saharsa (1.03 per cent). In the districts of Saran, Muzaffarpur, Darbhanga, Singhbhum and Ranchi the change in the yield is insignificant. When we consider linear rate of increase in these 11 districts, we find, that the increase in almost all the districts has been positive except Singhbhum which recorded its value negative (-0.0009). The value for remaining 9 districts ranges from 0.0001 (Saran) to 0.04 (Patna). While taking into account the districts which have recorded a negative compound growth are Monghyr (-1.09 per cent) followed by Dhanbad (-0.64), Santhal Parganas (-0.62), Hazaribagh (-0.55), Champaran (-0.16), and Palamau (-0.14). The linear rate of increase in these districts has also been negative except in one district i.e. Champaran (0.02). When we compare the linear rate of increase in these districts with state average (Table-19), there are 8 districts which have experienced an increase more than state average. We find that the increase in yield has been experienced by those districts which have more or less better irrigational facilities.

However, it becomes more clear when we consider change in yield of rice grown in different seasons, as yield depends on many factors for example maintenance of land, inputs and water facilities etc. Therefore, it is not necessary that the yield will be same for all crops of rice. Hence, the growth of yield of each rice has been analyse separately.

4.7.2 Changes in yield of Autumn Rice :

There are 14 districts which have experienced an increase so far as yield of autumn rice is concerned. It ranges from constant (0.00 per cent) in Bhagalpur to 5.40 per cent in Shahabad district. It is quite interesting to note the state average on the whole has a growth of 0.80 per cent for this particular crop. Therefore, 11 districts have experienced a change more the state average. There are only three districts which have experienced a negative growth in a period from 1961 to 1973, these districts are; Purnea (-1.46 per cent), Hazaribagh (-0.02 per cent), and Dhanbad (-0.28 per cent). While considering the linear rate of increase in these districts , 13 have experienced positive whereas the remaining 4 including Bhagalpur (-0.01) experience negative rate of increase. It implies that autumn rice is much more in practice inviting all types of inputs to increase the yield.

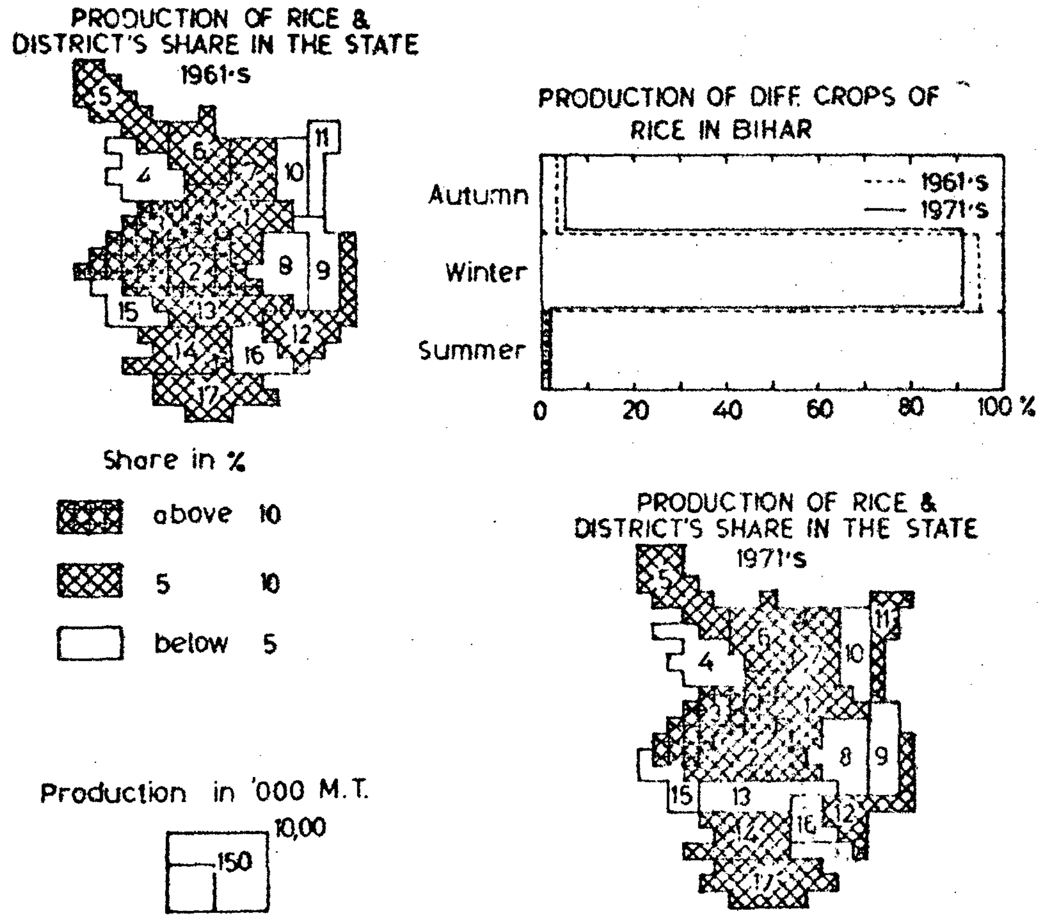
4.7.3 Change in yield of Winter Rice :

So far as the yield of winter rice is concerned only six districts have recorded of positive change. It ranges from 0.05 per cent in Gaya to 1.5 per cent in Patna district. It implies that the yield of winter rice is decreasing.

Because the State average has shown a negative growth (-0.9) for this particular crop. Therefore, all the six districts have registered a growth more than the state average. These are Patna (1.4 per cent), Gaya (0.6 per cent), Monghyr (0.7 per cent, while considering the linear rate increase, only four districts have experienced positive viz. Patna (0.03 per cent), Monghyr (0.002 per cent) and Saharsa (0.02 per cent) and have recorded more than the state average (-0.012 per cent). We find that winter yield in practice is decreasing during this period (1961-73), even in districts which are having good irrigational facilities because, depending on rainfall (for this particular crop) farmers are not irrigating or they might have transferred to the other profitable crops.

4.7.4 <u>Change in Yield of Summer Rice</u> :

There are 15 districts (out of 17) which have experienced of positive growth as far as the yield of summer rice is concerned. It ranges from constant (0.00 per cent) in Dhanbad to 50.5 per cent in Patna district. It is interesting to note the state average on the whole has a growth of 3.50 per cent for this particular crop. The districts having growth in yield of summer rice higher than the state's average are Patna (50.5 per cent), Gaya (25.4 per cent) and Bhagalpur (5.7 per cent). Only two districts Purnea (2.86 per cent) and Palamau (0.67 per cent) have shown negative



Note: Districts S.N. see in the text.

Fig. 24.

increase in the production (1971's over 1961's) is concerned 13 districts have gained viz; Patna (267 to 299), Gaya (445 to 459), Shahabad (495 to 543), Saran (150 to 174), Champaran, Muzaffarpur, Darbhanga, Monghyr, Bhagalpur (140 to 177), Saharsa (85 to 111), Purnea (33 to 259), Ranchi (303 to 342), and Singhbhum (341 to 384) during this period. The production of all the plateau districts (Santhal Parganas, Hazaribagh, Palamau and Dhanbad) have declined in 1971's over 1961's. It implies that these districts have suffered from the lack of irrigational facilities.

4.8.1 Growth in Production of Rice :

The significance of production depends upon acreage given to rice and yield of rice per hectare. Some of the districts have both advantages but their density of population is high, but some of the districts share greater acreage and average yield with low density.[12] The latter is true of lowland districts. Highland districts have surplus whereas the lowland districts seldom list as dominating surplus district of rice except Champaran.

Table-20 reveals the compound growth (% per annum) and linear rate of increase during 1961-62 to 1972-73. When

---

12. R.P.Singh and A.Kumar (1970) - 'Monograph of Bihar' Bharati Bhavan, Patna, p.41.

Table - 20

Compound growth rates and Linear rates of increase of production of different crops of rice (1961-63 to 1972-73)

Districts	Total production		Production of Autumn Rice		Production of Winter Rice		Production of Summer Rice	
	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase	Compound growth rates	Linear rates of increase
Bihar Plain								
Patna	1.70	13.37	4.00	0.03	1.40	6.49	183.20	6.85
Gaya	-0.32	-12.00	4.70	-0.32	-0.67	17.97	198.00	5.31
Shahabad	0.20	9.42	-4.72	-0.48	-0.18	2.87	75.00	7.05
Saran	0.00	3.38	8.50	8.08	-5.14	-1.78	13.40	0.30
Champaran	1.10	12.15	6.30	147.78	-1.53	17.03	92.30	13.35
Muzaffarpur	1.83	16.81	1.90	0.70	-2.00	-16.99	53.90	0.61
Darbhanga	0.53	12.23	0.20	1.13	-0.96	-4.44	36.90	0.79
Monghyr	-1.91	12.33	-5.96	-0.19	-0.91	-13.33	76.60	1.19
Bhagalpur	3.0	18.10	-1.03	-0.001	2.90	17.34	81.80	0.74
Saharsa	4.10	12.62	4.10	1.11	3.70	10.21	49.30	1.21
Purnea	3.61	25.98	3.00	5.39	-4.54	-32.97	22.60	1.57
Bihar Plateau								
Santhal Parganas	-0.96	-27.49	-3.73	-0.78	-1.98	-30.35	9.20	0.17
Hazaribagh	-5.01	-40.25	-0.32	-0.003	-2.53	-27.52	34.70	0.10
Ranchi	3.00	20.76	0.80	1.63	1.50	15.86	5.50	0.14
Palamau	-3.02	-7.58	0.80	0.23	-2.97	-7.57	12.70	0.04
Dhanbad	-3.15	-11.49	2.00	-0.009	0.00	-6.83	64.30	0.06
Singhbhum	1.11	18.34	-2.55	-0.62	-1.11	-17.88	17.00	0.19
State	0.50	92.83	3.50	31.55	-4.35	-299.30	51.80	41.03

we look at the table we find that the State of Bihar experienced a growth 0.5 per cent growth. There are 11 districts which have also recorded a positive growth; but only 9 districts have experienced a growth which is more than state average are Patna (1.7 per cent), Champaran (1.1 per cent?, Muzaffarpur (1.83 per cent), Bhagalpur (3.0 per cent), Saharsa (4.1 per cent), Purnea (3.61 per cent), Ranchi (3.0 per cent) and Singhbhum (1.11 per cent). When we consider linear rate of increase in these 11 districts has been positive but non of them are above the State's average (92.83). We find that the growth of production has been recorded by those districts which have the growth in area under rice and more or less better irrigational facilities. That's why the districts of South Bihar only responded negative growth.

4.8.2 Growth in Production of Autumn Rice :

There are 11 districts which have registered a positive growth and the districts sharing higher than the State's average 3.5 per cent are Patna (4.0 per cent), Gaya (4.7 per cent), Saran (8.6 per cent), Champaran (6.3 per cent) and Saharsa (4.1 per cent). There are only six districts which is in south Bihar have registered negative. While analysing the linear rate of increase we find that only one district Champaran (147.78) has experienced higher than the state

COMPOUND GROWTH RATES

OF PRODUCTION OF

RICE

(1961 – 73)

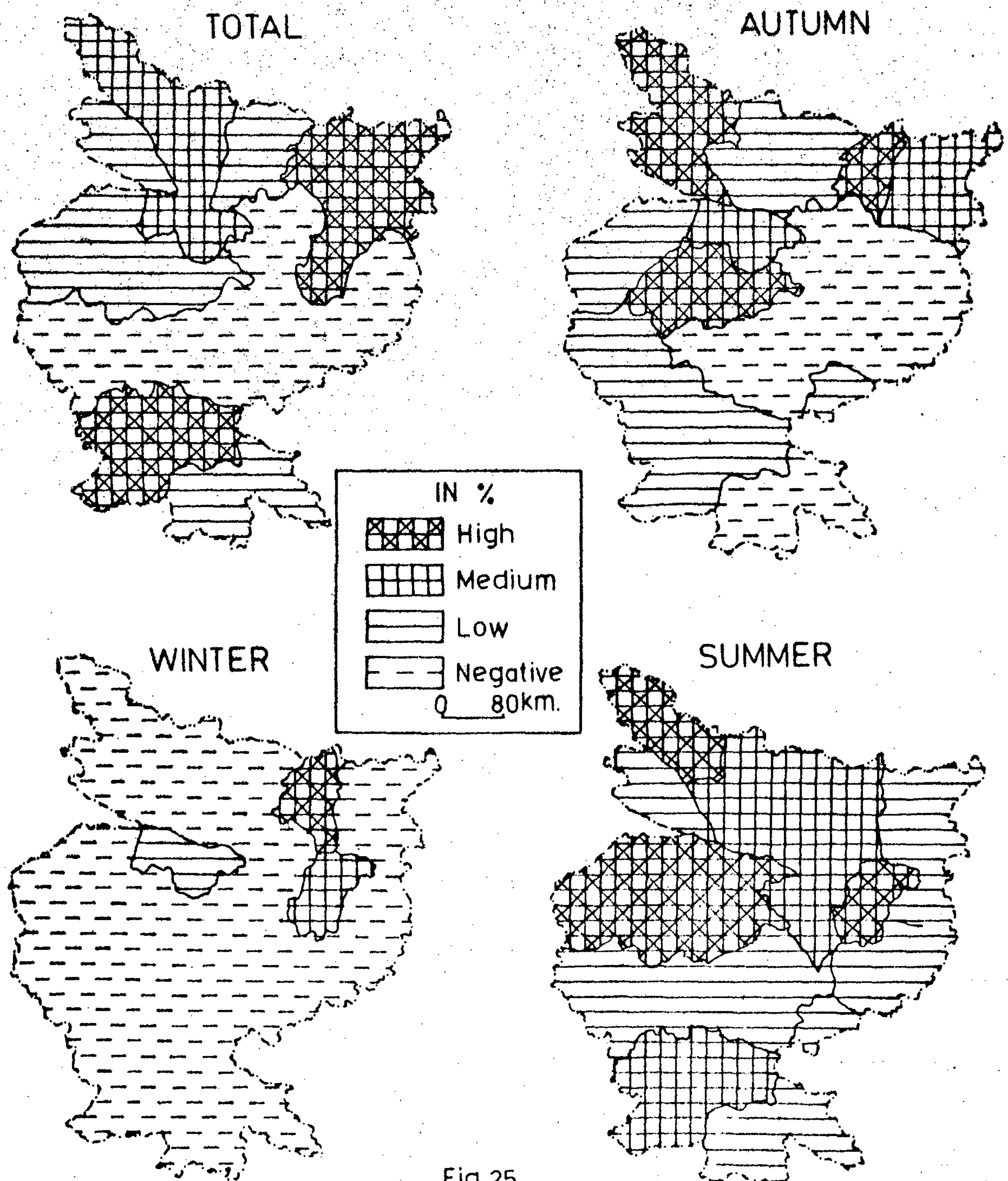


Fig.25

average (31.55). A close perusal of the Map 25 reveals that Patna, Gaya, Saran, Champaran and Saharsa are by far the most important districts which produce autumn rice. Other districts share its production but do not account for greater concentration. The districts which responded negative are the districts of negative growth either in area or in yield for this particular crop. For example Shahabad have increased their yield rate but the area under autumn rice has gone down, same in the case of Santhal Parganas, Hazaribagh and Singhbhum. However, except Shahabad these districts do not have good irrigational facilities.

4.8.3 Growth in Production of Winter Rice :

As we have seen while analysing the growth of area and yield of this particular crops, it is decreasing and it responded more or less the same pattern here also. Only the districts which is having highest share in irrigation have responded positive growth in both compound and linear. The districts having positive growth in production of this particular crop during 1961-73 are; Patna (1.4 per cent), Bhagalpur (2.8 per cent), Saharsa (3.7 per cent) and Ranchi (1.5 per cent). Rest all the districts have experienced negative growth but out of 13 districts, 10 have recorded higher than the state's average (-4.35 per cent) are Gaya (-0.67 per cent), Shahabad (-0.18 per cent), Champaran (-1.53 per cent), Muzaffarpur (-2.0 per cent), Darbhanga

(-0.96 per cent), Monghyr (-0.91 per cent), Santhal Parganas (-1.98 per cent), Hazaribagh (-2.53 per cent), Palamau (-2.97 per cent), Singhbhum (-1.11 per cent). Since the area and yield of this particular crops are decreasing it is quite obvious that the production will also decrease, it depends upon acreage given to rice and yield of rice kg/hectare.

4.8.4 Growth in Production of Summer Rice :

The production of summer rice is now gaining ground in favoured areas of the districts of the State. All the districts have experienced an increase in production of summer rice (Table 20) from 1961-62 to 1972-73. However, the districts sharing production of summer rice higher than the state's average of 51.8 per cent are: Patna (183.2 per cent), Gaya (198.0 per cent), Shahabad (75.0 per cent), Champaran (92.3 per cent), Muzaffarpur (63.9 per cent), Monghyr (76.6 per cent), Bhagalpur (81.8 per cent), and Dhanbad (64.8 per cent) whereas in linear rate of increase no one has crossed the State's average of 41.03.

However, high yield better irrigational facilities and liesure hours of farmers are some of the factors favour in the spread of summer rice in Bihar.

Considering the percentage production of the district to state total production the districts of Patna, Shahabad, Saran, Champaran, Muzaffarpur, Darbhanga, Bhagalpur, Saharsa, Purnea, Ranchi and Singhbhum are registering gain in its share in 1971's over 1961's. And the districts of Monghyr, Santhal Parganas, Hazaribagh, Palamau and Dhanbad are recorded in loss during this period. Here also the plateau districts have shown negative response.

This becomes more pronounced when we consider the percentage production of individual crop (autumn, winter and summer) to total production in 1961's and 1971's. When we look at the fig. 24 (which shows the percentage share of production 1961's and 1971's of autumn, winter and summer in Bihar). We find that there is an increase of autumn and summer production and decrease in winter production. As we have seen in the area and yield of winter rice in Bihar, it has shown decline. Here also it is obvious to show decline in the production of winter rice.

Production Model :

A model has been developed taking the production of each individual year (for each district) to total avera ge production of the district(for the period of 12 years), and presented in fig. 26 and 27. The figures which are in brackets are the percentage of area under irrigated rice to total area under rice. Taking the maximum and mimimum production ratio, ranges are calculated. Therefore, an attempt has

