INTEGRATED RURAL DEVELOPMENT WITH SPECIAL REFERENCE TO BIJNOR DISTRICT, U.P.

A THESIS

submitted in fulfilment of the requirements for the award of the degree

of

DOCTOR OF PHILOSOPHY

in

ARCHITECTURE & PLANNING

By

NALINI SINGH

DEPARTMENT OF ARCHITECTURE AND PLANNING
UNIVERSITY OF ROORKEE
ROORKEE-247 667, INDIA

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled ***"Integrated Rural Development with Special Reference to Bijnor District, U.P."*** in fulfilment of the requirement for the award of the Degree of Doctor of Philosophy submitted in the Department of Architecture and Planning of the University of Roorkee is an authentic record of my own work carried out during the period from April 1994 to December 1997 under the supervision of Professor (Dr.) Najamuddin and Dr. C.S. Raghuvanshi.

The matter embodied in this thesis has not been submitted by me for the award of any other Degree.

N.Singh

(Nalini Singh)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

C.S. Raghuvanshi 7.1.98

Dr. C.S. Raghuvanshi
Emeritus Fellow and
Formerly Professor
WRDTC,
University of Roorkee
ROORKEE

Dr. Najamuddin 7/1/98
Professor & Head
Deptt. of Architecture
& Planning
University of Roorkee
ROORKEE

Date :

The Ph.D. Viva-Voce examination of Ms. Nalini Singh, Asst. Professor was held on 6/7/98

Signature(s) of Supervisors

C.S. Raghuvanshi 6.7.98

Signature of Head of Deptt.of Architecture & Planning 6.7.98

Signagure of External Examiner 6.7.98 (Prof. R.C. Gupta)

A B S T R A C T

Integrated Rural Development involves policies and programmes for the development of rural areas with the ultimate aim of achieving a fuller utilisation of the available physical and human resources resulting in higher income and better living conditions for the rural population. It is a matter of concern to planners in India that there has been a steady decline of the share of agriculture in GNP. This has been the trend in presently industrialized countries as well but unlike them there has been only a marginal shift in the percentage of population dependent on agriculture. The result is that those engaged in the agricultural sector are on the average - less than half as well off as those in other sectors. It is imperative to think of a planning approach to evolve a methodology and to demonstrate that it is possible to increase substantially the agricultural income by optimal utilisation of land and water resources. This would result in a stimulus to the entire rural economy as additional income in the hands of the rural population will generate demand for industrial goods and other services. To sustain and accelerate economic growth it would also be necessary to provide other services and infrastructure out of which the most important is a road transport network. In view of this fact, the case study of Bijnor District has been taken up as an illustration. It is a typical agriculturally oriented district of Western U.P. with low industrial development. It has a total

land area of 4,84,800 ha with a total population of 24.55 lakhs according to 1991 census. The present study consists of the following three parts.

I. Planning to increase agricultural income by optimal use of land and water resources

II. Estimating the impact of increased agricultural production on the economy of the district

III. Demonstration of methodology for planning a Rural Road Transport Network

A brief description of each of the three follows :

I. Planning to increase agricultural income : This involves the following steps :

a) Estimation of available water resources - So far irrigation in Bijnor district has been predominantly based on ground water. The estimated annual draft comes to 115,673 ham and the monthly pumping capacity to 53,987 ham. It is assumed that 85% of this or 45,000 ham/month will be available for irrigation. A network of Eastern Ganga Canal system is being extended into the district for supply during Kharif only. Its present contribution to irrigation is small.

Estimating the ground water recharge from rainfall and increased seepage from canal system and irrigated fields, it is worked out that annually 1,66,500 ham will be available from ground water and 1,16,170 ham from canals, the latter during kharif only.

b) Selection of crops and estimation of their water requirements - After studying the existing cropping pattern, 17 crops were selected for planning purposes. The considerations kept in view were soil and climate, farmer preference, well distributed demand for water, self sufficiency in food and fodder and problems of storage and marketability. For these crops the Field Irrigation Requirement (FIR) on monthly basis was determined from pan evaporation data after making due allowance for effective rainfall.

c) Estimation of costs and benefits of the selected crops - Computation of net crop benefits involves estimation of gross production, its market price and cost of cultivation including inputs and human labour. The quantities of inputs like seeds, fertilizers etc. were taken on the basis of recommended agricultural practices. It was assumed that full water requirement will be provided to all crops and irrigation costs were taken according to the availability of tubewell and canal water. Labour costs were taken on the basis of available surveys and direct enquiry. The productivity was taken such as was being obtained in similar irrigated areas at present.

d) Optimisation of cropping pattern through linear programming model.

A linear programming model has been adopted to obtain optimum crop combination for maximum net benefit with available land and water - that is -

Objective Function

Maximise $Z = \Sigma X_i * B_i$

where, X_i is the i^{th} crop and B_i is the net benefit for that crop.

Constraints

The following constraints are obligatory.

1. Total cropped area not to exceed available area in any month.

   $\Sigma X_i * a_{it} \leq A_t$

   where a_{it} represents the fraction of month for which the crop is in the field and A_t is the total available area for cultivation.