PRODUCTION RATIO

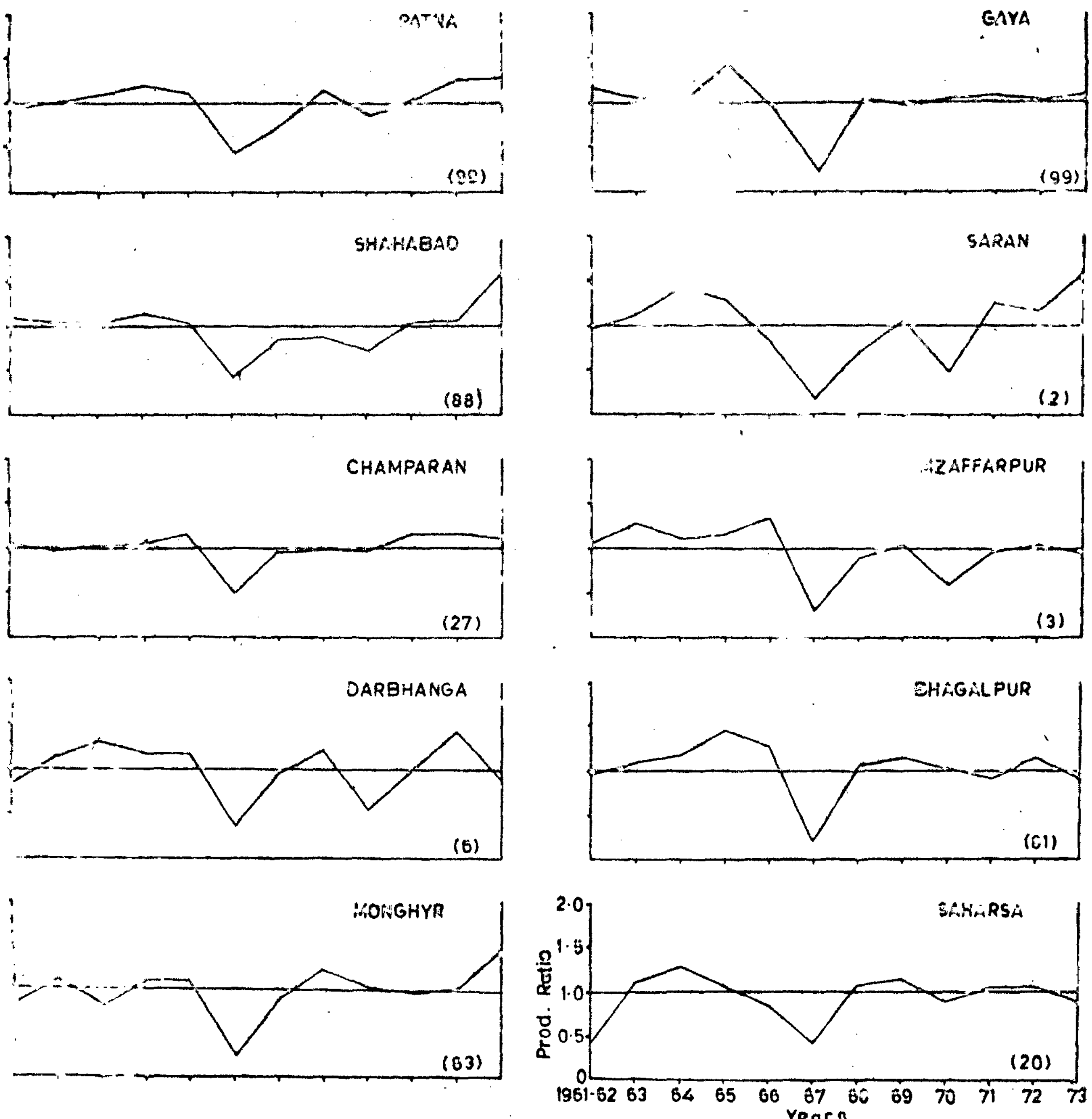


Fig. 26

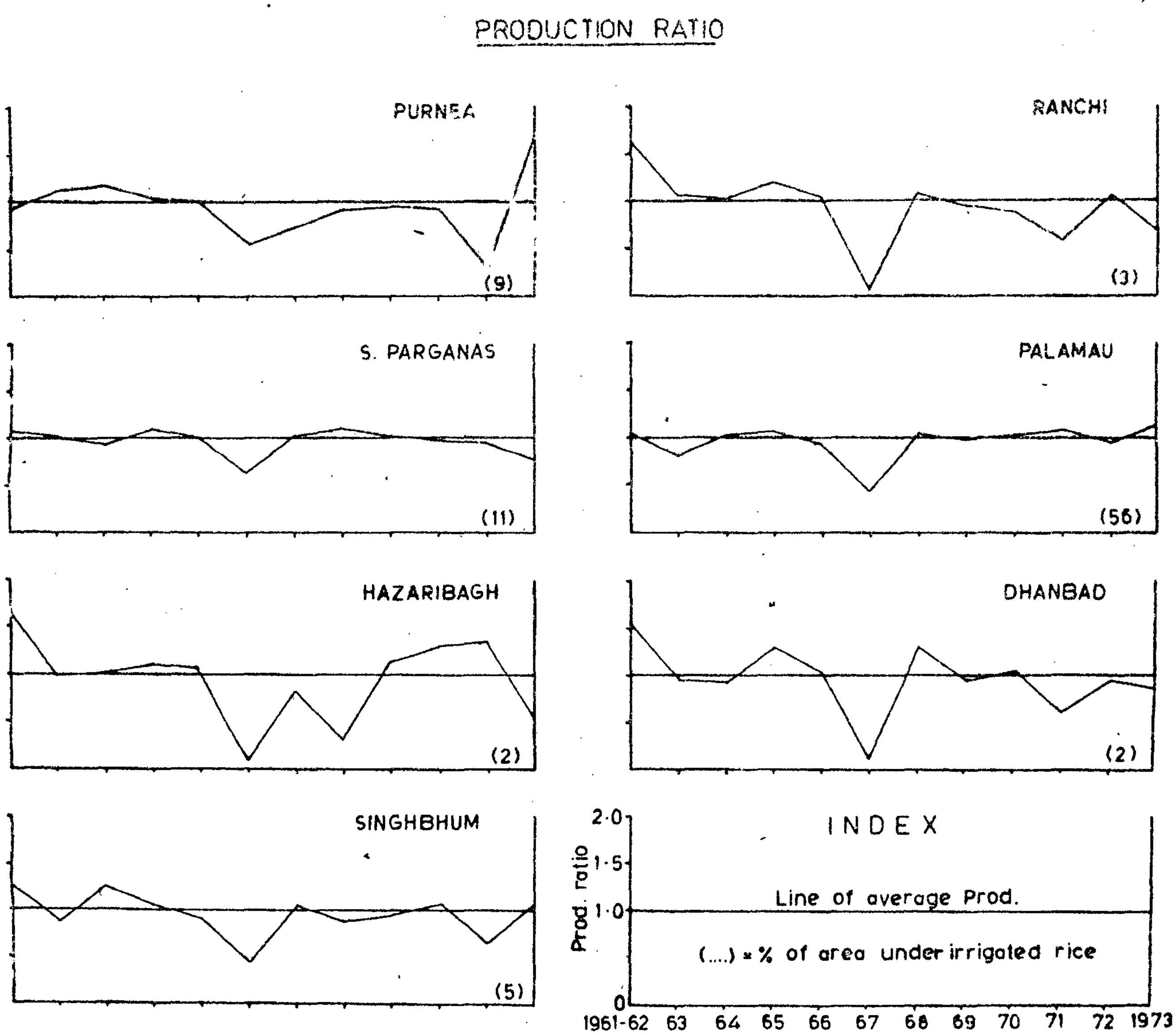

PRODUCTION RATIO
PURNEA
(9)
RANCHI
(3)
S. PARGANAS
(11)
PALAMAU
(56)
HAZARIBAGH
(2)
DHANBAD
(2)
SINGHBHUM
(5)
INDEX
2·0
1·5
1·0
0
Prod. ratio
Line of average Prod.
(....) = % of area under irrigated rice
1961-62 63 64 65 66 67 68 69 70 71 72 1973

Fig. 27

been made to establish the fluctuation in production. It is hypothesised that districts having a higher percentage of irrigated area would experience a less range in the production of rice.

A close perusal of Table 21 shows that entire districts can be grouped as:

(a) districts having range between 0.60 to 1.01
(b) districts having range between 1.01 to 1.09
(c) districts having range between 1.10 to 1.20
(d) districts having range of 1.21 and above.

Considering the first group of districts, we find that there are four districts viz. Gaya, Shahabad, Bhagalpur, and Patna. However, these districts have registered more than 80 per cent area under irrigated rice during the period 1961-63 and 1971-73. It shows that in these districts the ratio of annual production to the normal production is not high. The fluctuation from the normal production is very low and it is due to good irrigation facilities.

In the second group of the districts are; Santhal Parganas, Singhbhum, Champaran, Saharsa, Palamau and Monghyr. Where Singhbhum and Monghyr are the exception. Because in the districts of Singhbhum percentage of irrigated area under rice, only 8 per cent and its range is 1.08 only. It shows that rainfall is managing the range of production. Whereas in Monghyr % of irrigated area is 63 per cent but the range

Table - 21

Distribution of districts in different ranges of production and different classes of irrigated area under rice (During 1961-62 to 1972-73)

Ranges / % of irri. rice to total rice	0 - 20 %	20 - 40 %	40 - 60 %	60 - 80 %	80 - 100 %
0.50 - 1.01					Gaya Shahabad Bhagalpur Patna
1.02 - 1.09	Santhal Parganas Singhbhum	Champaran Saharsa	Palamau	Monghyr	
1.10 - 1.20	Muzaffarpur Darbhanga Purnea				
1.21 and above	Saran Ranchi Hazaribagh Dhanbad				

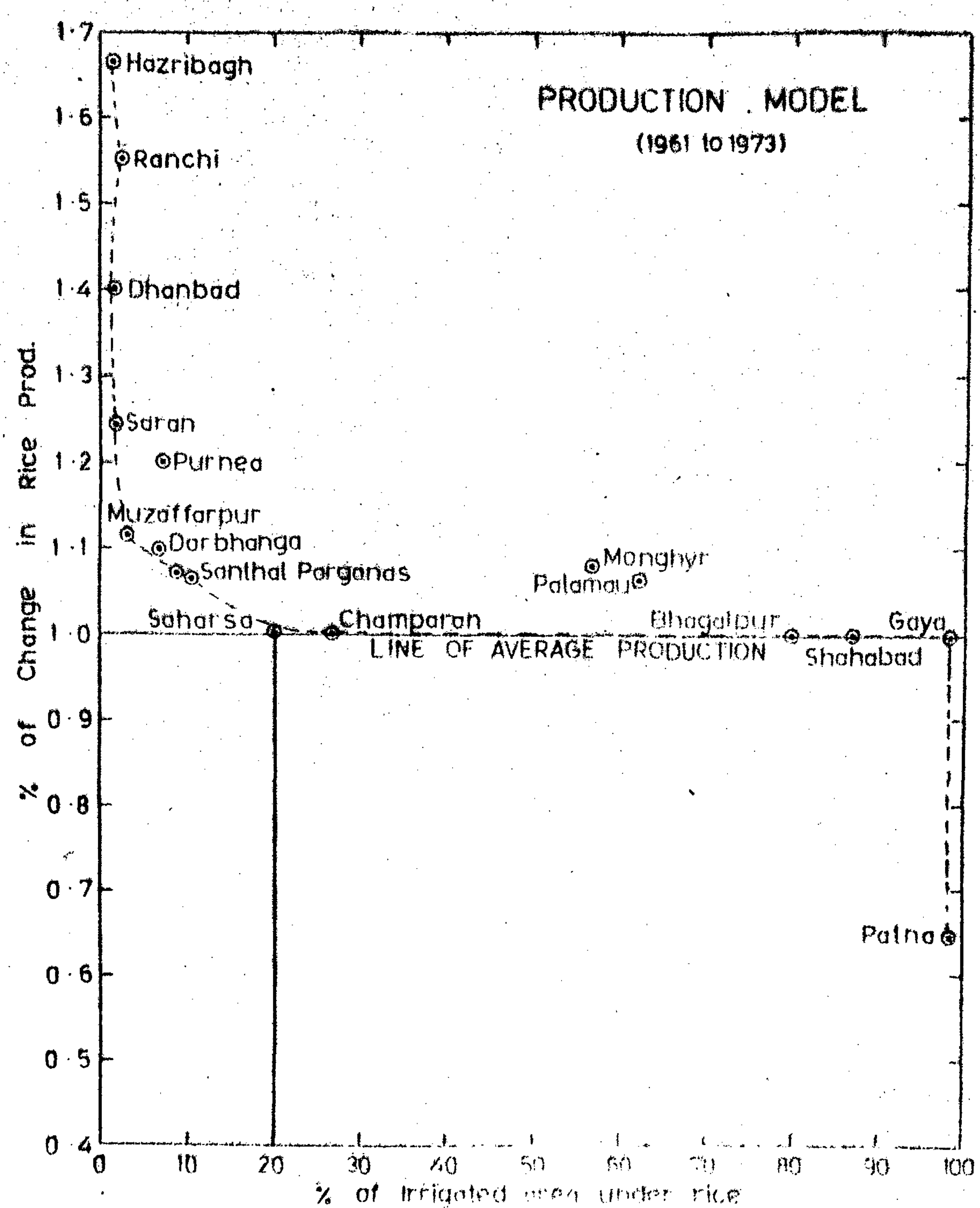

PRODUCTION . MODEL
(1961 to 1973)
Hazribagh
Ranchi
Dhanbad
Saran
Purnea
Muzaffarpur
Darbhanga
Santhal Parganas
Monghyr
Palamau
Saharsa
Champaran
Bhagalpur
Gaya
LINE OF AVERAGE PRODUCTION
Shahabad
Patna
% of Change in Rice Prod.
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0
10
20
30
40
50
60
70
80
90
100
% of irrigated area under rice

Fig 28

is high. It implies that the water management in this district is not good.

As far as 3rd and 4th groups are concerned, 7 districts have shown positive relationship. There are the districts of Bihar where the % of irrigated area ride is very low. So it is quite obvious that fluctuation in the production will occur, since rainfall is highly variable in these districts (except the districts of Plateau).

Having examined the production ratio and its ranges, it can be said that irrigation plays an important tole to establish the rice production since rainfall is erratic in Bihar. As it is seen in figure 28; that a minimum of 25 per cent of area under rice should be irrigated in order to reduce the fluctuation in rice production. Once the fluctuation is moderated, introduction of other advanced inputs would be feasible and that would rise the overall production with the increase in yield level, the area under rice can also be reduced.

4.9 Conclusion :

Among the rice growing State in India, Bihar has the largest area under rice. Nearly 13 per cent of the total area in India occurs in Bihar. In the year 1972-73, 62.2 per cent of gross sown area was under rice. In some districts it is as high as 80 per cent. Bihar has also the dubious distinction of recording the lowest yield in rice in India. In all the plans it was envisaged that irrigation development would reduce the area under rice and increase its yield.

There are three seasons for rice cultivation in Bihar. The summer rice (Garwa) is cultivated during March/April to July/August. Autumn rice is grown as rainfed crop during June to October. Winter rice is the most important and grown during June/July to November/December.

Although Bihar State Government and Central Rice Research Institute have released 14 improved strains, the percentage of rice area under high yielding varieties is only 23.3 per cent. In the remaining area only rainfed traditional varieties are grown.

In the State of Bihar, as a whole, the area under rice has marginally decreased. It was 5.22 million hectares in the triennial average for 1961-63 and 5.16 million hectares during the period confined to the districts with high percentage of irrigated area. On the other hand in districts where the percentage of gross irrigated area is low the acreage under rice has decreased as in the districts of Champaran, Bhagalpur, Saharsa and Purnea.

In all 11 districts have experienced a positive compound growth rates in gross area under rice. The compound growth rate indicates marginal increase in the rice acreage in two districts of the plain while decrease is noticed particularly in the plateau.

The percentage of rice area irrigated in Bihar was 33.17. However, the percentage area under irrigated rice to the gross area under rice was more than 80 per cent in the districts of Patna (99.49 per cent). Except Palamau and Monghyr, other districts had less than 30 per cent of total area under rice irrigated. In Bihar as a whole the irrigated rice has declined during the period of study. The districts in the plateau, and the districts of Saran, Muzaffarpur, Bhagalpur and Singhbhum show a decrease in irrigated area while the other districts had an increase in the area under irrigated rice. Saharsa had the maximum increase in area under irrigated rice 493 to 33,723 hectares.

Like the gross area under rice, different crops of rice also have various rate of growth in the districts of Bihar. Autumn rice, which constitutes only 6 per cent of the total rice in Bihar, as grown relatively on a larger area. The proportion of area under autumn rice to the total area under rice is maximum in Ranchi district (23.2). In other districts in the plateau, its share is comparatively less. In the plain districts Saran, Champaran, Saharsa and

Purnea, the percentage is above 10. Autumn rice is mainly rainfed. Area under autumn rice has increased during the study period. The increased in area is marked in the Champaran district (compound growth rate 46.93 per cent). However, 8 districts have registered a negative growth rate.

Winter rice is the major rice crop, comprising nearly 90 per cent of the total rice area in almost all the districts of Bihar. In Gaya and Patna nearly the entire rice (99 per cent) is irrigated. Except Palamau district, in all the districts of plateau, irrigated winter rice is very less. In general area under winter rice as well as irrigated winter rice has marginally decreased.

Summer rice is very insignificant in Bihar. In most of the districts they constitute less than 0.02 per cent of the total area under rice. The highest itself is only 1.16 per cent in the district of Purnea. However, it is full irrigated crop and the area under summer rice is increasing wherever there is an increase in the irrigated area.

Bihar has the lowest yield of rice, 789 kg/hectare. The increase in irrigated rice had only marginal effect in the yield. The compound growth in the yield in Bihar state is only 0.70. Rather 7 districts have registered negative change in growth rate. About 2 per cent compound growth in yield is witnessed only in Patna, Bhagalpur and Purnea districts. Winter rice generally gives a higher yield. Highest yield is obtained in Patna 1437 kg/hectare. Average yield of autumn rice is 551 kg/hectare and that of summer rice is 881 kg/hectare. It is distressing to note that the compound growth rate of winter rice, the most important, is negative. Yield of summer rice has the highest compound growth rate 3.50. It is very high in Patna which has registered the growth rate of 50.5.

Production of rice is interlinked with area and yield. The total production of rice has increased from 4.4 M.T. to 4.6 M.T. The year to year duration of production from average brings out that with irrigated area less than 20 per cent, greater is the fluctuation and fluctuation gets reduced with increased in irrigated area.

C H A P T E R - V

IRRIGATION AND RICE

CHAPTER - V

IRRIGATION AND RICE

5.1 Growth of Irrigation and its impact on the area under Rice and Yield of Rice :

In the previous Chapter III and IV we have discussed the growth of irrigation and changes in area, production and yield of rice during the period 1961 to 1973. Since rainfall is unreliable both in its time of incedence and amount, irrigation is the most important factor which determines the rice cultivation in Bihar. Here, it is argued that the inter-district variations in the growth of rice are mainly due to differences in growth of irrigation.

It is clear from the table of compound growth rates and linear rates of increase (which are tabulated in Chapter III and IV) that irrigation leads to the growth in area, yield and production of rice in Bihar. It is hypothesized that there is a direct relationship between the irrigation and rice cultivation.

A comparative study of the tables of irrigation and rice in Bihar chapters shows that out of 17 districts 10 districts have responded positively. Districts of Gaya, Shahabad, Saran, Champaran, Muzaffarpur, Darbhanga, Bhagalpur, Saharsa, Purnea and Ranchi have shown positive growth in gross and net irrigated area as well as gross area under rice, average yield of rice and total production of rice. Five districts viz; Monghyr, Hazaribagh, Palamau, Dhanbad and Singhbhum have shown decline in both irrigated area, yield and production of rice. The remaining two districts Patna and Santhal Parganas have shown completely a different type of result. There is a positive growth in irrigated area of Patna but negative growth in area of rice. Here, the permissible cause is that due to the increase in irrigated area, irrigated crops other than rice might have been cultivated. In the district of Santhal Parganas there is a negative growth in irrigated area but positive growth in the gross area under rice. This is only because of that district is having very low percentage (GIA 9.65 per cent and NIA 2.23 per cent) of irrigated area, so due to lack of irrigational facilities, farmers are still dependent on rainfall. That's why there is only growth in area of rice not in the yield and production.

Thus, from the above discussion we can conclude that rice cultivation is highly affected by the development of irrigation. Since rainfall is unreliable, an artificial source of watering is necessary for the growth of rice in Bihar. It encourage the farmers to adapt more scientific techniques as well as intensive cultivation. Irrigation plays a decisive role in determining the cultivation of paddy.

5.2 Introduction of Variables :

It is clear from the above analysis that considerable variation exists in rice cultivation in Bihar. An attempt has therefore been made to analyse quantitatively the determinants of rice cultivation to establish the functional relationship between the rice cultivation and associated variables by means of suitable correlation matrix. For this purpose the following dependent and independent variables have been chosen.

5.2.1 The dependent variables :

The most important dependent variables are area under rice and yield of rice. Although the gross area under rice and average yield of rice are the most significant components of rice cultivation, an analysis of the variations in these alone will not bring out the full impact of irrigation on rice cultivation in Bihar. Therefore these components are subdivided into major crops of rice that are grown in Bihar. Thus the following eight dependent variables are chosen:

Y_1 = % of gross area under rice to gross sown area.

Y_2 = % of autumn rice to gross area under rice.

Y_3 = % of winter rice to gross area under rice.

Y_4 = % of summer rice to gross area under rice.

Y_5 = Average yield of rice

Y_6 = Yield of autumn rice

X_7 = Yield of winter rice

X_8 = Yield of summer rice

The data pertain to district level and the differences in the growth rate of these variables in the districts are related to the variation in the corresponding growth rate in irrigation.

5.2.2 <u>The Independent Variables</u> :

The explanation to the variation in area and yield of rice in the districts of Bihar during the period of study has been attempted by correlating them the factors on water. The choice of water parameters does not be little the importance of other factors, particularly of those pertaining to improved technology of cultivation, like the use of high yielding varieties and application of insecticides. However, the application of improved technology will not possible without an assurred supply of water. Moreover, the impoved technology is used very marginally and almost in the entire rice belt in Bihar still traditional practices prevail. Naturally the crucial parameter, that affects the rice cultivation in Bihar continues to be water. Because of its paramount importance, all the independent variables chosen are related to water.

The variables chosen relate to rainfall, water availability index, sources of irrigation and the extent of irrigation development. The variables are listed as under:

X_1 = % of Canal irrigated area to net irrigated area.

X_2 = Percentage of Tank irrigated area to net irrigated area.

X_3 = % of Well and Tubewell irrigated area to net irrigated area.

X_4 = % of area irrigated by other sources to net irrigated.

X_5 = Annual average rainfall (in mm.)

X_6 = % of gross irrigated area to gross area sown

X_7 = % of total irrigated rice to gross area under rice.

X_8 = Water availability index (in mm.)

X_9 = % of net irrigated area to net sown area.

It is generally accepted fact that the benefits of the new agricultural strategy based mainly on irrigation. Therefore, it is assumed that irrigation is directly related to the area under high yielding variety and use of chemical fertilizers. Here, the percentage of irrigated area to gross cropped area has been taken as an explanatory variable.

Since GIA is the total of different sources of irrigation, it needs to be emphasised for planning purposes, which one of these sources is more effective for rice cultivation. Thus, the percentage of area irrigated from canal, Tank, Well and Tubewell and other source to net irrigated area are taken as independent variables.

Rainfall :

Rainfall is the most important factors for the growth of rice crop. The rainfall region as it effects the rice cultivation is brought out in detail in chapter-II. Here, a brief account is given on the rainfall behaviour during the study period.

Looking at the appendix 5 we find that the annual average rainfall for Bihar as a whole was below normal in 8 years out of 12 but 7 years have received equivalent to the normal rainfall. And same types of rainfall pattern we find in South and North Bihar Plain, whereas in Bihar Plateau this pattern was completely different. In the districts of Bihar plateau, we find except the drought year (1966-67), in all years rainfall was either above the normal rainfall or almost equal to the normal figure. Copying with plateau districts, rainfall is highly varying in nature in the districts of Bihar plain.

A close perusal of the table-22 reveals that the districts which receives higher amount of rainfall (see fig. 4) have experienced higher variation from the normal rainfall. The districts of Bhagalpur, Monghyr, and Dhanbad have registered more than 10 per cent rainfall from the

Table - 22

Number of years when rainfall was deviated from normal (1961-62 to 1972-73)

Districts	More than +10%	+10% to - 10%	- 10% to - 20 %	Below - 20 %
Bihar Plain				
Patna	6	3	1	2
Gaya	2	7	0	3
Shahabad	2	2	3	5
Saran	3	6	1	2
Champaran	6	1	2	3
Muzaffarpur	3	2	5	2
Darbhanga	2	5	3	2
Bhagalpur	5	2	1	4
Monghyr	6	2	1	3
Saharsa	3	0	6	3
Purnea	2	5	1	4
Bihar Plateau				
Santhal Parganas	3	4	3	2
Ranchi	3	2	4	3
Palamau	3	3	6	0
Hazaribagh	4	2	1	5
Dhanbad	5	2	1	4
Singhbhum	2	5	1	4
State	3	5	2	2

normal, in more than 5 years, whereas the drought areas of South Bihar plain (Gaya, and Shahabad) have noted only in two years.

Considering the last category (below - 20 per cent) we find that Shahabad and Hazaribagh have received below 20 per cent of normal in five years and Bhagalpur, Purnea, Dhanbad and Singhbhum have received in four years. It implies that rainfall is highly varying in these districts.

Thus, since rainfall is highly varying in nature it is essential to measure that to what extent it determines the rice cultivation in Bihar. It is presumed that higher the rainfall the more will be area under rice and yield of rice. Within this context the rainfall is taken as an independent variable.

Water availability Index :

An attempt has been made in this study to combine rainfall and irrigation into an index called water availability index. The index is expressed in rainfall equivalent i.e. in mm. The concept of water requirement of crop and effective rainfall are the basis for computing the water availability index. In this context the following assumptions are made :

(a) The water requirement of crops equal to the potential evapotranspiration (PE) during the growing period.

(b) In irrigated area the water availability equals to the PE.

(c) In unirrigated area the water availability equals to the effective rainfall.

(d) The total water availability in a district is carried at by irrigation, the annual PE by the percentage of gross irrigated area and the effective rainfall by the percentage of gross non-irrigated area.[1]

Thus, water availability index is calculated on the following formula:

$$WI = \frac{E_R \times NIA + P_E \times GIA}{GSA}$$

where, NIA = Non irrigated area (GSA - GIA)

GIA = Gross irrigated area

GSA = Gross sown area

In this computation, PE values as calculated by K.N.Rao, C.J.George and K.S.Ramashastri (1972)[2] was used in this study. The monthly effective rainfall was computed using the USDA method of ratio to PE. The sum of twelve months effective rainfall is the annual effective rainfall. This index thus would indicate the extent of water availabi-

---

1. Chaitali Sanyal (1980) - '<u>Agricultural water requirements and its availability in the natural regions of India</u>'. An M.Phil. Dissertation, C.S.R.D./S.S.S., J.N.U., New Delhi, unpublished, p.140.

2. K.N.Rao, C.J.George and K.S.Ramashstri (1972) - 'Agro-climatic classification of India', Meteor. Monograph, Agrimet. No.4, IMD, Poona.

lity better than either rainfall or irrigated area.

5.3 Correlation Matrix :

Here is the analysis of correlation between the dependent and the independent variables. The results of correlation matrics has been given in Appendics 10 to 21. Two types of analysis have been taken into consideration in finding out the causal relationship among the variables, which are:

(a) Time-series analysis; and
(b) Cross-section analysis

While analysing the former, each district has been taken as a separate entity where both the independent and the dependent variables have been analysed over a period of 12 years (1961-62 to 1972-73). In the latter types of analysis, all the distticts have been grouped together where the correlation has been done taking four years into account separately and not in a period of over 12 years as has been done in the former case. The correlation coefficient has been calculated on Karl Pearrson's formula.*

5.3.1 Time-Series analysis :

For this analysis all the dependent variables have been taken into consideration separately.

5.3.1.2 Gross area under Rice :

We have seen the relationship between gross area under rice and the independent variables. It is quite clear from the analysis (Chapter - III and IV) that gross irrigated area is significantly correlated with gross area under rice. This is very much common in ten districts viz; Patna (0.934), Gaya (0.792), Shahabad (0.944), Saran (0.944), Champaran (0.676), Muzaffarpur (0.598), Purnea (0.562), Santhal Parganas (0.511), Ranchi (0.490), and Palamau (0.795). Also the two districts - Darbhanga (0.490), and Monghyr (0.360), have a positive correlation (Appendix - 10). The remaining 5

---

* The correlation coefficient is calculated on the following formula:

$$r = \frac{\sum dxdy - \frac{(\sum d_x) \times (\sum d_y)}{N}}{\sqrt{\sum d_x^2 - \frac{(\sum d_x)^2}{N}} \sqrt{\sum d_y^2 - \frac{(\sum d_y)^2}{N}}}$$

where, d_x = deviation of X Series from an assumed mean

Similarly d_y refers to deviations of Y series.

$d_x d_y$ = Sum of the product of the deviations of X & Y

d_x^2 = Sum of the squares of the deviation of x series.

d_y^2 = Sum of the squares of the deviation of Y series.

districts (out of a total 17 districts) have a negative relationship or the gross irrigated area have not a significant impact on the gross area under rice in these districts. Except the districts of Bhagalpur and Saharsa, the remaining 3 districts of these 5 are in the plateau region of South Bihar. It is also quite interesting to observe that besides 'gross irrigated area', some other independent variables like water availability index, rainfall, canal and tank irrigation have been considered; but only one i.e. gross irrigated area has the important bearing on the gross area under rice in all these districts of Bihar. The impact of Rainfall has got the second order of importance. It has positive relation with gross area under rice in as much as in 13 districts. However, it is significant in the case of 3 districts viz. Muzaffarpur (0.536), Monghyr (0.616), and Ranchi (0.639). It is therefore, interesting to point out that despite the development in the irrigational facilities, farmers of many of these districts still depend on rainfall so far as rice cultivation is concerned. Although, the districts having highly and developed irrigational facilities, rainfall has very low level of importance. These districts are Patna (0.047), Gaya (0.068) and Shahabad (-0.007) etc.

The importance of canal, tank, well and tubewell irrigation is quite significant as compared to other sources of irrigation. In eight districts, the canal irrigation has positive influence on 'gross area under rice.' These districts are; Gaya (0.196), Champaran (0.110), Saharsa (0.234), Muzaffarpur (0.390), Purnea (0.116), Santhal Parganas (0.118), Ranchi (0.107), and Singhbhum (0.654). The remaining districts do not have positive correlation between canal irrigation and gross area under rice. The tank irrigation has a positive influence on gross area under rice in 9 districts. Among these districts, Muzaffarpur (0.608) and Singhbhum (0.518) are significant at 0.10 per cent level. The well and tubewell irrigation have a positive correlation in 8 districts - of which the district of Palamau (0.517) is significant at 0.10 per cent level. Therefore, to sum up it can be said that the irrigation by canal, tank, well and tubewell play a dominant role in so far as gross area under rice is concerned, as evident from higher level. Besides irrigation the availability of water or water availability index has also been considered to see its impact on gross area under rice. It is having a positive correlation in the districts of Shahabad (0.064), Saran (0.192), Monghyr (0.091) and is significant in Hazaribagh district (0.439). In the remaining districts, it has a negative, rather no role to play so far as variation in gross area under rice is concerned. However, net irrigated area is significant in the districts of Purnea (0.656) and Palamau (0.641). It has also a positive response in the districts of Patna (0.055), Shahabad (0.216), Champaran (0.023), Bhagalpur (0.100), Monghyr (0.176) and Hazaribagh (0.404).

Thus, permissible conclusion, would be that the gross irrigated area and the rainfall have an important bearing on the variation or the fluctuation either 'gross area under rice'. However, the fact remains that gross irrigated area includes the irrigation by different sources e.g. canal, tank, well and tubewell and the net irrigated area. But, here also the role of each of these elements (under gross irrigated area) has been analysed separately to assess its individual importance with regard to 'gross area under rice'.

5.3.1.2 <u>Area under Autumn Rice (AAR)</u> :

Here the impact of independent variables on AAR (Appendice 12) has been analysed. We find that net irrigated area (NIA) is having maximum relation with AAR than any other independent variables. In all, 11 districts have a positive relationship between NIA and AAR. Out of these; 4 distbicts viz; Saran (0.675); Champaran (0.710); Muzaffarpur (0.840) and Singhbhum (0.884) have a significant relationship. In remaining 6 districts (out of 17), there do not exist any relationship, rather it is negative between NIA and AAR. When we examine the correlation between rainfall and AAR, we find that the districts, having a high correlation between UIA and AAR, show either a very low level or negative relationship. It implies that autumn rice totally depends on early monsoon rain in all these districts. In this category, the eastern and plateau districts (Purnea - 0.929 , Santhal Parganas: 0.134, Ranchi: 0.213, and Singhbhum: 0.514) have shown a positive relationship between rainfall and AAR.

The next comes water availability index. It is positively correlated in 9 districts where it is significant in 2 districts (Muzaffarpur: 0.714 and Ranchi: 0.518). This is also having a positive correlation in the districts where irrigation facilities are much developed: such as Patna (0.161), Gaya (0.221), Shahabad (0.240), Saran (0.082), Darbhanga (0.287), Saharsa (0.185) and Singhbhum (0.028). Among the sources of irrigation; only well and tubewell irrigations have a good relationship with AAR; while the other sources of irrigation, such as canal and tank are significantly correlated in the districts of Saran (0.675), Darbhanga (0.601), Saharsa (0.541), and Santhal Parganas (0.735). In all, there are 10 districts where it has a positive relationship. In all these districts, wells and tubewells have second order of importance. However, 2 of these districts viz. Champaran (0.837) and Purnea (0.575) have a significant relationship. On the whole; from this analysis, it implies and since we know that canals and tanks are not very much useful for this crop. Because sowing season for autumn rice falls in June and July months. And during this period water in canals and tank is not enough to meet the requirement of the time as due to 'just prevailed hot summer season' leaves not much water in it. Hence, due to this reason the water availability index does not show any special significant role so far as the AAR is concerned.

5.3.1.3 Area under Winter Rice (AWR):

When we look at the Appendics - 13, we find that canals and tanks play an important role so far as, AWR is concerned. There are 14 districts where correlation between canal irrigation and AWR is positive. Out of these, it is significant in the districts of Patna (0.678), Shahabad (0.891) and Saran (0.497) at 0.05 per cent level; and also at 0.10 per cent level. Whereas, in the case of tank irrigation, 13 districts have a positive relationship where the districts of Patna (0.886); Shahabad (0.538); Saran (0.617); Muzaffarpur (0.686); Monghyr (0.479); and Singhbhum (0.656) have experienced a signigicant correlation at 0.01 per cent, 0.10 per cent, 0.05 per cent, 0.05 per cent, 0.10 per cent and 0.05 per cent respectively. Wells and tubewells have a significant role only in two districts viz. Purnea (0.552); and Ranchi (0.718). The rest of the district have either very low level or negative correlation of wells and tubewells with AWR. Same is the case with other sources of irrigation; but they are significant only in the districts of Patna (0.631), and Shahabad (0.678).

The fact that rainfall is significant only in one district i.e. Purnea (0.980) which receives a good amount of rainfall; however, 10 more districts are showing a positive correlation between rainfall and AWR. It implies that besides the irrigation, rainfall too has an important role to play so far as 'area under winter rice' is concerned. Gross irrigated area has also the similar kind of relationship. It is significant in Hazaribagh district (0.568) out of a total of 10 districts where it is having a positive correlation. Water availability index and net irrigated area have also shown the similar results. Both are positively correlated in 8 districts and are significant in Santhal Parganas (0.522) and Patna (0.497).

Having examined the correlation, coefficient results of 'area under winter rice'; we may conclude that canal and tank irrigation have a determining role in leading the IWR. Because the period of winter rice is from July-September to November-December; and during this period plenty of water is available in tanks and canals caused due to the monsoon rainfall.

5.3.1.4 Area under Summer Rice (ASR):

Considering all these independent variables(Appendix - 14), it becomes quite clear that canals are very important for growing summer rice. Canal irrigation has a positive correlation with ASR in 13 districts. Out of these, it is significant in Gaya (0.501), Patna (0.553), Shahabad (0.707), Champaran (0.719), Bhagalpur (0.591), Saharsa (0.497), Ranchi (0.612), Palamau (0.497), and Singhbhum (0.497), districts. Next in order is net irrigated area' which has a positive impact over ASR in 12 districts; in which it is significant in the districts of Saran (0.598), Champaran (0.834), Bhagalpur (0.617), and Palamau (0.497). 'Gross irrigated area' has third place of importance and is significant only in Saharsa (0.577) and Santhal Parganas (0.571). But it is such in those districts where irrigation facilities are good. So far as the sources of irrigation is conserned, only canal is important for this crop i.e. summer rice. It is quite obvious to assume that with the development of river valley projects, canals are always full of water, even during summer season. Secondly, the districts which are facilitated by river valley projects, these canal irrigation has responded well to or has a positive correlation with 'area under summer rice'.

5.3.1.5 Average yield of Rice* (AYR):

When we analyse the impact of these variables (Appendix -16) on average yield of rice; we find that water availability index influences greatly as compared to other variables. Its impact is significant in the districts of Gaya (0.514), Palamau (0.734), Shahabad (0.497), Saran (0.597) Monghyr (0.497) and Dhanbad (0.678). However, altogether 11 districts have shown a positive impact of water availability index on AYR. Rainfall, being next in order of importance, has shown a positive correlation with AYR in 12 districts. However, it is significant only in the districts of Muzaffarpur (0.661), Santhal Parganas (0.614), Ranchi (0.960), and Palamau (0.608). Again among the sources of irrigation, canal irrigation holds the pride of the place which has a positive correlation with AYR in 9 districts. Among these, the only district i.e. Bhagalpur (0.591) is significant at 0.10 per cent level. Among other sources of irrigation, positive correlation exists in 9 districts. Of these 9 districts, Monghyr (0.626), Saharsa (0.684), Ranchi (0.828), and Palamau (0.640) districts have a significant correlation. Tanks, wells and tubewells are insignificant. Both, the gross irrigated area (GIA) and the net

---

* The average of yields of three crops - winter, summer and autumn crops of rice.

irrigated area (NIA), have shown similar correlation with AYR. Although GIA is positively correlated with AYR in 9 distbicts of which Saran (0.711), and Ranchi (0.960) districts are significant at 0.01 per cent level. Whereas NIA is having a positive correlation with AYR in 8 districts where in Bhagalpur districts (0.617) is significant at 0.10 per cent level.

On the basis of above analysis, the permissible conclusion may be that water availability index, rainfall, canal irrigation and gross irrigated area are the factors which greatly determine the average yield of rice in Bihar. However, the facts we gathered from this analysis that water availability index and rainfall were not so important in the area of rice. Therefore, it implies that farmers have sown the rice where the assured water supply - irrigation, is available.

6.3.1.6 <u>Yield of Autumn Rice (YAR)</u>:

To have a clear picture, correlation has also been done so as to examine which particular factor or factors influences the yield of rice in a particular time period. The Appendix -16 shows that rainfall has a great bearing on YAR. So far as rainfall is concerned, it has a positive correlation in 12 districts. Among these, the districts of Gaya (0.620), Shahabad (0.607), Saran (0.619), Ranchi (0.968) and Palamau (0.608) are significant. After the rainfall, 'gross irrigated area' comes. Its impact is significant in the districts of Gaya (0.580, Shahabad (0.717), Saran (0.509), Darbhanga (0.692) and Palamau (0.720). However, it is positive altogether in 10 districts. GIA and NIA are not so significant for this particular crop. Among the sources of irrigation, canal irrigation tops the list followed by other sources of irrigation. The canal irrigation has positively been correlated in 9 districts in which the districts of Champaran (0.642) is siginficant. While other sources of irrigation has positive impact in 7 districts of which Monghyr (0.835), and Ranchi (0.804) are significant.

On the whole, we may conclude that rainfall and canal irrigation are the determining factors for the yield of autumn rice, especially the canal which gets its water filled from rivers.

8.3.1.7 <u>Yield of Winter Rice (YWR)</u> :

It is evident from Appendix-17 that rainfall determines the yield of winter rice. Because, if the water is enough, the yield is bound to increase. Also the transplantation of winter rice is done during rainy season. The rainfall has a positive correlation with YWR in 10 districts of which Saran (0.835) and Shahabad (0.748) are significant at 0.05 per cent level and 0.01 per cent level respectively.

Again among sources of irrigation, canal takes the lead over all other sources of irrigation. It has a high positive correlation with YWR in 8 districts, but in non of these districts, it is significant. However, the other sources of irrigation do have significant correlation at 0.05 per cent level in one district i.e. Hazaribagh (0.678) and is also positive in 7 districts. As compared to all these, tank has a few districts where positive correlation with YWR exists, but has a significant correlation in the districts of Gaya (0.538) and Muzaffarpur (0.708).

Thus, we may conclude that rainfall determines the yield of winter rice to a greater extent.

5.3.1.8 <u>Yield of Summer Rice YSR)</u>:

As, already we have seen, the area under summer rice is greatly affected by the canal irrigation. In Bihar, a number of perrenial rivers supply water to various canals even during the summer season. Appendix-13 shows that rainfall is practically insignificant so far as this crop is is concerned. Canal irrigation has the pride of place among all the independent variables. About 11 districts having a positive correlation between canal irrigation and YSR. Out of these, it is Bhagalpur district (0.535) where it is significant at 0.10 per cent. Here, we also find that the districts, which have a negative correlation, are devoid of any river valley projects, viz; Saran (-0.186), Muzaffarpur (-0.091), Monghyr (-0.164), Purnea (-0.050), Palamau (-0.137), and Dhanbad (-0.164). Tanks, wells and tubewells do not have any significant role. All other sources of irrigation has a positive correlation in 8 districts and they are all in South Bihar. Among these districts, Ranchi (0.804) does have a significant correlation at 0.01 per cent level. Net irrigated area and water availability index have a equal place - having 8 districts each where the correlation is positive. The net irrigated area is significant in the districts of Saran (0.838) and Bhagalpur (0.524), where as the net irrigated area is significant in Palamau district (0.618) at 0.10 per cent level. The gross irrigated area does have a positive correlation in 6 districts where in Ranchi (0.890) it is significant.

Thus, it is beyond doubt to say that the yield of summer rice totally depends on the canal irrigation. Therefore, to sum up this time series analysis based on the correlation behaviour between independent and dependent variables in each district, the permissible conclusions may be drawn that the farmers , to ensure a proper farming of rice and its output, may have been considering the following 3 factors:

(a) area where the assured water is available;

(b) past experience of rainfall; and

(c) duration/timing of rainfall.

Because, if we see the data of area under rice and rainfall, there we find the year which received maximum or high rainfall does not have much gross area under rice but of course, the yield is high. It implies that the farmers did sow the rice in that particular season on the basis of last year's experience. In the case of autumn rice, as soon as the rain started, they utilize the maximum area under this rice. Hence, we find a high correlation between rainfall and autumn rice; whereas the yield of this crop seems to be very much sensitive to rainfall occurence. In the case of summer rice where rainfall is absent, it is highly affected by the canal and other sources of irrigation. As we have seen (in methodology) that water availability index is the combination of both the variables - rainfall and irrigation; it has shown a positive response with yield of the rice. Secondly, its position has 2nd or 3rd almost with all the dependent variables. This becomes more pronounced when we consider its role in step-wise regression.

6.3.2 <u>Cross Section Analysis :</u>

(a) 1961-62

(b) 1964-65

(c) 1968-69

(d) 1972-73.

Here all the 17 districts are number of observations. To see the causal relationship between independent and dependent variables, correlation analysis of all these 4 points of time needs to have a close perusal.

1961 - 62

Appendix-18 has the correlation between independent and dependent variables for the year 1961-62. Column one shows the correlation between gross area under rice and all the independent variables. We find that tanks (0.437) and rainfall (0.602) are significantly correlated with gross area under rice. Net irrigated area shows a very low correlation (0.080) with gross area under rice. The gross area under rice has a negative correlation with all the rest of the variables. The area under autumn rice has a positive correlation with other sources of irrigation (0.201); and well and tubewell irrigation (0.284). In case of area under winter rice, it is significantly correlated with gross irrigated area (0.502). However, well irrigation (0.466) has a high correlation with the area under winter rise but occupies second position after gross irrigated area. In the case of net irrigated area (0.404); total irrigated area (0.340); canal (0.177); and tank (0.318) - they have also responded positively so far as area under winter rice is concerned. Considering the correlation between area under summer rice and the independent variables, we find that well and tubewell (each 0.120); other sources (0.133) and total irrigated area (0.167) have a positive impact over area under summer rice. When we examine the correlation with 'average yield of rice'; we find a positive correlation of well and tubewell (0.112 each); other source (0.133); and total irrigated area (0.168). Whereas the yield of autumn rice has a positive correlation with canal (0.153); well and tubewell (0.366); and gross irrigated area (0.048). In the case of the yield of winter rice, rainfall has a significant correlation (0.833) while net irrigated area (0.457); and water availability index (0.231) have a very high correlation with winter rice yield. In this case, canal (0.041) and tank (0.211) are in significant. Lastly, the correlation between average yield of summer rice and the independent variables, shows a peculiar result as no variable except other sources of irrigation (0.330) has a positive impact on average yield of summer rice. The permissible conclusion may be due to the lack of irrigation development, especially during 1961-62.

<u>1964 - 65</u>

When we consider the correlation result of this period (Appendix-29); we find that tank (0.724); and rainfall (0.223) play an important role affecting the gross area under rice. Rainfall (0.570) alongwith other sources of irrigation (0.299) have a positive correlation with area under autumn rice as also witnessed earlier in the analysis that rainfall plays an important role in determining the autumn rice cultivation. In the case of area under winter rice; water availability index (0.458); gross irrigated area (0.446); and net irrigated area (0.448) do play an important role or have a positive correlation with area under winter rice. So far as the area under summer rice is concerned, canal (0.250); and other sources of irrigation (0.416) are the determining factors.

Average yield of rice is highly correlated with gross irrigated area (0.864); TIR (0.768); water availability (0.831); and net irrigated area (0.878). All these are significant at 0.01 per cent level. The average yield of autumn rice has a positive correlation with canal (0.201); well and tubewell (0.153); other sources of irrigation (0.013) and rainfall (0.035). Whereas the yield of winter rice has a significant correlation with gross irrigated area (0.523); TIR (0.420); well irrigation (0.519); and net irrigated area (0.532). However, canal (0.048); tank (0.337) and other sources of irrigation (0.071) are also positively correlated but not so significant in this case. In case of average yield of summer rice, some type of result is seen where gross irrigated area (0.783); TIR (0.722); well irrigation (0.795); and net irrigated area (0.805) are significantly correlated at 0.01 per cent level.

1968 - 69

During this period (Appendix-21) we find that once again rainfall (0.663); tank (0.557); and gross irrigated area (0.351) play an important role in determining the gross area under rice. Besides these, all other factors or variables show a negative correlation. While analysing the area under rice in different seasons; we find that canal (0.261); well and tubewell (0.033); and rainfall (0.068) have a positive correlation with area under autumn rice. While the area under winter rice does have a positive correlation with gross irrigated area (0.184); TIR (0.068); well irrigation (0.189) and net irrigated area (0.314). Rest of the variables are insignificant. In case of area under summer rice, it is correlated significantly with well irrigation (0.650); net irrigated area (0.581); TIR (0.611); whereas canal irrigation (0.042) has a positive correlation.

So far as the average yield of rice is concerned; it is significantly correlated only with well irrigation (0.605) but it has a positive impact of rainfall (0.110); net irrigated area (0.367); TIR (0.411) and other sources (0.341). However, taking the yield of rice in various seasons separately, we find that the yield of autumn rice has a positive correlation with well irrigation (0.056); net irrigated area (0.356); and canal (0.184) where the winter rice yield shows a positive correlation with tank (0.324); other sources (0.219); rainfall (0.173); gross irrigated area (0.125); TIR

(0.185); well irrigation (0.242); and net irrigated area (0.179). In the case of yield of summer rice, again well irrigation (0.526) tops the list followed by total irrigated area (0.468); other sources (0.412); and net irrigated area (0.301). The only variable i.e. tank (-0.206) has a negative correlation and that too may be due to summer season.

1972 - 73

Considering the correlation analysis of this period (Appendix-21); we find that tank (0.745); and gross irrigated area (0.649) are highly correlated with gross area under rice and significant at 0.05 per cent level followed by rainfall (0.455). Rest of the variables are insignificant. However, the area under autumn rice is once again, highly correlated with rainfall (0.473) followed by canal (0.299). With regards to area under winter rice, tank (0.427); and well irrigation (0.323) have shown high correlation followed by net irrigated area (0.197). In case of area under summer rice, gross irrigated area (0.618) has a significant correlation at 0.05 per cent level followed by canal (0.427). Rest of the variables are not significant.

While considering the average yield of rice, it is affected positively by canal (0.343), tank (0.332) and rainfall (0.152). These three viz. canal (0.375); tank (0.294); and rainfall (0.143) have also a positive impact over yield of autumn rice. But in the case of yield of winter rice, canal (0.228); TIR (0.168); well irrigation (0.092) and net irrigated area (0.042) have a positive correlation. The yield of summer rice is mainly affected or governed by the tank (0.268) and canal (0.240).

Thus, the analysis of both* enables one to have conclusions that the gross area under rice is largely governed by the gross irrigated area, canal irrigation and water availability index. In both the analysis, these three factors have been found correlated significantly. These factors have also influenced the average yield of rice. However, the area and the yield of autumn rice seem to be highly influenced by rainfall and well irrigation. On the other hand, the area and the yield of winter rice are dominated by canal, tank, well and tubewell irrigations. Same relationship can also be seen in the case of summer rice.

Therefore, gross irrigated area, well irrigation, canal irrigation are very important factors for the variations in the rice cultivation of Bihar. The variations caused by these variables have been analysed under multiple or step-wise regression analysis which follows on the proceeding lines.

---

* Time-series analysis and Cross- section analysis.

8.4 Regression Analysis :

The logic underlying the hypothesis is that the spatial variation in the rice cultivation is attributable to the co-variation of the factors mentioned in the hypothesis. In other words, there is a functional relationship between the variables; which are, the area under rice and yield of rice with selected independent variables.

The analysis is carried out using multiple step-wise regression coefficient[3]. An attempt has been made to analyse more quantitatively the determinants of rice area and yield to establish functional relationship by means multiple regression analysis.

The selection of the variables in respect of area and yield of rice are made on the basis of their correlation coefficients. To avoid the effect of multicolinearity, only these independent variables have been selected which are not having inter correlation more than 0.70.

---

3. The method recursively constructs a prediction equation regarding one independent variable at a time. The first step is to chose the single variable which is the best predictor. The second independent variable to be added to the regression equation is that which provides the best prediction in conjunction with the first variable. Accordingly the other variables are added in order of their significane to the overall goodness of fit. Equation is given as :

$$Y_1 = a + b_1 X_1 + b_2 X_2 \ldots\ldots + b_n X_n$$

The regression coefficient's 'R' is adjusted for the degree of freedom in the 'R'[4] and its square '$\bar{R}^2$' is used in the estimation of regression coefficient. To test the significant of these coefficients Student's 't'[5] test has been used. The calculated 't' value is given in brackets alongwith estimated parameters.

So, in order to identify that most effective independent variables, time-series and cross-section analysis are done.

5.4.1 <u>Time-series analysis</u> :

A time-series analysis discloses relationship between two variables over a period of time. However, the effect of

---

4. $\bar{R}$ value for regression coefficient is calculated on the following formula:

$$\bar{R} = 1 - (1 - R)\frac{n - 1}{df} \quad \text{or} \quad \bar{R}^2 = 1 - (1 - R^2)\frac{n - 1}{df}$$

where,
df = degree of freedom

5. The test of significance for zero order regression coefficient is calculated according to the following formula:

$$t = \frac{r}{\sqrt{1 - r^2}} \times \sqrt{n - 2}$$

where,

r = correlation coefficient

n = number of observation

different factors spread over a period of 12 years (1961-62 to 1972-73) for each districts and for each dependent variables are taken into consideration.

5.4.1.1 Gross area under Rice (GAR):

The gross area under rice (Y_1) has been taken as dependent variables and X_1 to X_9 as independent variables. The gross area under rice (Y_1) is regressed on X_1 to X_9 but the significant regression equation comes only with four variables as X_6 X_9, X_5, and X_1, (Table 23). The most significant variables is GIA (X_6) which alone is responsible for more than 70 per cent change in the gross area under rice in the districts of Bihar plain and Plateau. The GIA (X_6) is significant at 99 per cent level of confidence in 8 districts of Bihar. It is absent from the districts of Muzaffarpur, Darbhanga, Monghyr, Dhanbad and Singhbhum. However, in these districts percentage of GIA is insignificant. The GIA (X_6) gives a negative effect in the districts of Bhagalpur, Purnea and Hazaribagh which implies that the proportion of increased in GIA put under rice is less than under other irrigated crops.

Consideration the canal (X_1), it is found significant at 95 per cent level in the districts of Patna, Palamau and Hazaribagh, whereas wells and tubewells are significant only in Ranchi. Other sources are important in Monghyr at 99 per cent level of confidence. Rainfall (X_5) is significant

Table - 23

Results of the multiple step-wise regression coefficient (A time-series Analysis)
1961 to 1973
Regression Coefficient with X_1 (Gross area under Rice)

Districts	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
1	2	3	4	5	6	7	8	9	10	11
Bihar Plain										
Patna	0.596 (2.986)**					0.742 (24.378)*		-4.410 (-3.637)*		0.986
Gaya	2.212 (1.881)	-5.483 (-4.264)*				0.647 (4.883)*				0.833
Shahabad						0.695 (9.070)*				0.891
Saran						1.610 (9.053)*				0.891
Champaran		-1.255 (-4.627)*				2.163 (6.820)*				0.832
Muzaffarpur			-0.103 -4.440)*	-0.167 (-4.778)*			-0.440 (-2.332)+			0.839
Darbhanga		-0.060 (-1.346)		-0.141 (-2.092)**	0.627 (1.493)		0.333 (5.221)*	-5.393 (-3.143)**		0.801

contd.

1	2	3	4	5	6	7	8	9	10	11
Bhagalpur	0.050 (1.239)			-0.052 (-2.576)**	0.338 (1.955)*	-0.239 (-4.37)				0.660
Monghyr				0.209 (4.674)*	1.511 (5.228)*			-4.428 (-2.072)*		0.802
Saharsa						0.675 (10.888)*	-0.253 (-4.850)*		1.365 17.372)*	0.940
Purnea		-1.065 (1.759)			0.629 (7.140)*	-3.741 (-4.863)*			5.113 (7.348)*	0.940
Bihar Plateau										
Santhal Parganas	-0.695 (-2.694)*	-0.421 (-6.236)*	-0.376 (2.219)	-0.413 (8.514)		0.639 (2.218)*	-2.083 (-3.350)**			0.833
Ranchi		-1.735 (-6.019)*	0.776 (3.466)**			1.372 (4.153)*				0.874
Palamau	0.668 (2.681)*	-0.065 (2.120)*			0.164 (1.307)	1.198 (6.654)*	-0.079 (4.179)*			0.904

1	2	3	4	5	6	7	8	9	10	11
Hazaribagh	2.226 (2.234)				-0.795 (1.507)	-8.707 (-3.668)*	1.871 (1.217)	2.930 (1.693)	6.712 (3.839)**	0.802
Dhanbad								-4.079 (-2.591)	-0.585 (-2.334)	0.591
Singhbhum					-0.116 (2.273)+				-0.106 (-4.231)*	0.635

* Significant at 99 per cent level

** Significant at 95 per cent level

\+ Significant at 90 per cent level

in Purnea (99 per cent level), Monghyr (99 per cent level) and Bhagalpur (90 per cent level). Water availability index is not important variable in explaining the change in gross area under rice. GIA (X_9) has experienced at 99 per cent level of confidence in Saharsa, Purnea, Hazaribagh.

In all the districts of Bihar (except Bhagalpur) the value of $\bar{R}^2$ has shown more than 80 per cent contribution in the variation of gross area under rice. Therefore, it can be concluded that the most significant variable in explaining the variation in gross area under rice is gross irrigated area which alone accounts for 60 per cent of the variation in the districts of North Bihar. And in the districts of Bihar plateau gross irrigated area in combination with other independent variables by canal (X_1) and rainfall (X_5) explains more than 80 per cent of the variation in the gross area under rice.

5.4.1.2 <u>Area under autumn Rice</u> :

Table 24 gives the result of step-wise multiple regression for the area under autumn rice (Y_2). The area under autumn rice (Y_2). is regressed on X_1 to X_9 but the significant equation has come only with well and tubewell (X_3) followed by GIA (X_8) and rainfall (X_5). The independent variables is significant in districts of Patna, Gaya and Shahabad, and the combined effect of the variables explain

Table - 24

Results of the multiple step-wise regression coefficient
(A time-series analysis) 1961 to 1973

X_2 = Area under autumn Rice

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Bihar Plain										
Patna		0.816	-0.369		0.037	0.106		13.506	0.223	0.817
		(3.115)**	(-2.814)+		(0.229)	(3.842)*		(4.206)*	(2.120)	
Gaya	-0.432	0.320				0.044	0.913	0.678		0.633
	(-3.951)*	(-2.120)				(2.537)+	(2.415)*	(3.012)+		
Shahabad	0.570	0.136	-0.693		1.303	0.046	1.945	12.429	-0.089	0.970
	(3.530)+	(1.731)	(-3.909)+		(13.989)*	(6.278)**	(7.179)*	(7.211)*	(-2.077)	
Saran		0.153	0.151	0.549	0.075	1.152			0.326	0.942
		(1.308)	(2.555)+	(4.608)*	(3.793)**	(1.130)			(3.065)+	
Champaran		0.464	0.124				-0.298	3.027		0.931
		(1.273)	(2.305)+				(-1.701)	(3.660)*		
Muzaffarpur		-0.037				1.066			-0.853	0.868
		(-2.439)+				(3.126)**			(-2.334)+	
Darbhanga	-0.029				-0.230	0.203				0.830
	(-2.718)**				(-1.894)	(5.081)*				

	1	2	3	4	5	6	7	8	9	10
Monghyr	-0.176 (-1.2011)		-0.431 (-3.206)				0.147 (2.232)*	12.034 (4.354)*		0.644
Saharsa	-0.220 (-5.218)*					0.207 (2.928)**	0.957 (10.190)*			0.942
Purnea	1.864 (2.442)**	-8.194 (-2.495)**	4.179 (2.895)**	1.431 (2.176)	0.281 (6.033)*				-0.515 (-1.130)	0.917
<u>Bihar Plateau</u>										
Santhal Parganas	-0.889 (-3.115)*	-0.187) (-1.738)	-0.292 (-1.093)	0.094 (1.256)		-1.216 (-1.073)				0.891
Ranchi			0.633 (3.998)*				1.472 (9.329)*	-4.134 (-2.135)		0.931
Palamau		0.058 (1.532)	0.133 (2.615)**		-0.151 (-0.977)					0.703
Singhbhum		-0.015 (-1.852)							0.028 (4.021)*	0.826

* = Significant at 0.01 per centllevel
** = Significant at 0.05 per cent level
\+ = Significant at 0.10 per cent level

more than 80, 60 and 90 per contribution respectively in variation of X_2. The canal (X_1) is significant at 90 per cent level of confidence in Shahabad only. In rest of the districts it shows negative effect, whereas tanks are significant only in Patna (95 per cent level). Taking the well and tubewell (X_3) we find that it is significant in the districts of Saran (90 per cent level), Champaran 90 per cent level), Purnea (95 per cent level), Ranchi (99 per cent level), and Palamau (95 per cent level). Other sources of irrigation (X_4) are significant only in Saran district (99 per cent level). Rainfall has been found significant at 99 per cent level of confidence in Purnea and Shahabad. TIR (X_7) is significant in Gaya (90 per cent level), Shahabad (99 per cent levelP, Monghyr (0 per cent level), Saharsa and Ranchi (99 per cent level). While NIA (X_9) is significant in Saran (90 per cent level), and Singhbhum (99 per cent level). The districts of Bhagalpur, Dhanbad and Hazaribagh have not registered significant regression equation with all the explanatory variable. The negative effect have maximum shown by Canal and Tank.

The selected explanatory variables (up to the maximum singificant steps) are in combination explain more than 80 per cent $(\bar{R}^2)$ variation in area of autumn rice (X_2). On the basis of the significant results it can be concluded that well and tubewell (X_3) and TIR (X_7) are the most

effective variables than rainfall (X_5), GIA (X_6) and
NIA (X_9). And it is because of that before sowing the
autumn crop water is to be required and it can be procured
through well and tubewell only in the month of June and
July.

5.4.1.3 Area under Winter Rice (X_3) :

Having examined the table 25 we find that canal (X_1), WI (X_8), and rainfall (X_5) are the most effective variable which determine the variation in the area under winter rice (X_3). Hence, the canal (X_1) is significant in the districts of Gaya, Champaran and Santhal Parganas at 99 per cent level of confidence and in Darbhanga at 95 per cent, whereas well and tubewell (X_2) is in the districts of Gaya and Ranchi at 99 per cent level. The other sources of irrigation (X_4) have recorded significant at 99 per cent level in Saharsa only. The rainfall (X_5) is significant in Purnea (99 per cent level), Santhal Parganas and Shahabad at 95 per cent level of confidence. While WI (X_8) has recorded significant in Gaya, Shahabad, Saran and Saharsa at 99 per cent level.

In this analysis two districts Patna and Purnea have shown peculiar results. The regression equation of district Patna is not found significant at any step and the cause behind this is that the decreasing rate of area under winter

Table - 25

Results of the multiple step-wise regression coefficient (A time-series analysis) 1961 to 1973

Regression with X_3 (area under winter rice)

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Bihar Plain										
Gaya	0.101	-1.248	0.997			-0.025	2.864	1.718		0.937
	(6.520)*	(-7.944)*	(3.234)*			(-1.788)	(2.880)*	(5.521)*		
Shahabad	0.739		0.039		0.260	0.019		8.399	0.073	0.923
	(5.811)*		(1.802)		(3.391)†*	(2.461)**		(7.237)*	(3.300)†	
Saran				-0.630		-0.113	-0.070	3.297		0.906
				(-3.994)*		(-3.949)*	(-1.699)	(4.324)*		
Champaran	0.701		0.231			-0.298	-0.131			0.912
	(4.012)*		(1.133)			(-3.698)†	(-1.080)			
Muzaffarpur		0.030					-0.378			0.851
		(1.645)					(-20.740)*			
Darbhanga	0.038						0.132			0.980
	(2.441)**						(6.068)*			

	1	2	3	4	5	6	7	8	9	10
Monghyr	0.064				0.224		-0.264			0.824
	(0.954)				(1.137)		(-8.418)*			
Saharsa				-0.230		-0.372		1.131		0.960
				(-7.239)*		(-15.864)*		(3.450)*		
Purnea					1.669					0.960
					(15.742)*					
<u>Bihar Plateau</u>										
S. Parganas	11.337	0.720		0.602	4.902	18.691	-13.278	13.603		0.983
	(7.408)*	(2.301)+		(0.720)	(3.201)*	(3.630)*	(-3.876)*	(1.830)		
Ranchi		-1.816	1.800			-0.841			0.900	0.799
		(-3.672)*	(4.614)*			(-1.472)			(1.067)	
Dhanbad			0.130	-0.158	-0.190					0.682
			(1.820)	(-2.641)**	(-1.606)					
Singhbhum		0.014					0.209	-0.397	-0.036	0.801
		(1.463)					(3.054)**	(-1.959)	(-4.094)*	

* Significant at 99 per cent level
** Significant at 95 per cent level
\+ Significant at 90 per cent level

rice is very high in Patna (as discussed earlier). But in case of Purnea district only one variable i.e. rainfall (X_5) is alone explaining 96 per cent variation in the area of winter rice (X_3).

It can be concluded that canal, WI as well as rainfall was the most effective variables which determined more than 80 per cent of the variation in the area of winter rice during the years 1961-73.

6.4.1.4 <u>Area under Summer Rice</u> :

It is observed from the table 26 that the canal (X_1), GIA (X_6) and WI (X_8) are the most effective variables which contribute more than 80 per cent of variation in the area under summer rice (X_4). It is quite interesting to note that only the districts of Bihar Plateau have significant results. The canal (X_1) is significant at 99 per cent level in the districts of Patna, Gaya, Shahabad, Champaran and Saharsa. Whereas well and tubewell (X_3) is only in Champaran. The other sources of irrigation (X_4) is significant at 99 per cent level in Muzaffarpur district where canal and tubewell irrigation is not so developed. The regression equation of WI (X_8) is significant at 99 per cent level of confidence in the districts of Gaya and Shahabad and at 95 per cent level in Monghyr.

Table - 26

Results of the multiple step-wise regression coefficient
(A time-series analysis) 1961 to 1973

X_4 = Area Under Summer Rice

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Bihar Plain										
Gaya	0.133 (5.142)*					-0.283 (-25.801)*	-1.605 (4.962)*	6.452 (12.339)*		0.988
Shahabad	0.673 (6.032)*		-0.039 (-2.092)		-0.220 (-3.401)**	-0.017 (2.602)+		3.331 (3.185)*	-0.041 (-2.086)	0.950
Saran			0.065 (1.901)	0.133 (1.170)	0.443 (2.670)**	0.067 (3.986)**		-0.933 (-3.463)**	0.134 (3.278)	0.828
Champaran	0.330 (4.102)*		0.338 (12.131)*			-0.059 (-2.533)*	0.259 (-2.857)+			0.962
Muzaffarpur			-0.198 (-1.537)	0.347 (2.929)*	-0.996 (-1.930)	3.692 (2.381)	-3.974 (-3.712)**	0.538 (1.076)	-7.923 (-2.134)	0.732
Darbhanga							0.803 16.914			0.966
Monghyr	-0.136 (-2.016)*	0.245 (1.057)				-0.812 (-2.662)	-0.064 (2.641)	2.584 (2.792)	0.998 (3.093)	0.760

	1	2	3	4	5	6	7	8	9	10
Saharsa	0.231 (3.991)*					0.583 (2.580)**	1.238 (4.052)			0.739
Patna	0.451 (3.901)*					0.670 (2.612)**				0.721
<u>Bihar Plateau</u>										
		Insignificant								

* Significant at 99 per cent level

** Significant at 95 per cent level

\+ Significant at 90 per cent level

However, considering the plain as a whole canal (X_1) and WI (X_8) are the most important explanatory variables.

5.4.1.6 Average yield of Rice :

While rainfall and water availability index are not important in the change in area under rice, they very much significant, particularly in plateau region as far as yield is concerned (Table 27). The regression equation of rainfall is significant at 99 per cent level of confidence in the districts of Purnea , Santhal Parganas, Hazaribagh and Dhanbad. On the other hand WI (X_8) is significant at 99 per cent level in Patna and at 95 per cent and 90 per cent in Champaran and Palamau districts respectively. Canal (X_1) takes 3rd position among the chosen variables, and significant at 99 per cent level in Patna and at 90 per cent in Champaran, Palamau, and Singhbhum. Well and tube-well (X_3) is significant at 99 per cent level only in Saran whereas GIA (X_6) in Saran and Champaran. TIR (X_7) is important in Patna, Champaran and Palamau. While NIA ($_9$) has registered significant at 99 per cent level, only in Dhanbad. Other sources and Tanks are not at all significant for the average yield of rice in Bihar.

The $\bar{R}^2$ shows that in all the districts (except Gaya, Purnea, Dhanbad and Hazaribagh) taken explanatory

Table - 27

Results of the multiple step-wise regression coefficient
(A time-series analysis) 1961 to 1973)

Y_5 = Average Yield of Rice

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Bihar Plain										
Patna	0.995						-1.155	7.973		0.972
	(4.075)						(-16.947)*	(4.628)*		
Gaya	0.074	-0.043		0.105	-0.094	-0.010	0.431	-0.378		0.447
	(6.585)	(-0.379)		(1.214)	(-0.844)	(0 .700)	(1.326	(1. 667)		
Shahabad	0.391					0.159)				0.651
	(1.121)*					(2.551)**				
Saran		-0.831	-1.013	0.781		0.635			-0.845	0.950
		(2.231)	(7.019)*	(2.129)		(10.499)*			(3.609)**	
Champaran	-0.025					0.045		0.358	-0.086	0.861
	(2.485)*					(3.723)*		(3.052)**	(-4.219)*	
Muzaffarpur		-0.033	-0.037		-0.316		-0.392	0.186		0.763
		(-1.628)	(-1.939)		(-2.800)*		(-2.897)*	(-1.239)		
Darbhanga							0.689			0.950
							(13.791)			
Monghyr	-0.447						-0.926			0.893
	-1.411						(8.334)			

	1	2	3	4	5	6	7	8	9	10
Saharsa						-0.163 -4.684	1.177 (87.993)*			0.900
Purnea		-0.322 (-1.813)			0.471 (3.261)					0.547
<u>Bihar Plateau</u>										
S.Parganas		0.006 0.961	0.031 (1.203)		0.328 (4.584)*	-0.302 (-1.413)	0.510 (3.633)*	-0.601 (-2.627)	-0.327 (2.454)	0.751
Ranchi						1.313 (67.329)		-1.877 (-5.314)		0.996
Palamau	0.250 (2.550)*	0.017 (1.482)	-0.154 (4.677)*			0.037 (0.606)	-0.201 (-3.922)	1.236 2.557)+		0.928
Hazaribagh					0.166 (4.152)*					0.633
Dhanbad					0.143 (3.244)**		0.046 (6.555)*		0.212 (5.116)*	0.833
Singhbhum	0.493 (2.343)*							-10.291 (-2.435)		0.442

* Significant at 99 per cent level
** Significant at 95 per cent level
\+ Significant at 90 per cent level

variables explain more than 70 per cent variation in the average yield of rice. And mainly WI, Rainfall, TIR and canal are responsible for the variation in average yield of rice.

5.4.1.6 <u>Yield of autumn Rice</u> :

The regression equation related to the variables of irrigation clearly indicates that the most contributing factor in the yield of autumn rice is the rainfall (X_5) (Table- 28) which is significant at 99 per cent level of confidence in the districts of Patna, Gaya, Shahabad and Purnea. Secondly, the yield of autumn rice is determined by the availability of water index which is significant at 90 and 95 per cent level of confidence in the districts of Shahabad and Muzaffarpur respectively. The effect of canal irrigation (X_1) is clearly visible in the districts of Champaran and Patna with a significance level of 95 per cent respectively. The effect of Tank (X_2) and well and tubewell irrigation is rather negligible and only visible in Patna which significant at 90 per cent level of confidence. Shahabad and Saran have a negative effect over yield of autumn rice, which explains the weak nature of tank (X_2) and well and tubewell (X_3) irrigation.

The combined effect of all the sources of irrigation as explained by $\bar{R}^2$ accounts for more than 80 per cent change in the districts of Patna, Shahabad, Saran, Muzaffarpur,

Table - 28

Results of the multiple step-wise regression coefficient (A time-series analysis) 1961 to 1973

X_6 = Yield of Autumn Rice

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Bihar Plain										
Patna	1.692	1.550	2.159	2.114	0.605		-0.610			0.988
	2.764)+	(2.975)+	(4.117)*	(3.875)*	(6.766)*		(-22.866)			
Gaya	0.105				0.214				-0.052	0.732
	(1.552)				(4.729)*				(-1.309)	
Shahabad			-0.036		0.301	0.009	0.607	.3.153		0.982
			(-6.844)		(12.380)*	(4.370)*	(11.759)*	(-8.552)		
Saran		-0.351	-0.317	-0.293						0.952
		(-4.140)*	(-12.700)*	(-2.139)						
Champaran	0.019				0.052		-0.084			0.674
	(3.275)**				(1.653)		(-2.370)			
Muzaffarpur	0.015			-0.001		-0.816	-0.173	-0.193	0.902	0.837
	(1.074)			(-0.072)		(-1.680)	(-1.231)	(4.031)**	(1.850)	
Darbhanga							~~0.418~~	~~-2.357~~		0.509
							(2.933)	(-1.234)		
Monghyr	-0.142						-0.260			0.876
	(-1.537)						(-7.550)*			

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
<u>Bihar Plateau</u>										
Ranchi						0.828 (39.167)*		-1.316 (-4.513)		0.994
Palamau								0.316 (3.487)*		0.549
Dhanbad					-0.037 -1.951	-0.057 (-2.632)+	0.006 (2.468)**			0.624

* = Significant at 99 per cent level
** = Significant at 95 per cent level
\+ = Significant at 90 per cent level

Monghyr and Ranchi more than 70 per cent change in Gaya and more than 60 per cent change in Champaran and Purnea.

Therefore, it can be said that in the variation of yield of autumn rice rainfall plays an important role followed by canal irrigation.

6.4.1.7 Yield of winter Rice :

In the case of winter rice, the rainfall (X_6) and WI (X_8) play a significant role in the yield of winter rice (Table - 29) due to the independently of other sources of irrigation in providing water according to the requirement of rice crop. The co-efficient of regression of X_8 is significant as it brings 70 to 96 per cent changes in the yield of winter rice in the districts of Champaran and Muzaffarpur but negatively associated. Similarly rainfall explains a change of 10 to 151 per cent in the yield of winter rice in the districts of Palamau and Dhanbad but negatively associated in the districts of Shahabad, Muzaffarpur and Monghyr. The permissible explanation can be made in terms of climatic changes. The districts of Champaran, Muzaffarpur, Saran, Shahabad and other districts of North Bihar experience source winter with dry climate. There is little chances of rainfall through the retreating monsoon. Plamau and Dhanbad being a hilly region form a barrier to the retreating monsoon and receive rainfall.

Table - 29

Results of the multiple step-wise regression coefficient
(A time-series analysis) 1961 to 1973

X_7 = Yield of Winter Rice

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
<u>Bihar Plain</u>										
Patna							-1.476 (-10.488)°			0.915
Gaya	-0.145 (-2.174)	0.100 1.637							-0.167 (-3.812)°	0.695
Shahabad	-0.344 (-1.852)		-0.051 (-1.378)		-0.164 (1.536)				0.147 (4.732)°	0.795
Saran		-0.344 (6.372)°	-0.180 (-16.760)°	-0.283 (-8.318)°			0.044 (2.619)*			0.982
Champaran		-0.132 (-1.370)						-0.723 (-2.704)*		0.622
Muzaffarpur	-0.014 (-1.184)	0.011 (0.820)			-0.181 (-6.548)°		-0.111 (-2.797)*	-0.966 (-4.313)°		0.910
Monghyr		0.737 (0.619)	0.834 (2.175)		-2.374 (-1.939)		-0.539 (-2.637)			0.633

	1	2	3	4	5	6	7	8	9	10
<u>Bihar Plateau</u>										
Palamau			-0.134		0.109		-0.118		0.228	0.606
			(3.407)*		(0.937)		(-2.609)		(2.053)	
Hazaribagh				0.091		-0.614	0.257			0.633
				(2.270)+		(2.334)	(2.009)			
Dhanbad			-0.082	0.944	1.516					0.643
			(-2.200)	(2.510)+	(2.049)					
Singhbhum	0.284							-4.563	0.109	0.602
	(2.032)+							(-3.731)**	(1.390)	

* Significant at 99 per cent level
** Significant at 95 per cent level
\+ Significant at 90 per cent level

The impact of Tank, Tubewell and other sources of irrigation is clearly visible in Saran which are significant at 99 per cent level of confidence but negatively related due to the above mentioned reason. The overall impact of the variable explain more than 60 per cent change in the yield of winter rice in most of the districts of Bihar other than singhbhum where the effect is only 60 per cent.

5.4.1.8 Yield of Summer Rice :

The most contributing factor in the yield of summer rice is the canal irrigation (X_1) (Table-30), which is significant at 99 per cent level of confidence in the district of Purnea, at 95 per cent in Shahabad and 90 per cent in Patna (through negatively associated). The regression co-efficient explain of change of 66 per cent to 181 per cent in yield of summer rice due to the canal irrigation. The second contributing factor is the availability of water index (X_8) which significant at 99 per cent level of confidence in the districts of Gaya, and Champaran. The third determining factor is the tank irrigation (X_2) which is significant at 99 per cent level of confidence in this districts of Patna, Gaya, Shahabad and Saran. Other sources of irrigation are important influencing factors in the districts of Shahabad, Saran and Purnea. The net irrigated area (NIA X_9) have important effect over the yield of summer

Table – 30

Results of the multiple step-wise regression coefficient
(A time-series analysis) 1961 to 1973

X_8 = Yield of Summer Rice

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Bihar Plain										
Patna	1.046	-1.508			0.640	-0.076	-1.348			0.949
	(2.761)*	(-4.633)*			(1.440)	(-1.426)	(11.583)*			
Gaya		0.904			-0.392	-0.054	1.295)	-1.205		0.828
		(-4.789)*			(-2.736)†	(-2.618)*	(2.595)†	(-5.472)		
Shahabad	0.685	1.097	-0.107	1.448	-0.151	0.045	1.131		-0.430	0.970
	(2.845)**	7.060)*	-3.758)	(5.988)†	(-1.348)	(4.304)*	(3.464)**		(-8.372)*	
Saran		-1.023	-0907	-1.704						0.973
		(-5.628)†	(-19.362)†	(-3.802)*						
Champaran	0.055					0.114	1.348	4.109	-0.250	0.884
	(1.728)					(2.935)*	(3.481)**	(7.281)†	(-3.812)*	
Muzaffarpur				0.125	-0.912		-1.138	-0.382		0.682
				1.767)	(-3.208)**		(-2.733)†	-1.148)		
Monghyr		2.448					-1.091			0.844
		1.526					(-3.548)			

	1	2	3	4	5	6	7	8	9	10
Purnea	1.807 (5.169)*		1.671 (3.838)*	1.831 (5.400)*				-0.347 (-0.167)	0.881	0.861
<u>Bihar Plateau</u>										
Ranchi						1.469 (22.017)*				0.980
Palamau					0.301 (2.422)+					0.369
Hazaribagh					0.216 (1.774)	-0.624 (-1.383)		0.542 (1.073)		0.573

* Significant at 99 per cent level

** Significant at 95 per cent level

\+ Significant at 90 per cent level

rice which are significant at 99 per cent level of confidence in the districts of Shahabad and Muzaffarpur through negatively associated perhaps due to their lower quantity. Similarly the Gross Irrigated Areas have (X_8) weaker influence as they are significant only at 90 per cent level (confidence in the districts of Gaya, Shahabad, Champaran and Ranchi. The overall impact of the variables explain more than 80 per cent change in the districts of Bihar other than Monghyr and Palamau.

5.4.2 A Cross sectional Analysis :

A Cross-sectional Analysis of the determining factors of rice cultivation in Bihar is carried out over a time period of 1961 to 1973. The purpose of the study is to observe the actual magnitude of the impact of each variable in a given period upon the area under various kinds of rice and their average yields. The following results are obtained. (Table -31 & 32).

5.4.2.1 Gross Area under Rice :

Taking gross area under rice as dependent variables (Y_1) and X_1, X_2 ..... X_9 as independent, the following inferences have been drawn.

In 1961-62, it was only GIA (X_8) which explains a positive change i.e. 67 per cent in gross area under rice and is

Table - 31

Results of the multiple step-wise regression coefficient
(A cross-sectional analysis)

Years	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
Y_1 = Gross area under Rice										
1961-63	-0.273		-0.480	-0.344	2.330	0.679	-0.412			0.783
	(-2.229)		(-4.249)*	(-2.311)	(2.184)	(2.630)*	(-2.934)*			
1964-66		0.504			2.835					0.573
		(4.393)*			(1.626)					
1968-69		0.403			1.309	1.055	-1.017	6.933		0.690
		(1.764)			(0.659)	(2.368)*	(2.410)*	(1.633)		
1972-73	0.179	0.833			2.902	-0.612			0.500	0.763
	(1.433)	(4.481)*			(1.315)	(-3.120)**			(2.575)*	
Y_2 = Area under autumn Rice										
1961-63				0.145		-0.369	0.752	-7.936		0.662
				(1.194)		(-0.454)	(4.196)*	(-2.308)*		
1964-66		-0.023		0.164	3.173	0.736	-0.458			0.628
		(-1.311)		(3.549)**	(2.843)**	(2.205)*	(-2.893)**			
1968-69		-0.333	-0.165			-0.453			-0.339	0.271
		(-1.620)	(-1.113)			(-1.405)			(-2.434)**	
1972-73		-0.326		0.050	4.381	0.504		-3.512		0.953
		(-6.779)*		(1.284)	(7.839)*	(11.920)*		(-7.627)*		

	1	2	3	4	5	6	7	8	9	10
Y_3 = Area under winter Rice										
1961-62		0.173		-0.039		0.637	-0.115			0.674
		(2.118)		-1.068)		(3.175)**	-1.157)			
1964-65				-0.208	-2.561			4.087		0.563
				(-3.139)**	(-2.120)+			(2.665)		
1968-69		Insignificant								
1972-73		0.334			-4.897	-0.490	-0.079	2.703		0.943
		(6.095)*			(-7.701)*	(10.565)*	(-0.924)	(3.531)**		
Y_4 = Area under summer Rice										
1961-62							1.094	-10.324	-0.170	0.765
							(5.819)*	(-5.953)*	(-1.331)	
1964-65			-0.003	0.008		0.027	-0.017			0.509
			(-1.329)	(3.379)*		(2.370)**	(-3.012)+			
1968-69				0.113		-0.243		0.542		0.528
				(1.820)*		(-2.754)**		(1.690)		
1972-73		-0.054				1.205		-1.952	-0.674	0.990
		(-0.054)				(35.947)*		(-5.140)*	(26.120)	

* Significant at 99 per cent level
** Significant at 95 per cent level
\+ Significant at 90 per cent level

Table - 32

Results of the multiple step-wise regression coefficient
(A cross-sectional analysis)

Years	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	$\bar{R}^2$
	1	2	3	4	5	6	7	8	9	10
<u>Y_6 = Average yield of Rice</u>										
1961-62							0.976 (6.548)*	-0.177 (-5.801)*	-0.121 (-1.013)	0.763
1964-66		0.005 (3.050)*	-0.003 (-3.982)*			0.064 (2.124)	-0.027 (-4.978)*	0.171 (3.812)	0.001 (0.099)	0.958
1968-69					0.105 (1.663)			0.178 (2.791)**		0.323
1972-73		Insignificant								
<u>Y_6 = Yield of autumn rice</u>										
1961-62		-0.006 (-2.281)			-0.037 (-3.173)**	0-024 (3.045)**	-0.011 (-3.781)*		-0.005 (-1.519)	0.620
1964-66	Insignificant									
1968-69				0.014 (-2.125)					0.012 (2.325)	0.296
1972-73	Insignificant									

	1	2	3	4	5	6	7	8	9	10
Y_7 = Yield of winter rice										
1961-62	-0.013 (-1.423)		-0.026 (-3.017)*	-0.014 (-1.921)	0.811 (2.524)**	0.044 (2.317)*	-0.011 (-1.029)			0.640
1964-65	0.007 (1.123)	0.023 (3.633)*		0.010 (1.709)					0.019 (3.245)*	0.839
1968-69	Insignificant									
1972-73	Insignificant									
Y_8 = Yield of summer rice										
1961-62				0.005 (2.195)*		-0.034 (-2.634)**		0.094 (1.706)	0.004 (1.387)	0.512
1964-65	-0.043 (-2.189)*	-0.019 (-0.075)	-0.047 (-2.672)*	-0.033 (-1.862)					0.054 (6.093)*	0.739
1968-69			0.043 (2.164)+	0.400 (2.593)*					0.555 (3.005)*	0.484
1972-73	Insignificant									

* Significant at 99 per cent level
** Significant at 95 per cent level
\+ Significant at 90 per cent level

significant at 90 per cent level of confidence. The tube-well irrigation (X_3) might have brought as significant change as it is significant at 90 per cent level of confidence but it was negatively associated. The overall impact of the variables in this period explain 78.6 per cent variation in the gross area under rice.

In the period of 1964-65, it was tank irrigation (X_2) which alone explained a change of 50 per cent and is significant at 99 per cent level of confidence. Its combined effect with rainfall explains 57.3 per cent variation in gross area under rice.

In the period of 1968-69, it was GIA (X_8) which brought a change of 105 per cent though significant at 90 per cent level of confidence. TIR (X_7) was also significant at 90 per cent level of confidence but not contributory. The overall impact of X_2, X_5, X_6, X_7 and X_8 explain a variation of 68 per cent.

In the period of 1972-73, the tank irrigation (X_2) again hold its position explaining alone a change of 88 per cent and significant at 99 per cent level of confidence. Though X_6 was significant at 95 per cent level of confidence but not contributory. X_9 (NIA) had its own importance during the period explaining 50 per cent change and was significant at 90 per cent level of confidence. The overall impact of the variables X_1, X_2, X_5, X_6 and X_9 explain 76.3 per cent variation in gross area under rice.

6.4.2.2 Area under autumn Rice (X_2) :

From the regression equation Table-31 it can be understood that there is no significant impact of the sources of irrigation over the area under autumn rice in any period other than rainfall (X_6) and other sources of irrigation (X_4) in the year of 1964-65) and 1972-73, which are significant at 95 and 99 per cent level of confidence in the respective periods. The variable X_8 is also feasible in the respective years of 1964-65 and 1972-73, whereas the variable X_9 has its own impact in 1961-62 and significant at 99 per cent level of confidence. The water availability index (X_8) is signfficant at 90 per cent and 99 per cent level of confidence in the respective years of 1961-62 and 1971-72 but negatively associated. The variable X_9 (GIA) has its negative impact in the year of 1968-69 and significant at 95 per cent level of confidence.

Thus overall impact of the variable is about 96 per cent in the year of 1971-72 while 63 to 66 per cent in the year of 1964-65 and 1961-62.

6.4.2.3 Area under Winter Rice (Y_3) :

The regression co-efficient of Y_3 upon X_1, X_2 ... X_9 over the decades of 1962-73 explain a combined effect of 67.4 per cent in 1961-62, 53.8 per cent in 1964-65 and 94.6 per cent in 1972-73. The impact of the variables is insignificant in the year of 1968-69. The impact of individual variables can be seen from the Table-31. Whereas X_6 is significant at 95 per cent level of confidence in the year of 1961-62. The index of water availability (X_8) is significant at the same level of confidence in 1964-65, whereas the variable X_4 and X_5 show a negative impact which are significant at the same level of confidence. In the year of 1972-73, Tank irrigation (X_2) has remained the most contributing factor followed by the variable of water availability index (X_8) whose co-efficient at regression is significant at 99 and 95 per cent level of confidence. The other factor in this period are negatively associated.

6.4.2.4 Area under Summer Rice (Y_4) :

The overall impact of the variables in bringing about a change in the areas under summer rice as explained by $\bar{R}^2$ is 76.5 per cent in 1961-62, 50.9 per cent in 1964-65, 58.8 per cent in 1968-69 and 99 per cent in 1972-73. The stepwise analysis explains that in 1961-62, X_7 was the determining factor which was significant at 99 per cent level of confidence. In the year of 1964-65 the most contributing factor was the other sources of irrigation (X_4) followed by X_6 whose co-efficient of regression explain a change at 99 and 95 per cent level of confidence, whereas the variable X_7 is equally important but with negative effect. In the year of 1972-73 the variable X_7 is the determining factor which alone explained a change of 120 per cent and is significant at 99 per cent level of confidence.

5.4.2.5 <u>Average yield of Rice (Y_5)</u> :

The combined contribution of the variables in the average yield of rice was 76.3 per cent in 1961-62, 95.8 per cent in 1964-65, 32.3 per cent in 1968-69 and the year of 1972-73 has no significant impact. X_7 is the most determining factor in 1961-62 which is significant at 99 per cent level of confidence. In the year of 1964-65, the variable X_2, X_6, X_8 and X_9 show their insignificant positive contribution. The availability of water index was the important factor in the year of 1968-69 which alone brought a change of 17.8 per cent in the average yield of rice. The coefficient of regression is significant at 95 per cent level of confidence.

5.4.2.6 <u>Yield of Autumn Rice (Y_6)</u> :

The effects of the variables were only visible in the year of 1961-62 and 1968-69. In the first year the combined effect of the variables explain 62 per cent change in the variation of yield of autumn rice. It is only X_8 which is positively significant at 95 per cent level of confidence, the other variables X_5 and X_7 which are significant at 95 and 99 per cent levels of confidence explain negative effect. In the year of 1968-69, the effect of X_4 and X_9 comes into the picture but their combined effect is very less which only explain a variation of 29 per cent.

5.4.2 7 Yield of winter Rice (Y_7) :

The impact of the explanatory variables is only visible and significant in the first five years. The combined effect as explained by $\bar{R}^2$ is 64 per cent in 1961-62 and 68 per cent in 1964-65. The most determining factor in the first year of 1961-62 is the rainfall (X_8) which alone explain a change of 31.1 per cent and is significant at 95 per cent level of confidence. The other influencing variables are X_3 and X_7 which are significant at 90 per cent level of confidence but negatively associated. In the year of 1964-65, the tank irrigation (X_2) is the most determining factor whose coefficient of regression is significant at 99 per cent level of confidence but the influence impact is very less i.e. 2 per cent only.

6.4.2.8 Yield of Summer Rice (X_8)

The combined impact of the explanatory variables in the yield of summer rice is experienced as 61.2 per cent in 1961-62, 79.9 per cent in the year of 1964-65 and 48.4 per cent in 1968-69. The year of 1972-73 does not show any significant change. The regression equation does not prove the significance of individual variable other than X_6 which had a negative impact significant at 95 per cent level of confidence in the yea r of 1961-62. The year of 1964-65 experiences a negative effect of all the sources of irrigation (X_1 ... X) but none of the indicators are significant at any level of confidence. On the contrary, in the year of 1968-69 the variables of X_3, X_5 and X_9 have their impact in the yield of summer rice. Among them, the rainfall (X_5) and WIA (X_9) individually explained a change of 40 and 86.5 per cent respectively.

6.5 Conclusion :

Thus in both the analysis (time-series and Cross-section) we find that the gross area under rice is largely governed by the gross irrigated area, canal irrigation and water availability index. In both the analysis, these three factors have been found correlated significantly. These factors have also influenced the average yield of rice. However, the area and the yield of autumn rice seem to be highly influenced by rainfall and well irrigation. On the other hand, the area and the yield of winter rice are dominated by canal, tank, well and tubewell irrigations. Some relationship can also be seen in the case of summer rice. Therefore, gross irrigated area, canal irrigation, and well and tubewell irrigation are very important factors for the variations in the rice cultivation of Bihar.

CHAPTER - VI

SUMMARY AND CONCLUSIONS

CHAPTER - VI

SUMMARY AND CONCLUSION

The present study is an attempt to asses the extent to which irrigation has determined the area and yield of rice in Bihar. The study reveals that agriculturally, Bihar is very insecure and still continues to be at the mercy of the weather. The planners often attribute failure on the agricultural front to unfavourable weather conditions which have an adverse effect on agricultural production, but the problem is not that, the problems of agriculture are deep rooted and weather alone cannot be blamed for its failure. Other factors include the lack of proper irrigation facilities, uneven distribution of land and traditional equipment and technology. To this may be added the present-day politics and the introduction of social changes with a view to lifting the rural economy out of the rent overnight. These factors have been responsible for stagnation.

As far as the environmental conditions are concerned, are very favourable for the cultivation of rice throughout Bihar. More than 50 per cent of the state area is highly productive alluvial plain, interspersed with numerous rivers. Even in the plateau level lands occur, where rice is grown extensively. Located in tropical latitudes, day temperatures are optimal for growth of rice throughout the year, while night temperature in four months from November to February may fall occasionally below the optimal requirement. Sunshine may be wanting sometimes in the months of July and August, but plenty in the rest of the year. Rainfall is adequate interms of quantity but unreliable in time. Occurrence of adequate rainfall from 13rh to 23rd June, from 5th to 15th July, and from 16th September to 15th October is very crucial for optimal growth of paddy. But in these periods the raigfails frequently. Irrigation is, therefore, a must for sustaining, leave alone increasing, the rice production.

Irrigation development in Bihar dates back to the middle of 19th century. Initially canal irrigation was taken up. Later in thirties twentieth century well and tubewell irrigation were developed. But these efforts were small in scale and sporadic in nature. Thus at the time of independence Bihar state had only 0.2 million hectares of land amounting only to a bare 3.4 per cent of cultivated land. Since independence rapid progress has been made in irrigation development.

During the study period the gross irrigated area in Bihar increased from 2.1 million hectares to 2.8 million hectares. The percentage of both net and gross irrigated area have increased by 5 per cent in the case of net irrigated area from 19.63 per cent to 25.6 per cent and by 5.02 per cent in the case of gross irrigated area, from 23.26 per cent to 28.28 per cent. The compound growth rates of gross and net irrigated area during the period 1961 to 1973 were respectively 2.8 and 2.1 per cent increase per annum.

The irrigated area is unevenly distributed. More than 55 per cent of the state irrigated area is distributed in three districts of South Bihar Plain, viz; Patna, Gaya and Shahabad, where more than 40 per cent of the gross sown area is irrigated. The percentage share of other districts is low and varies from as low as 0.87 in Hazaribagh to 7.5 per cent in Champaran. In the plateau districts, excluding Palamau less than 10 per cent of the gross sown area is irrigated.

The rate of growth of irrigation in the districts of Bihar is also uneven. The compound growth rates in the net irrigated area are highest in Saharsa (65.47 per cent) and Purnea (58.8 per cent). In other districts the compound growth rates are not significant, rather in the districts of Monghyr in the plain and of Palamau, Dhanbad and Singhbhum in the plateau, they are negative.

The percentage of net sown area irrigated by canal and tubewell have increased considerably in this state, from 29 per cent to 37 per cent in case of canal and from 15 per cent to 27 per cent in the case of well and tubewell. The percentage of net sown area irrigated by tanks decreased from 17 per cent to 7 per cent and by other sources from 39 per cent to 29 per cent. The compound growth rates for the state of Bihar in area irrigated by canal, well and tubewell, tanks and other sources are respectively 4.6 per cent, 7.6 per cent, -5.7 per cent, -2.2 per annum.

Highest compound growth rates in area irrigated by canal and well and tubewell have been registered in Saharsa (226 per cent and 42 per cent) and Purnea (288.4 per cent and 43.8 per cent). In the plateau region, the districts of Santhal Parganas and Dhanbad have registered higher compound growth rates, 28.9 per cent and 88.2 per cent respectively, in area irrigated by canal. Compared with area irrigated by canal, the compound rates of growth of area irrigated by well and tubewell are more uniform in the districts of Bihar. Shahabad in the plain and Santhal Parganas in the plateau had the highest rate of decrease in area irrigated by tank and other sources.

Among the rice growing State in India, Bihar has the largest area under rice. Nearly 13 per cent of the total area in India occurs in Bihar. In the year 1972-73, 62.2 per cent of gross sown area was under rice. In some districts it is as high as 80 per cent. Bihar has also the dubious distinction of recording the lowest yield in rice in India. In all the plans it was envisaged that irrigation development would reduce the area under rice and increase its yield.

There are three seasons for rice cultivation in Bihar. The summer rice (Garwa) is cultivated during March/April to July/August. Autumn rice is grown as rainfed crop during June to October. Winter rice is the most important and grown during June/July to November/December.

Although Bihar state government and Central Rice Research Institute have released 14 improved strains, the percentage of rice area under high yielding varieties is only 23.3 per cent. In the remaining area only rainfed traditional varieties are grown.

In the State of Bihar, as a whole, the area under rice has marginally decreased. It was 5.22 million hectares in the triennial average for 1961-63 and 5.15 million hectares during the period confined to the districts with high percentage of irrigated area. On the other hand in districts where the percentage of gross irrigated area is low the acreage under rice has decreased as in the districts of Champaran, Bhagalpur, Saharsa and Purnea.

In all 11 districts have experienced a positive compound growth rates in gross area under rice. The compound growth rate indicates marginal increase in the rice acreage in two districts of the plain while decrease is noticed particularly in the plateau.

The percentage of rice area irrigated in Bihar was 33.17. However, the percentage area under irrigated rice to the gross area under rice was more than 80 per cent in the districts of Patna (99.63 per cent), Gaya (96.07 per cent), Shahabad (86.23 per cent) and Bhagalpur (80.49 per cent). Except Palamau and Monghyr, other districts had less than 30 per cent of total area under rice irrigated. In Bihar as a whole the irrigated rice has declined during the period of study. The districts in the plateau, and the districts of Saran, Muzaffarpur, Bhagalpur and Singhbhum show a decrease in irrigated area while the other districts had an increase in the area under irrigated rice. Saharsa had the maximum increase in area under irrigated rice 466 to 33,726 hectares.

Like the gross area under rice, different crops of rice also have various rate of growth in the districts of Bihar. Autumn rice, which constitutes only 6 per cent of the total rice in Bihar, as grown relatively on a larger area. The proportion of area under autumn rice to the total area under rice is maximum in Ranchi district (23.2). In other districts in the plateau, its share is comparatively less. In the plain districts Saran, Champaran, Saharsa and Purnea, the percentage is above 10. Autumn rice is mainly rain fed. Area under autumn rice has increased during the study period. The increased in area is marked in the Champaran district (compound growth rate 46.93 per cent). However, 8 districts have registered a negative growth rate.

Winter rice is the major rice crop, comprising nearly 90 per cent of the total rice area in almost all the districts of Bihar. It is highly irrigated (35.30 per cent) rice in Bihar. In Gaya and Patna nearly the entire rice (99 per cent) is irrigated. Except Palamau district, in all the districts of plateau, irrigated winter rice is very less. In general area under winter rice as well as irrigated winter rice has marginally decreased.

Summer rice is very insignificant in Bihar. In most of the districts they constitute less than 0.02 per cent of total area under rice. The highest itself is only 1.16 per cent in the district of Purnea. However, it is full irrigated crop and the area under summer rice is increasing wherever there is an increase in the irrigated area.

Bihar has the lowest yield in rice, 789 kg/hectare. The increase in irrigated rice had only marginal effect in the yield. The compound growth in the yield in Bihar state is only 0.70. Rather 7 districts have registered negative change in growth rate. About 2 per cent compound growth in yield is witnessed only in Patna, Bhagalpur and Purnea districts. Winter rice generally gives a higher yield. Highest yield is obtained in Patna 14.37 kg/hectare. Average yield of autumn rice is 651 kg/hectare and that of summer rice is 881 kg/hectare. It is distressing to note that the compound growth rate of winter rice, the most important, is negative. Yield of summer rice has the highest compound growth rate 3.50. It is very high in Patna which has registered the growth rate of 50.5.

Production of rice is interlinked with area and yield. The total production of rice has increased from 4.4 M.T. to 4.6 M.T. The year to year duration of production from average brings out that with irrigated area less than 20 per cent, greater is the fluctuation and fluctuation gets reduced with increased in irrigated area.

Thus, the growth of irrigation plays an important role in the change of area, yield and production of rice. The marked increase is noticed in the districts of Bihar plain (except Monghyr). In the districts of Bihar plateau only two districts, Singhbhum and Ranchi have shown significant result in both area and yield as well as in irrigation.

The study reveals that varietious environmental and technological variables exercise a dominant effect on the area and yield of rice. Among them irrigation alone explains about 60 per cent variation in area and yield of rice. But the rainfall explain only 15 to 20 per cent variation in the area whereas in yield and particularly in autumn crop, it explains more than 40 per cent variation. While water availability index explains about 20 to 30 per cent in the area and 40 to 50 per cent variation in the yield of rice. All in combination explains more than 70 per cent variation in area and yield of rice which indicates the use of technological inputs like fertilisers, HYV etc are uncommon.

To conclude, the following inferences may be drawn from the analysis, impact of irrigation development on rice cultivation in Bihar: (a) the rice producing districts in state are situated in the eastern part of the state (Purnea, Santhal Parganas, Singhbhum etc) which receives high rainfall (b) the increase in irrigated area leads to increase in the total cropped area under rice, especially in the districts having low irrigated area. (c) with more development of irrigation particularly canal irrigation, the area under summer rice has increased. (d) In the districts of Patna, Gaya and Shahabad which have relatively high percentage of irrigated area, but the area under rice is stagnant or low which leads to the conclusion that crops other than rice is cultivated. (e) Irrigation development tends to reduce the year to year fluctuation in the production of rice in the districts of Shahabad, Gaya, Saharsa, Champaran and Ranchi. (f) Canal and well and tubewell irrigation are the most effective explanatory variables for the variation in summer crops of rice.

Since the explanatory model developed here has given very encourageous result, it could also be applied to other levels especially at lower level of reference - anchal. The variations in physio-socio-economic conditions at micro-level, make it imperative for such an indepth study of the rice at the village level with data generated through field work.

APPENDICES AND BIBLIOGRAPHY

APPENDIX - 1

Difinitions of the terms used
Compound Growth rates & Linear rates of increase

The compound growth rates reflect the strength of any movement, the linear rates of increase, which are in actual (rather than percentage) terms, show us the impact of such movement, free from the magnitude of a given series. Besides, the linear rates are additive and are less sensitive to terminal values.

Water Availability Index :

To combine rainfall and irrigation called water availability index. The concept of water requirement of crop and effective rainfall are basis for computing the water availability index.

Effective Rainfall :

The effective rainfall value is defined as the depth of rainfall equivalent to the volume of runoff. The evaluation of effective rainfall involves measurements of rainfall and/or irrigation, losses by surface runoff, percolation beyond the rootzone and soil moisture use by the crops.

The monthly effective rainfall cannot exceed the consumptive use value and if does, the lower value of the two is taken.

Potential Evapotranspiration (PE):

Moisture transfer from a vegetated surface is often referred to as evapotranspiration, and when the moisture supply in the soil is unlimited the term potential evapotranspiration (PE) is used. It has been suggested that PE can be defined more specifically as the evaporation equivalent of the available net radiation, i.e.:

PE = RN/L, where L is the latent heat of vaporization (59 Cal cm^{-2} 1mm evaporation)

Coefficient of Variation :

The standard deviation is an absolute measure of dispersion. The corresponding relative measure is known as the coefficient of variation. It is used in such problems where we want to compare the variability of two or more than two series. That series for which the coefficient of variation is greater is said to be more variable or conversely less consistent, less uniform, less stable or less homogeneous.

Correlation Coefficient :

The correlation coefficient summarizes in one figure not only the degree of correlation but also the direction, i.e. whether correlation is positive or negative. The coefficient of correlation measures the degree of relationship between two sets of figure.

Regression Coefficient :

The statistical tool with help of which we are in a position to estimate (or predict) the unknown values of one variable from known values of another variable is called regression. Regression coefficient gives the value by which one variable changes for a unit change in the other variable.

APPENDIX - 2

Statistical Equations

Coefficient of Variation

Coefficient of variation is denoted by the symbol C.V. and is obtained as follows:

$$C.V. = \frac{\sigma}{\bar{X}} \times 100$$

where,

σ = Standard deviation

$\bar{X}$ = Mean

Water availabilitu index :

It is calculated by the formula:

$$WI = \frac{I(PE - Er) + Er}{GSA}$$

where,

WI = Water availability index

I = % of irrigated area

Er = effective rainfall

GSA = gross sown area

Compound growth rate :

Compound growth rate is calculated by the formula:

r is annual compound growth rate (in %)

X_t = area, production and yield in terminal year

X_o = area, production and yield in initial year

t = time interval.

Correlation Coefficient :

The Pearsonian coefficient of correlation is denoted by the symbol 'r'. The formula for computing Pearsonian 'r' is :

$$r = \frac{\Sigma XY - \frac{\Sigma X \, \Sigma Y}{n}}{\sqrt{\Sigma x^2 - \frac{(\Sigma x)^2}{n}} \; \sqrt{\Sigma y^2 - \frac{(\Sigma y)^2}{n}}}$$

where,

Σxy = sum of the product of the deviations of X and Y series from their assumed.

Σx^2 = sum of the squares of the deviations of X series from an assumed mean.

Σy^2 = sum of the squares of the deviation of Y series from an assumed mean.

Σx = sum of the deviations of X series from an assumed mean.

Σy = sum of the deviations of Y series from an assumed mean

n = number of observations.

t - test

The test of significance for zero order correlation coefficient and regression coefficient is calculated to the formula :

$$t = \frac{r}{1 - r^2} \sqrt{n - 2}$$

where 'r' represents the correlation coefficient and 'N' is the number of observations.

F - test

F - test formula is adopted to measure the multiple correlation coefficient as follows:

$$F = \frac{R^2}{1-R^2} \times \frac{N-P-1}{P}$$

where,

R = multiple correlation coefficient

N = No. of observations

P = No. of variables used in the measurement of multiple correlation.

$\bar{R}$ - Value

As the value of 'R' increases with any additional indicator and may lead to the wrong results in the analysis of regression coefficient. Therefore, the value of 'R' is converted into '$\bar{R}$' which stands for average multiple correlation coefficients adjusted for the degree of freedom in the estimation of regression coefficient on the following formula:

$$\bar{R} = 1-(1-R)\frac{N-1}{d.f.} \quad \text{or} \quad \bar{R}^2 = 1-(1-R^2)\frac{N-1}{d.f.}$$

d.f. represents the degree of freedom.

Regression Equation :

The regression equation of 'Y' on 'X' is expressed as follows:

$$Y = a + b_x$$

where,

$$a = \bar{Y} - b\bar{X}$$

and,

$$b = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\Sigma(x - \bar{x})^2}$$

or,

$$b = r_{xy} \frac{\sigma y}{\sigma x}$$

'a' is the intercept and 'b' represents the regression coefficient of the individual variables.

APPENDIX 3.

Average monthly effective rainfall as related to mean monthly rainfall and mean monthly consumptive use.

(U.S D.A. SCS, 1969) →

Monthly mean rainfall mm	Mean monthly consumptive use, mm (PET) 25	50	75	100	125	150	175	200	225	250	275	300	325	350
	Mean monthly effective rainfall, mm													
12.5	7.5	8.0	8.7	9.0	9.2	10.0	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5
25.0	15.0	16.2	17.5	18.0	18.5	19.7	20.5	22.0	24.5	25.0	25.0	25.0	25.0	25.0
37.5	22.5	24.0	26.7	27.5	28.2	29.2	30.5	33.0	36.2	37.5	37.5	37.5	37.5	37.5
50.0	25.0	32.2	34.5	35.7	36.7	39.0	40.5	43.7	47.0	50.0	50.0	50.0	50.0	50.0
62.5	at 41.7	39.7	42.5	44.5	46.0	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5
75.0	↓	46.2	49.7	52.7	55.0	57.5	60.2	63.7	67.5	73.7	75.0	75.0	75.0	75.0
87.5	↓	50.0	56.7	60.2	63.7	66.0	69.7	73.7	77.7	84.5	87.5	87.5	87.5	87.5
100.0	↓	at 80.7	63.7	67.7	72.0	74.2	78.7	83.0	87.7	95.0	100	100	100	100
112.5	↓	↓	70.5	75.0	80.2	82.5	87.2	92.7	98.0	105	111	112	112	112
125.0	↓	↓	75.0	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125
137.5	↓	↓	at 122	88.7	95.2	98.7	104	111	118	126	132	137	137	137
150.0	↓	↓	↓	95.2	102	106	112	120	127	136	143	150	150	150
162.5	↓	↓	↓	100	109	113	120	128	135	145	153	160	162	162
175.0	↓	↓	↓	at 160	115	120	127	135	143	154	164	170	175	175
187.5	↓	↓	↓	↓	121	126	134	142	151	161	170	179	185	187
200.0	↓	↓	↓	↓	125	133	140	148	158	168	178	188	196	200
225	↓	↓	↓	↓	at 197	144	151	160	171	182				
250	↓	↓	↓	↓	↓	150	161	170	183	194				
275	↓	↓	↓	↓	↓	at 240	171	181	194	205				
300	↓	↓	↓	↓	↓	↓	175	190	203	215				
325	↓	↓	↓	↓	↓	↓	at 287	198	213	224				
350	↓	↓	↓	↓	↓	↓	↓	200	220	232				
375	↓	↓	↓	↓	↓	↓	↓	at 331	225	240				
400	↓	↓	↓	↓	↓	↓	↓	↓	at 372	247				
425	↓	↓	↓	↓	↓	↓	↓	↓	↓	250				
										at 412				
450	25	50	75	100	125	150	175	200	225	250				

APPENDIX - 4

Annual Water Availability Index

(in mm)

Districts	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73
<u>Bihar Plain</u>												
Patna	1462	1459	1470	1473	1472	1417	1493	1479	1494	1495	1496	1493
GAYA	1641	1641	1641	1639	1637	1623	1196	1650	1650	1651	1651	1750
Shahabad	1514	1483	1516	1547	1502	1381	1482	1499	1513	1539	1536	1525
Saran	614	598	658	506	497	535	524	652	644	672	425	788
Champaran	854	883	871	663	749	782	749	801	783	860	795	789
Muzaffarpur	652	605	623	656	488	441	456	654	594	647	403	623
Darbhanga	557	647	679	536	574	529	522	727	610	838	570	646
Monghyr	1143	1160	1174	1080	1108	1110	1148	1137	1119	1152	1127	1037
Bhagalpur	1252	1305	1343	1246	1316	1273	1298	1260	1291	1336	1297	1300
Saharsa	624	702	639	397	609	614	642	719	802	659	295	734
Purnea	638	616	644	583	518	618	614	773	658	737	748	734
<u>Bihar Plateau</u>												
S. Parganas	847	825	858	719	725	759	641	858	730	861	743	639
Hazaribagh	654	728	637	667	544	474	510	575	541	696	578	448
Ranchi	627	657	612	591	433	852	474	863	544	639	569	572
Palamau	1054	1061	1065	1085	1023	408	1041	985	1017	1046	1032	955
Dhanbad	740	775	773	688	574	681	1094	725	574	575	681	611
Singhbhum	535	553	625	542	564	658	479	669	587	710	603	487

APPENDIX - 6

Annual Average Rainfall

Districts	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	Normal Rainfall
Bihar Plain													
Patna	1290	1122	1209	1143	949	637	881	982	1197	914	1157	758	952
Gaya	1320	1008	1115	1011	754	618	1008	1024	1137	1023	1888	749	1151
Shahabad	1308	872	975	1122	753	568	871	947	995	1025	1340	665	1123
Saran	1032	1078	1299	1013	953	811	789	1052	1416	1276	1043	1032	1121
Champaran	1170	1401	1553	1504	1299	1107	1086	1223	1575	1605	1392	1072	1391
Muzaffarpur	1004	1081	1181	1308	1190	659	1049	1056	1285	1016	848	997	1184
Darbhanga	1167	1196	1329	1136	1222	966	1033	1142	1066	1371	1060	961	1250
Bhagalpur	1216	1118	1208	1113	939	712	915	1257	1311	932	1518	742	1166
Monghyr	1067	1701	1356	1086	1118	709	791	1425	1273	1267	1284	726	1206
Saharsa	1129	1708	1623	1075	1206	1018	1068	1058	1418	999	661	878	1385
Purnea	1464	1532	1573	1442	1291	1141	1116	1985	1804	1505	446	1227	1585
Bihar Plateau													
S.Parganas	1247	1259	1365	1186	1114	1105	998	1985	1297	1457	1763	975	1377
Ranchi	1608	1036	1190	1114	983	741	1032	1616	1059	1237	1695	861	1258
Palamau	1724	1168	1435	1365	1151	1097	1376	1295	1252	1525	1782	1201	1483
Hazaribagh	1546	1066	1052	1416	1039	723	1387	1330	1062	1312	1485	1068	1335
Dhanbad	1445	1016	1326	1158	887	896	1280	1634	1085	1420	1912	1147	1311
Singhbhum	1441	1048	1312	1350	1111	1296	1163	1316	1135	1340	1440	1093	1435
State	1318	1172	1300	1230	1060	873	1050	1258	1256	1249	1295	0952	1272

Source : Season and Crop Report

APPENDIX - 6

List of High Yielding Varieties grown in Bihar

Zone I - North Bihar Plains

Area to the north of Ganges River extending to the foot hills of the Himalayas (Purnea, Saharsa, north Bhagalpur, north Monghyr, Darbhanga, Muzaffarpur, Champaran and Saran districts).

Predominant Varieties	Varieties Recommended
Summer Crop :	
N 136, NC 1626, Ch 1039, Pusa 2-21, Padma, Prahlad	Bala, Cauvery, Padma, Prahlad Narsing, Vishnu, Sabarmati, Jamuna, Pusa-2-21.
Autumn Crop :	
Early: Pusa 2-21, Prahlad Ratna	Prahlad, Narsing, Vishnu, Ratna, Pusa 2-21
Late: Sita, IR 8, Jaya	Sita, Deepa, Jaya, IR 8, Archana.
Winter Crop :	
Early and medium: BR 3, BR 4, BR 5, BR 34, Malinja, Mahsuri	Jayanthi, IR 20, Prahlad, Narsing, Vishnu, Rajendradhan-201, Archana, Deepa, Sita, Ratna, Jaya, IR 8, Mahsuri.
Late :	
T 141, BR 8, BR 7, T 3, BR 9, BR 10, BR 13, (for flood affected areas)	Pankaj, Jagannath
BR 14, BR 15 (for deep water areas).	Panidhan 1, Panidhan 2, 64-117.

BR 11 and BR 12 are the pigmented varieties used for eradicating weeds. BR 11 has straw-coloured hull; BR 12 has dark gold hull colour. BR 11 is a fortnight earlier to BR 12.

Zone 2 - South Bihar Plains :

Areas to the south of Ganges comprising Patna, Gaya, Shahabad, South Bhagalpur and South Monghyr come in this zone.

Predominant Varieties	Varieties Recommended
Summer Crop :	
N 136, Padma, Prahlad	Bala, Cauvery, Padma, Prahlad, Narsing, Vishnu, Pusa 2-21.
Autumn Crop :	
Early: Cross B 2, Cross 116	Prahlad, Narsing, Vishnu, Ratna, Archana.
Late: Jaya, IR 8, Sita	Sita, Deepa, Jaya, IR 8
Winter Crop :	
Early and Medium :	
BR 3, BR 4, BR 5, BR 6, BR 34, Malinja, Mahsuri	Jayanthi, IR 20, Prahlad, Vishnu, Narsing.
Late :	
T 141, BR 8, BR 7, T 3, BR 9, BR 10, BR 13 (for flood affected areas)	Pankaj, Jagannath.
BR 14, BR 15, (for deep water areas)	Panidhan 1, Panidhan 2, 64-117)

BR 11 and BR 12 are grown for eradicating weeds.

Zone 3 - Chotanagpur Plateau

Ranchi, Hazaribagh, Palamau, Dhanbad, Singhbhum and Santhal Parganas districts are comprising the area.

Predominant Varieties	Varieties Recommended
Early :	
Tanr Lands :	
Brown Gora 23-19 (BR 16) Bora Gora 5748 (BR 17) Black Gora	Bala, Cauvery, Kiran, Kanchan
Don III : Early Varieties Kolaba (BR 1)	Prahlad, Narsing, Vishnu, Archana
Don II : Medium Varieties Sarguja (BR 2)	Sita, Deepa, Jaya IR 8
Winter Crop :	
III - drained areas: BR 34	Panidhan 1, Panidhan 2
Well - drained areas BR 8, T 141	Jayanthi, IR 28

Source : 'Improved Rice varieties for different Regions of India', Directorate of Extension, Ministry of Agriculture and Irrigation, New Delhi.

APPENDIX - 7

Percentage of total irrigated rice to gross area under rice, Area of different Crops of rice irrigated to gross area under rice and share of total irrigated rice in the state (1961-63 and 1971-73)

	1961 - 63					1971 - 73				
	TIR/GAR	Dist. TIR to State TIR	AIAR/AAR	AIWR/AWR	AISR/ASR	TIR/GAR	Dist. TIR to State TIR	AIAR/AAR	AIWR/AWR	AISR/ASR
Bihar Plain										
Patna	95.63	13.47	19.38	94.69	-	99.14	12.54	74.68	99.20	95.07
Gaya	95.07	27.62	22.63	97.90	-	99.58	26.51	42.62	99.60	99.90
Shahabad	86.23	23.83	10.54	87.00	91.56	88.22	25.80	31.89	88.40	99.67
Saran	1.61	0.18	4.16	1.58	33.90	2.01	0.23	1.69	1.48	77.89
Champaran	27.73	6.07	13.82	30.75	-	25.99	6.78	16.77	28.00	19.63
Muzaffarpur	9.92	0.52	3.49	6.19	-	2.48	0.46	6.74	1.98	89.60
Darbhanga	1.58	0.33	3.18	2.71	-	6.00	1.32	9.03	5.50	79.10
Monghyr	64.99	7.40	12.82	65.61	-	63.45	5.25	24.36	63.20	86.50
Bhagalpur	80.49	6.74	22.40	75.91	-	87.39	7.44	8.10	81.57	94.70
Saharsa	0.37	0.02	-	0.77	-	20.16	2.26	10.71	21.44	20.90
Purnea	0.17	0.04	-	0.03	57.99	10.39	3.05	2.26	11.90	57.60
Bihar Plateau										
S. Parganes	18.89	4.59	1.90	27.19	55.23	10.89	2.00	2.10	11.02	53.60
Hazaribagh	6.28	0.98	-	7.12	-	2.17	0.28	-	2.70	97.80
Ranchi	1.45	0.36	-	2.06	91.01	2.72	0.75	-	4.30	86.90
Palamau	61.61	3.76	1.01	73.26	8.90	55.82	3.46	-	64.70	99.00
Dhanbad	7.44	0.34	-	4.48	-	1.65	0.06	-	1.48	99.00
Singhbhum	1.63	1.31	-	7.47	80.59	5.04	1.04	-	5.21	79.50
State	36.64		6.01	37.11		33.17		5.95	35.30	82.70

TIR = TOTAL Irrigated Rice
AIAR = Area under irrigated autumn rice
AIWR = Area under irrigated winter rice
AISR = Area under irrigated summer rice
GAR = Gross area under rice
AAR = Area under autumn rice
AWR = Area under winter rice
ASR = Area under summer rice.

APPENDIX - 8

Percentage of area under different crops of rice to gross area under rice

	1961 - 63			1971 - 73		
	% of area under autumn rice/GAR	% of area under winter rice/GAR	% of area under summer rice/GAR	% of area under autumn rice/GAR	% of area under winter rice/GAR	% of area under summer rice/GAR
Bihar Plain						
Patna	0.11	99.88	0.02	0.11	96.27	3.62
Gaya	0.40	99.59	0.01	0.45	97.79	1.76
Shahabad	1.81	98.15	0.03	0.91	96.71	2.38
Saran	11.2[illegible]	88.55	0.21	18.51	80.83	0.67
Champaran	13.74	83.14	0.02	21.63	62.04	16.33
Muzaffarpur	4.27	95.69	0.03	5.36	94.33	0.31
Darbhanga	4.44	95.42	0.04	6.04	93.53	0.43
Monghyr	1.22	98.92	0.06	0.78	97.07	2.15
Bhagalpur	0.33	99.61	0.01	0.43	98.99	0.58
Saharsa	10.72	89.00	0.01	10.98	86.12	2.90
Purnea	18.73	80.97	1.16	20.49	78.65	0.86
Bihar Plateau						
S. Parganas	2.90	96.08	0.02	1.91	97.90	0.19
Hazaribagh	2.99	96.99	0.01	3.98	95.67	0.35
Ranchi	23.15	75.72	1.12	23.15	73.61	0.24
Palamau	9.71	91.32	0.01	13.81	86.05	0.14
Dhanbad	0.45	99.64	0.01	0.34	99.47	0.19
Singhbhum	6.69	93.24	0.02	5.75	94.07	0.18

GAR = Gross area under rice

APPENDIX - 9

Average and crop-wise yield of rice

(in kg/hectare)

Districts	Average of 1961, 62 and 63				Average of 1971, 72 and 1973			
	Average yield	Yield of Autumn rice	Yield of winter rice	Yield of Summer rice	Average yield rice	Yield of Autumn rice	Yield of winter rice	Yield of summer rice
<u>Bihar Plain</u>								
Patna	788	459	1178	727	999	784	1437	778
Gaya	717	438	966	717	883	784	984	881
Shahabad	775	460	1108	760	968	784	1187	932
Saran	810	652	829	948	869	896	881	831
Champaran	887	767	945	963	892	744	833	980
Muzaffarpur	823	738	761	949	835	603	614	986
Darbhanga	787	606	812	948	790	522	708	1106
Monghyr	635	309	874	631	660	513	885	582
Bhagalpur	733	545	1026	628	874	513	1143	965
Saharsa	648	549	768	628	696	448	951	390
Purnea	723	550	929	691	729	518	638	447
<u>Bihar Plateau</u>								
S.Parganas	776	530	1142	657	693	612	887	580
Hazaribagh	652	421	908	657	606	432	700	953
Ranchi	639	397	831	689	666	357	887	755
Palamau	677	396	853	782	602	513	683	910
Dhanbad	754	391	1180	691	740	393	987	929
Singhbhum	643	383	1115	450	697	390	902	798
State	749	535	969	742	787	551	943	867

Appendix - 10

Production of Rice

Districts	1961's		1971's	
	Produc-tion in '000 M.T.	% of Dist-rict to State	Produc-tion in '000 M.T.	% of Dist-rict to State
1. Patna	267	6.07	299	6.49
2. Gaya	445	10.11	459	9.75
3. Shahabad	495	11.25	543	11.79
4. Saran	150	3.41	174	3.77
5. Champaran	329	7.48	369	8.01
6. Muzaffarpur	224	5.09	295	6.40
7. Darbhanga	278	6.32	368	6.67
8. Monghyr	157	3.56	158	3.43
9. Bhagalpur	140	3.18	177	3.84
10. Saharsa	85	1.93	111	2.41
11. Purnea	33	0.75	259	5.62
12. Santhal Parganas	446	10.14	371	8.05
13. Hazaribagh	234	5.32	180	3.90
14. Ranchi	303	6.88	342	7.42
15. Palamau	78	1.77	69	1.49
16. Dhanbad	90	2.04	69	1.49
17. Singhbhum	341	7.75	384	8.33
State	4398		4605	

APPENDIX - 11

Results of the correlation matrix
(Correlation with Gross area under rice)
1961-62 to 1972-73

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	-0.106	0.271	-0.041	-0.081	0.047	0.934	-0.177	-0.108	0.055
Gaya	0.196	-0.360	0.285	-0.059	0.068	0.792	-0.060	-0.172	-0.085
Shahabad	-0.219	0.154	-0.003	0.212	-0.007	0.944	0.067	0.064	0.216
Saran	-0.154	0.212	0.073	0.340	0.068	0.944	0.290	0.122	-0.244
Champaran	0.110	-0.272	-0.073	-0.037	0.195	0.675	0.191	-0.080	0.023
Muzaffarpur	0.390	0.508	-0.094	-0.692	0.536	0.598	-0.615	-0.281	-0.595
Darbhanga	-0.104	0.214	0.005	-0.231	0.386	0.490	-0.369	-0.194	-0.076
Bhagalpur	-0.043	0.283	-0.132	-0.247	-0.193	-0.193	-0.707	0.089	0.100
Monghyr	-0.401	0.203	-0.525	-0.515	0.615	0.369	-0.099	0.091	0.176
Saharsa	0.234	-0.072	-0.139	-0.266	-0.025	-0.720	-0.471	-0.328	-0.191
Purnea	0.116	-0.040	0.193	-0.199	0.382	0.562	0.264	0.280	0.666
Bihar Plateau									
S.Parganas	0.113	-0.206	-0.071	-0.379	0.234	0.511	-0.442	-0.227	-0.305
Ranchi	0.107	-0.752	0.373	0.531	0.539	0.497	-0.414	-0.720	-0.048
Palamau	-0.023	0.257	0.517	-0.412	0.302	0.795	-0.251	-0.245	0.641
Hazaribagh	-0.100	0.480	-0.333	0.356	0.470	-0.168	0.485	0.499	0.404
Dhanbad	-0.330	-0.300	0.178	0.337	0.039	-0.214	-0.108	-0.076	-0.506
Singhbhum	0.654	0.518	0.214	-0.101	-0.452	-0.061	-0.303	-0.188	-0.692

APPENDIX - 12

Results of the correlation matrix
(Correlation with area under autumn rice)
1961-62 to 1972-73

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	0.047	-0.182	0.089	-0.006	0.301	0.188	0.083	0.161	0.356
Gaya	-0.519	-0.137	-0.354	0.440	0.453	0.162	0.125	0.221	0.340
Shahabad	0.074	-0.073	-0.053	-0.062	0.605	0.215	0.248	0.240	0.316
Saran	0.481	-0.658	-0.187	0.675	0.033	0.178	0.429	0.082	0.675
Champaran	-0.601	0.690	0.837	-0.292	0.014	0.374	-0.408	-0.084	0.710
Muzaffarpur	0.018	-0.658	0.434	0.173	-0.224	0.875	0.501	0.714	0.840
Darbhanga	-0.392	-0.330	0.332	0.601	-0.380	0.844	0.426	0.287	0.249
Bhagalpur	-0.392	-0.330	-0.159	-0.134	0.152	0.101	-0.045	-0.005	0.333
Monghyr	-0.134	0.036	-0.145	0.150	-0.170	-0.028	-0.162	-0.084	-0.084
Saharsa	-0.409	0.292	0.079	0.541	-0.066	0.297	0.887	0.185	0.008
Purnea	-0.335	-0.193	0.575	0.194	0.929	-0.177	-0.279	-0.100	-0.202
Bihar Plateau									
S.Parganas	-0.464	-0.726	-0.344	0.735	0.134	-0.180	-0.029	-0.158	-0.013
Ranchi	0.078	0.431	0.187	0.087	0.213	0.355	0.893	0.518	-0.151
Palamau	0.202	-0.067	0.184	-0.090	-0.601	-0.577	-0.438	-0.445	-0.559
Hazaribagh	-0.022	-0.277	0.343	-0.306	-0.308	-0.091	-0.271	-0.391	0.168
Dhanbad	0.014	-0.108	0.144	0.102	-0.121	-0.196	-0.103	-0.312	-0.225
Singhbhum	-0.437	-0.746	-0.240	-0.327	0.514	0.104	0.174	0.028	0.884

APPENDIX - 13

Results of the correlation matrix
(Correlation with area under winter rice)
1961-62 to 1972-73

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	0.678	0.886	-0.875	0.631	0.286	-0.107	-0.349	-0.392	0.497
Gaya	0.194	-0.525	0.141	0.103	0.076	0.085	-0.057	-0.002	-0.092
Shahabad	0.591	0.538	-0.519	0.678	0.094	0.156	0.096	0.016	0.133
Saran	0.497	0.617	0.156	-0.643	-0.045	0.333	-0.564	-0.131	-0.613
Champaran	0.301	-0.298	-0.408	0.123	-0.180	0.086	0.201	-0.188	-0.344
Muzaffarpur	0.054	0.666	-0.492	-0.148	0.281	-0.900	-0.391	-0.733	-0.886
Darbhanga	0.300	0.180	-0.450	-0.483	0.253	-0.499	-0.984	0.067	-0.056
Bhagalpur	-0.195	0.099	0.131	0.028	-0.114	-0.096	0.012	-0.025	-0.229
Monghyr	0.386	0.479	0.201	-0.458	0.291	0.220	0.900	-0.097	0.304
Saharsa	0.153	-0.042	0.169	-0.209	0.365	-0.762	-0.683	-0.052	-0.453
Purnea	0.356	0.230	0.552	-0.229	0.980	0.218	0.318	0.185	0.237
Bihar Plateau									
S.Parganas	0.117	0.171	-0.002	-0.096	0.345	0.081	0.067	0.522	0.079
Ranchi	0.371	-0.543	0.718	-0.066	-0.195	-0.284	-0.573	-0.428	0.069
Palamau	-0.101	0.034	-0.104	-0.103	0.293	0.349	0.081	0.094	0.322
Hazaribagh	-0.468	0.255	-0.381	0.303	-0.486	0.568	0.425	0.094	-0.079
Dhanbad	0.177	0.471	-0.310	-0.557	-0.563	0.302	0.031	0.064	0.443
Singhbhum	0.391	0.656	0.190	0.419	-0.304	0.034	0.088	0.043	-0.781

APPENDIX - 14

Results of correlation matrix
(Correlation with area under summer rice)
1961 to 1973

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	0.553	-0.748	0.647	-0.452	-0.280	-0.027	0.336	0.293	-0.459
Gaya	0.501	0.036	0.130	-0.081	-0.882	0.383	0.059	0.059	0.150
Shahabad	0.707	-0.645	0.557	-0.772	-0.102	-0.070	-0.039	0.013	0.037
Saran	-0.094	-0.443	-0.358	0.342	0.299	0.445	0.343	-0.204	0.592
Champaran	0.719	0.767	0.937	-0.248	0.089	0.410	-0.261	0.036	0.834
Muzaffarpur	-0.011	-0.001	-0.387	0.512	-0.001	0.018	-0.074	0.068	0.078
Darbhanga	-0.223	-0.113	0.403	0.338	-0.199	0.350	0.983	-0.126	0.067
Bhagalpur	0.591	-0.104	-0.274	-0.324	-0.360	0.032	0.237	-0.112	0.517
Monghyr	0.060	-0.129	0.210	-0.142	0.001	0.075	-0.447	-0.053	0.270
Saharsa	0.497	0.135	-0.072	0.398	-0.129	0.577	0.768	-0.176	0.116
Purnea	0.217	-0.232	0.015	-0.269	0.375	0.122	0.206	-0.028	0.006
Bihar Plateau									
S.Parganas	0.152	-0.491	-0.435	0.359	0.284	0.571	-0.507	-0.243	-0.464
Ranchi	0.612	0.118	-0.409	0.057	0.430	0.442	0.313	-0.101	-0.176
Palamau	0.497	0.325	0.052	-0.236	0.205	0.419	0.089	0.113	0.497
Hazaribagh	0.322	-0.153	0.342	-0.388	0.400	-0.469	-0.297	-0.127	0.264
Dhanbad	-0.023	0.032	-0.030	-0.026	0.011	-0.348	-0.155	-0.355	-0.280
Singhbhum	0.497	-0.007	-0.312	-0.028	-0.205	0.434	0.253	0.017	-0.095

APPENDIX – 15

Results of the correlation matrix
(Correlation with average yield of rice)
1961-62 to 1972-73

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	-0.087	0.421	-0.218	-0.016	-0.241	-0.022	-0.955	0.116	0.117
Gaya	0.145	0.093	-0.339	0.256	0.161	-0.301	0.560	0.514	-0.082
Shahabad	0.020	0.135	-0.657	-0.140	0.147	0.311	0.430	0.497	0.274
Saran	-0.215	-0.062	-0.578	-0.110	0.400	0.711	0.165	0.579	0.351
Champaran	0.436	-0.043	-0.275	-0.329	-0.054	0.036	-0.347	0.438	-0.380
Muzaffarpur	-0.001	-0.174	-0.104	0.268	-0.561	-0.337	-0.287	0.429	0.358
Darbhanga	-0.225	-0.110	0.392	0.380	-0.158	0.310	0.975	-0.143	-0.004
Bhagalpur	0.591	-0.104	-0.275	-0.324	-0.360	0.032	0.237	-0.112	0.517
Monghyr	-0.388	-0.453	-0.304	0.525	-0.230	-0.248	-0.939	0.497	-0.368
Saharsa	-0.498	0.428	0.258	0.684	0.015	0.202	0.830	-0.011	-0.341
Purnea	0.129	-0.497	-0.397	-0.001	0.176	-0.265	-0.079	-0.301	-0.369
Bihar Plateau									
S.Parganas	-0.004	0.141	-0.054	-0159	0.614	0.174	0.210	0.273	0.088
Ranchi	0.286	-0.089	-0.064	0.828	0.960	0.992	0.249	-0.416	-0.095
Palamau	-0.077	-0.078	-0.814	0.540	0.608	-0.032	0.678	0.734	-0.011
Hazaribagh	0.037	0.201	-0.157	0.307	0.796	-0.252	0.210	0.404	0.305
Dhanbad	0.282	0.228	-0.203	-0.270	0.009	0.274	0.770	0.678	0.494
Singhbhum	0.400	-0.153	0.019	-0.115	-0.346	-0.381	-0.340	-0.429	-0.091

APPENDIX - 16

Results of the correlation matrix
(Correlation with yield of autumn rice)
1961-62 to 1972-73

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	-0.100	0.428	-0.184	-0.046	0.311	0.041	-0.930	0.108	0.131
Gaya	0.232	-0.163	-0.133	0.209	0.620	-0.015	0.330	0.213	-0.400
Shahabad	0.030	-0.087	0.095	-0.115	0.607	0.213	0.717	0.681	0.693
Saran	-0.148	-0.388	-0.936	-0.050	0.619	0.035	0.502	0.139	0.872
Champaran	0.642	-0.224	-0.543	-0.275	0.430	-0.247	-0.490	-0.195	-0.603
Muzaffarpur	0.417	0.426	-0.476	-0.155	0.394	0.585	-0.444	-0.277	-0.528
Darbhanga	0.199	-0.083	0.193	0.104	-0.438	0.159	0.692	-0.360	-0.673
Bhagalpur	-0.602	0.748	0.770	0.305	0.136	0.359	0.278	0.233	0.733
Monghyr	-0.410	-0.464	-0.298	0.535	-0.262	-0.259	-0.926	0.166	-0.379
Saharsa	-0.282	0.245	0.284	0.144	0.335	0.057	-0.441	0.061	-0.292
Purnea	-0.217	-0210	-0.251	0.445	-0.085	-0.316	-0.333	-0.594	-0.266
Bihar Plateau									
S.Parganas	-0.134	-0.165	-0.058	0.362	0.347	0.059	0.071	0.164	-0.039
Ranchi	0.285	-0.103	-0.043	0.804	0.955	0.991	0.241	-0.428	-0.106
Palamau	-0.167	-0.069	-0.612	0.465	0.605	0.270	0.720	0.741	0.291
Hazaribagh	0.139	0.115	-0.150	-0.311	0.276	-0.163	0.092	0.377	-0.210
Dhanbad	0.482	0.148	-0.184	-0.194	0.160	-0.454	0.432	0.342	-0.437
Singhbhum	0.399	-0.144	0.035	-0.112	-0.368	-0.374	-0.341	-0.435	-0.101

APPENDIX - 27

Results of the correlation matrix
(Correlation with the yield of winter rice)
1961 to 1973

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
<u>Bihar Plain</u>									
Patna	-0.121	0.408	-0.227	-0.018	0.266	0.024	-0.957	0.087	0.144
Gaya	0.309	0.532	-0.137	-0.070	-0.092	-0.052	0.087	-0.004	-0.742
Shahabad	-0.409	0-320	-0.045	0.347	0.105	0.161	0.653	0.603	0.746
Saran	-0.001	-0.435	-0.911	-0.109	0.661	0.033	0.630	0.349	0.835
Champaran	0.422	-0.618	-0.575	0.208	0.011	-0.100	0.277	-0.128	-0.603
Muzaffarpur	-0.007	0.702	-0.589	0.049	-0.045	-0.554	0.031	-0.535	-0.838
Darbhanga	0.367	0.005	-0.134	-0.275	-0.387	-0.109	-0.095	-0.300	-0.094
Bhagalpur	0.120	-0.094	0.169	-0.181	0.135	0.892	0.040	-0. 120	0.128
Monghyr	-0.246	-0.607	0.325	0.052	-0.473	0.059	-0.587	-0.314	0.072
Saharsa	0.227	-0.076	-0.155	-0.218	-0.366	-0.110	-0.083	-0.389	0.079
Purnea	-0.269	-0.199	-0.202	0.488	-0.036	-0.362	-0.381	-0.621	-0.310
<u>Bihar Plateau</u>									
S.Parganas	0.410	0.067	-0.164	-0.177	0.009	-0.444	-0.317	-0.123	-0.390
Ranchi	0.488	-0.270	-0.158	0.177	0.336	0.404	-0.041	-0.425	-0.113
Palamau	0.160	-0.117	-0.636	0.467	0.437	-0.086	0.415	0.462	0.040
Hazaribagh	-0.078	0.394	-0.422	0.678	0.466	0.161	0.615	0.448	0.199
Dhanbad	-0.201	-0.193	0.008	0.285	0.889	-0.485	0.003	-0.025	-0.471
Singhbhum	0.387	-0.183	0.003	-0.201	-0.302	-0.322	-0.335	-0.494	0.008

APPENDIX - 18

Results of the Correlation matrix
(Cofrelation with the yield of summer rice)
1961 - 73

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Bihar Plain									
Patna	0.001	0.284	-0.180	-0.002	0.137	0.113	-0.897	0.247	0.052
Gaya	0.197	-0.154	-0.128	0.176	0.010	-0.248	0.415	-0.568	0.211
Shahabad	0.283	-0.116	0.114	-0.296	-0.164	0.036	-0.327	-0.267	-0.507
Saran	-0.186	-0.355	-0.951	-0.089	0.401	0.022	0.497	0.132	0.838
Champaran	0.182	0.197	-0.012	-0.325	-0.102	0.034	-0.346	0.237	-0.150
Muzaffarpur	-0.091	-0.332	0.034	0.314	-0.542	-0.145	-0.209	-0.425	-0.070
Darbhanga	0.373	-0.034	-0.103	-0.135	-0.376	-0.022	-0.014	-0.244	-0.099
Bhagalpur	0.565	-0.156	-0.396	-0.198	-0.356	-0.300	0.153	-0.102	0.324
Monghyr	-0.164	-0.032	-0.198	0.235	-0.007	-0.065	-0.686	0.040	0.024
Saharsa	0.374	-0.214	-0.284	-0.338	-0.470	-0.085	0.032	-0.393	0.201
Purnea	-0.050	-0.339	-0.430	0.305	-0.103	-0.278	-0.228	-0.566	-0.270
Bihar Plateau									
S.Parganas	0.449	0.023	-0.161	-0.164	-0.041	-0.436	-0.331	0.120	-0.409
Ranchi	0.320	-0.065	-0.099	0.204	0.421	0.990	0.291	-0.254	-0.100
Palamau	-0.131	0.166	-0.424	0.191	0.450	0.157	0.490	0.518	0.137
Hazaribagh	0.124	0.029	0.087	-0.109	0.410	-0.504	-0.141	0.162	0.241
Dhanbad	-0.174	-0173	0.009	0.257	0.400	-0.309	0.061	0.018	-0.251
Singhbhum	0.396	-0.186	0.109	0.039	-0.221	-0.433	-0.264	-0.292	-0.139

APPENDIX - 19

Results of the correlation matrix (A Cross-sectional analysis)

1961 - 62

	GAR (Y_1)	Aut (Y_2)	Wint. (Y_3)	Sumr. (Y_4)	Av. Yield (X5)	Aut. Yield (X_6)	Wint. Yield (X_7)	Sumr. Yield (X_8)
Canals (X_1)	-0.233	-0.188	0.177	-0.170	-0.173	0.153	0.041	-0.363
Tanks (X_2)	0.497	-0.184	0.318	-0.032	-0.029	-0.210	0.211	-0.006
W. Tubewells (X_3)	-0.356	0.224	-0.243	0.120	0.112	0.365	-0.553	-0.160
O. Sources (X_4)	-0.431	0.201	-0.293	0.183	-0.057	0.133	-0.169	0.330
RF (X_5)	0.050	-0.038	-0.196	-0.218	-0.211	-0.522	0.533	-0.381
GIA (X_6)	0.258	-0.433	0.502	-0.251	-0.240	0.048	0.231	-0.461
TIR (X_7)	-0.479	-0.056	0.240	0.167	0.168	-0.192	0.052	-0.278
UI (X_8)	-0.383	-0.337	0.456	-0.301	-0.190	-0.082	0.231	-0.231
NIA (X_9)	0.080	-0.372	0.404	-0.255	-0.250	-0.117	0.457	-0.347

APPENDIX - 20

Results of the correlation matrix (A Cross-sectional analysis)
1964 - 65

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
X_1	-0.134	-0.132	0.073	0.250	0.147	0.201	0.046	0.094
X_2	0.724	-0.300	0.333	-0.140	0.098	-0.376	0.387	0.073
X_3	-0.291	-0.038	0.057	-0.167	-0.365	0.156	-0.410	-0.425
X_4	-0.266	0.299	-0.288	0.416	0.092	0.013	0.071	0.170
X_5	0.223	0.570	-0.503	-0.010	-0.356	0.085	-0.236	-0.292
X_6	0.372	-0.390	0.445	-0.207	0.864	-0.096	0.528	0.788
X_7	-0.447	-0.390	0.440	-0.244	0.758	-0.063	0.420	0.722
X_8	-0.332	0.337	0.456	-0.220	0.831	-0.109	0.519	0.795
X_9	-0.342	-0.400	0.448	-0.196	0.876	-0.108	0.532	0.805

APPENDIX - 21

Results of the correlation matrix (A Cross-sectional analysis)
1968 - 69

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
X_1	-0.184	0.261	-0.152	0.042	-0.024	0.184	-0.209	0.018
X_2	0.557	-0.068	-0.005	-0.238	-0.106	-0.318	0.324	-0.206
X_3	-0.264	-0.033	-0.012	-0.138	-0.060	-0.074	-0.221	0. 048
X_4	-0.188	-0.262	0.155	0.481	0.341	-0.291	0.412	0.412
X_5	0.668	0.068	-0.009	-0.341	0.116	-0.158	0.173	0.109
X_6	0.351	-0.172	0.184	-0.297	-0.006	-0.331	0.125	0.018
X_7	-0.605	-0.207	0.038	0.611	0.411	-0.053	0.185	0.458
X_8	-0.516	-0.333	0.182	0.650	0.505	0.056	0.242	0.526
X_9	-0.499	-0.400	0.314	0.581	0.367	0.356	0.179	0.301

APPENDIX - 22

Results of the correlation matrix (Cross-sectional analysis)
1972 - 73)

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
X_1	-0.184	0.299	-0.347	0.427	0.243	0.275	0.278	0.240
X_2	0.745	-0.377	0.427	-0.209	0.332	0.294	-0.030	0.268
X_3	-0.148	-0.077	0.080	-0.308	-0.287	-0.277	-0.116	-0.247
X_4	-0.011	-0.172	0.186	-0.258	-0.182	-0.212	-0.100	-0.184
X_5	0.455	0.473	-0.428	-0.124	0.152	0.143	-0.254	-0.068
X_6	0.643	0.186	-0.238	0.618	-0.203	-0.158	-0.044	-0.234
X_7	-0.428	-0.352	0.286	-0.043	-0.181	-0.164	0.168	-0.145
X_8	-0.379	-0.388	0.323	-0.090	-0.226	-0.207	0.092	-0.214
X_9	-0.372	.0.275	0.197	-0.028	-0.153	-0.158	0.042	-0.203

B_I_B_L_I_O_G_R_A_P_H_Y

BOOKS

Ahmad, E. (1965), *Bihar*, (Ranchi University Press, Ranchi)

Anonymous (1960, *Rice in India*, (New Delhi, Indian Council of Agricultural Research).

Anonymous (1971), *Rice*, (New Delhi, Fertiliser Association of India).

Anonymous (1973), *Rice Economy of India*, (New Delhi, Ministry of Agriculture, Government of India).

Anonymous (1977), *Water Requirement and Irrigation Management of Crops in India*, (New Delhi, I.A.R.I. Monograph No. 4).

Baier, Worfgang (1977), *Crop-weather models and their use in Yield assessments*, W.M.O. No. 458, Geneva, World Meteorological Organisation).

Bhalla, G.S. and Alagh, Y.K. (1979), *Performance of Indian Agriculture* (A District-wise study) (New Delhi, Sterling Publishers Pvt. Ltd)

Chamber, Robert (1976), *Water management and paddy production in the dry zone of Sri Lanka*, (Colombo, A.R. and T.Ins.)

Chang, J.H. (1968), *Climate and Agriculture*, (Chicago, Aldine).

Dakshinamurthi, C.D. Michael, A.M. and Shri Mohan (1973), *Water Resources of India and their Utilisation in Agriculture* (New Delhi, I.A.R.I.).

Das, J.C. (1970), *Forecasting the Yield of principal crops in India on the basis of weather-paddy/rice* (Poona, Meteorological Office).

Farmer, B.H. (1977), Green Revolution: Technology and change in rice-growing area of Tamil Nadu and Sri Lanka, (London, Macmillion).

Goble, R.W. and Goringer, J.F. (1973), Comparing Administrative "reality worlds", A Preliminary report of the administration of rice production (New York; Asia Society Seadag).

Gamo Watte, P.(1974), Fragmentation of Paddy land (Colombo; A.R. & T. Ins.)

Gerhard, G. (1970), Rice - technical fundamentals (Bombay, Asia Publishing House).

Grist, D.H. (1965), Rice, (Longmans, Green and Co. Ltd.)

Hussain, M. (1979), Agricultural Geography, (Delhi), Inter-India Publications)

Ichikawa, S. (1974), Economic development in Asian perspective, (Tokyo, Kinokuniya Book Store Co. Ltd.)

Izumi, K. And Ranatunga, A.S. (1964), Environmental and Social Constraints on Paddy production under existing conditions: A Case Study in Hambantota District, (Colombo, Agrarian Res. & Train. Ins.).

Jackson, I.J. (1977), Climate, Water and Agriculture in the tropics (London, Longman).

Khare, M.P. (1979), 'Growth of irrigation in Maharashtra' Artha Vijnana, June, vol.21, no.2.

Mahmood, A. (1977), Statistical methods in Geographical Studies, (New Delhi, Rajesh Publications)

Mohammad, Noor, (1980), Perspective in Agricultural Geography, (New Delhi, Concept Publications), vol.IV.

Mukherjee, B.K. and Chatterjee, S.S. (1967), Review of work done on water requirement of crops in India, (new Delhi), ICAR, Tech. Bulletin no.8.

Ramdas, L.A. (1960), Crop and Weather in India, (New Delhi, ICAR).

Richaria, R.H. and Govindaswami, S. (1966), Rice of India, (Patna, Scientific Book Comp.).

Robertson, G.W. (1975), Rice and Weather, technical note no.144, (Geneva, W.M.O.).

Seizo, M. (1976), High-Yielding Rice Cultivation, University of Tokyo Press).

Sharma, P.S. (1973), Agricultural regionalisation of India, (Delhi, New heights Publishers and Distributors).

Singh, J. (1974), An Agricultural Atlas of India, A Geographical Analysis, (Kurukshetra, Vishal Publications).

Singh, R.P. and Kumar, A. (1970), Monograph of Bihar, (Patna, Bharati Bhawan).

ARTICLES :

Abraham, T.P. (1965), 'Isolation of effect of weather on productivity including other risks such as damage by pests and diseases', Journal of Indian Society of Agricultural Statistics, vo..17, no.2.

Abraham, T.P. and Rakheja, G.K. (1967), 'An Analysis of growth production of rice and wheat crops in India', Indian Journal of Agricultural Economics, vol.22, no.1.

Aiyaswamy, P.K. and Subramanian (1979), Growth rates in area, production and productivity of rice in Tamil Nadu', Agricultural Situation in India, vo..33, no..12.

Anonymous (1977), 'All India compound rate of growth of Agricultural yield during 1960-61 to 1975-76', Agricultural Situation in India, vol.31.

Bagchi, K. (1979), 'Agriculture in the drought prone areas', Geographical Review of India, vol.41,no.4.

Bhalla, G.S. (1977), 'Agricultural Growth: Role of Institution and Structural Factors', Economic and Political Weekly, vol. XII, no.45.

Chatterjee, S.B. (1969), 'Agroclimatic Approach to India's Developing Economy', inBBanerjee, B. (ed) Essays on Agricultural Geography, (Calcutta).

Chattopadhyay, R.N. and Misra, S.K. (1979), 'Towards Balance Development of Bihar - A Case Study of Inter-regional allocation of resources', Geographical Review of India, September vo..41, no.3, Calcutta1

Chowdhary, K.A. and Ghose, S .S. (1953), 'Rice in Ancient India', Science and Culture, vol.19.

Das, J.C. and Mehra, A.K. (1971), 'Forecasting the yield of principal crops in India on the basis of weather: paddy/rice (Gangetic, W.B. & Bihar)', Meteorological Monograph, Agri. met. no.1, part II, IMD, Poona.

Das, Nikhilesh (1968), Agroclimatic factors of rice production', International Geographical Congress-selected paper, vol.1.

Dastane, N.G. and Patil, V.S. (1968), 'Water needs of crops', Indian Farming, vol.17, no.10.

Dayal, P. (1969), 'The Bihar Plain - A Regional Study', Transaction, Indian Council of Geographer, I.G.J.? vol.5, December.

Dayal, R. (1965), 'Impact of rainfall on crop yield and acreage', Indian Journal of Agricultural Economics, vo..20, no.3

Desai, D.A. and Thingalaya, N.K. (1965), 'Irrigation factor and yield variability of rice growing districts in India', Indian Journal of Agricultural Economics, vol.20, no.3.

Gopinath, C. (1976), 'Problems and Concepts in Irrigation use', Seminar on Role of Irrigation in the development of India's Agriculture, The Indian Society of Agricultural Eco., Bombay.

Govind, N. (1979), 'Variations in wheat and rice responses to new technology in agriculture - A Case Study of Selected Regions of India' - An unpublished Ph.D. Thesis, (CSRD/SSS, J.N.U., New Delhi.

Malik, A.K. (1964), ' Climatology of the Crop seasons of Indian Rice', Indian Journal of Meteorology and Geo-physics, vol.15, no.4.

Panse, V.G. (1959), 'Recent trends in the yield of rice and wheat in India, 'Indian Journal of Agricultural Economics, vol.14, no.1.

Ramakrishnan, K. and Subramaniam, V. (1971), ' Rice Production in Tamil Nadu', Indian Farming, vo..11, no.7.

Rao, K.P.C. and Pandey, V.K. (1976), 'Supply response of paddy in Andhra Pradesh', Indian Journal of Agricultural Economics, vol.31,nl.2.

Rao, K.N.George, C.J. and Ramashastri, K.S. (1972), 'Agro-climatic classification of India', Meteorological Monograph, Agrimet. no.4, IMD, Poona.

Reddy, T.V. (1971), 'Rice research and extension in Andhra Pradesh', Indian Farming, vol.11, no.7.

Sadhkhan, S.K.and Sadhukhan, S. (1974), ' A Quantitative Analysis of an agro-irrigation facet of West Bengal', Geographical Review of India, vol. 36, no-3.

Shreedharan, C. Vamdevan, V.K. and Padmaja, P. (1979), 'Degree of ripening in rice as influenced by Meteorological factors', Oryza, vol.16, no.2.

Sivaraman, B. (1971), 'National Policies of Rice Research and Development', Indian Farming, vol.11 no.2.

Thakur, B. (1977), 'Spatial and Temporal variations in crop levels, Bihar', Indian Geographical Studies Research Bulletin, no.8, March.

Vachhani, M.V. (et. al. 1963), 'Crop rotation, double cropping, and cropping pattern in rice areas in India', Newletters International Rice Commission.

Yadav, D. Bajpai, D.D. and Patnaik, S.P. (1976), 'Effect of fertility levels and spacing on grain yield of rice', Indian Journal of Agronomy, vol. 21, no.4.

Yadav, J.S.P. (1972), 'Water management and Irrigation scheduling in relation to rice production', Oryza, vol.9, no.2.

REPORTS ETC.

FAO/UNESCO (1973) 'Irrigation, Drainage and Salinity', An International Source Book, Hutchinso.

Fertilizer Association of India (1975) Rice, New Delhi.

Govt. of Bihar, Planning Department, Bihar, Report of the First Five Year Plan, 1951-56, Patna.

__________ Report of the Second Five Year Plan.

__________ Report of the Third Five Year Plan .

__________ Report of the Fourth Five Year Plan.

__________ Report of the Annual Plan .

Govt. of India, Ministry of Agriculture and Irrigation, Improved rice variation for different regions of India, 1979.

__________ Ministry of Irrigation and Power, Report of the Irrigation Commission, 1972, vol. II.

__________ Ministry of Agriculture and Irrigation, Report of the National Commission on Agriculture <u>Climate and Agriculture</u>, part IV, 1976.

__________ Ministry of Agriculture and Irrigation, <u>Report of the National Commission on Agriculture</u>, 'Rainfall and cropping pattern', vol. III, Bihar, 1976.

International Rice Research Institute (1970), <u>Annual Report</u> of 1969, (Philippines).

Government of Bihar, Selected Plan on Statistics Bihar, 1976.

__________ <u>Season and Crop Report Bihar 1961-71</u>, Directorate of Statistics and Evaluation, Bihar, Patna.

__________ Statistical Hand Book, Bihar, 1961-73.

__________ <u>Bihar through figures</u>, Directorate of Statistics and Evaluation, Bihar, Patna, 1977.

__________ Report on Agricultural Census, 1970-71 Bihar.

Souvenier (1976) <u>Rice Farming</u>, Directorate of Rice Development, Patna.