2. Monthly water requirement not to exceed available pumping capacity plus canal water input in that month

   $\Sigma X_i * \Delta_{it} \leq W_t$

   where Δ_{it} is the monthly water requirement for the i^{th} crop and W_t is the maximum water availability in that month.

3. Annual ground water withdrawal not to exceed recharge

   $\Sigma W_{gt} \leq 1,66,500$

   Where ΣW_{gt} is the ground water pumpage during 12 months of the year.

4. Non negativity constraint

   $X_i \geq 0$

   $W_t \geq 0$

By a process of trial a crop pattern was evolved which increased the present crop benefits by 80% or a net increase of Rs. 182.7 crores. This involved no radical departure from existing farming practices or technology.

II. Estimation of the impact of increased agricultural production on the Economy of the District.

The additional agricultural production will require agricultural processing units like Dal (pulses) mills, flour and rice mills, oil expellers and cold storages etc. Their number was estimated and it is seen that they will provide regular employment to 32,400 persons.

The more intensive cropping will result in increased employment directly in the farm sector of 15 million mandays. Besides these activities there will be substantial additional employment through trade and service activities.

Besides the direct impact, there will also be a multiplier effect due to increased demand for consumer goods and services as well as social sector services. According to John Glasson the multiplier effect K is defined as

$$K = \frac{1}{1 - (c - m)(1 - t)}$$

Where C = marginal prospensity to consume

C = I - S where S is marginal capacity to save

m = marginal prospensity to import

t = marginal rate of taxation

Taking reasonable values of 20% for S, 30% for m and 5% for t, k comes to 2.10. With this factor the economic activity generated will be 2.1 x 182.7 = Rs. 383.609 crores.

III. Demonstration of methodology for planning a rural Road Transport, Net work - The most important infrastructural development for sustained economic growth is an all weather road network. Najibabad Tehsil in Bijnor district was selected for planning a most efficient rural road network.

A number of growth centres were initially identified based on their population and other attributes like education, health, P & T, market days, communications and power supply etc. The entire area was then divided into hexagons having a side of 4 km. 25 such hexagons were formed, a few of them partial. A growth centre was selected for each hexagon. The road network has to link these growth centres to each other and to the major urban centre of Najibabad. The demographic force of interaction between any two centres was calculated by the following expression.

$$F_{ij} = \frac{P_i \times P_j \times CS_i \times CS_j}{d^2_{ij}}$$

where Pi and Pj are the populations, CSi and CSj the centrality scores and dij the distance between centres i and j respectively.

A road network has been planned which keeps the total link length (total road length to be constructed) and the total route length (the total distance required to be travelled from every node to all other nodes) at a minimum or optimum level.

CONCLUSIONS

The study revealed that optimal use of resources can result in a substantial increase in rural incomes. This results in a very considerable rise in economic activity and employment. A methodology has been domonstrated to plan a rural road network for maximum efficiency at minimum cost.

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(Nalini Singh)

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CHAPTER - 1

INTRODUCTION

1.0 INTEGRATED RURAL DEVELOPMENT

The concept of Integrated Rural Development has acquired a distinct connotation in the literature. It is used to convey much more than what `community development' implies.

Anker gives the following working definition of Integrated Rural Development `Strategies, policies and a programmes for the development of rural areas and the promotion of activities carried out in such areas (agriculture, forestry, fishery, rural crafts and industries, the building of the social and economic infrastructure) with the ultimate aim of achieving a fuller utilization of available physical and human resources, and thus higher incomes and better living conditions for the rural population as a whole, particularly the rural poor, and effective participation of the latter in the development process'. The critical element in rural development is improvement of living standards of the poor through opportunities for better utilization of their physical and human resources; in the absence of this, utilization of rural resources has no functional significance. However, Sulabha Brahme clarified the Integrated Rural Development as `The Strategy of development emphasizes to begin with scientific management of resources and providing adequate work to the masses of workers in the region and in the process increases the internal potential rate of growth. It also emphasizes the retaining of growth impulses in the region through providing backward and forward linkages in the non-agricultural sector and in the region". Thus, the integrated rural development could be brought about by the maximum reliance on local resources and by a coordinated support on the part of all institutions and agencies, governmental and voluntary, working in the region.

With such a view the following elements could be identified so that all these should be considered essential aspects of Integrated Rural Development.

i) There should be an application of science, and technology for the use of natural resources,

ii) There should be a functional linkage between the use of these resources,

iii) Better use of natural resources should be socially useful and lead to full employment, and

iv) It should serve basic needs of Society, and science and technology should be geared to the production of these,

Planning in India is both Centralised and sectoral. Plans are prepared by the Planning Commission at the Centre and importance was given to prepare sectoral plans for Agriculture, Industry, Transport and Communications, Health, Education etc. Both at the State and the National levels sectoral planning has dominated all these years and very limited importance is given to spatial planning. The second Five Year Plan emphasized the need for Regional Planning. However, the concept of Balanced Regional

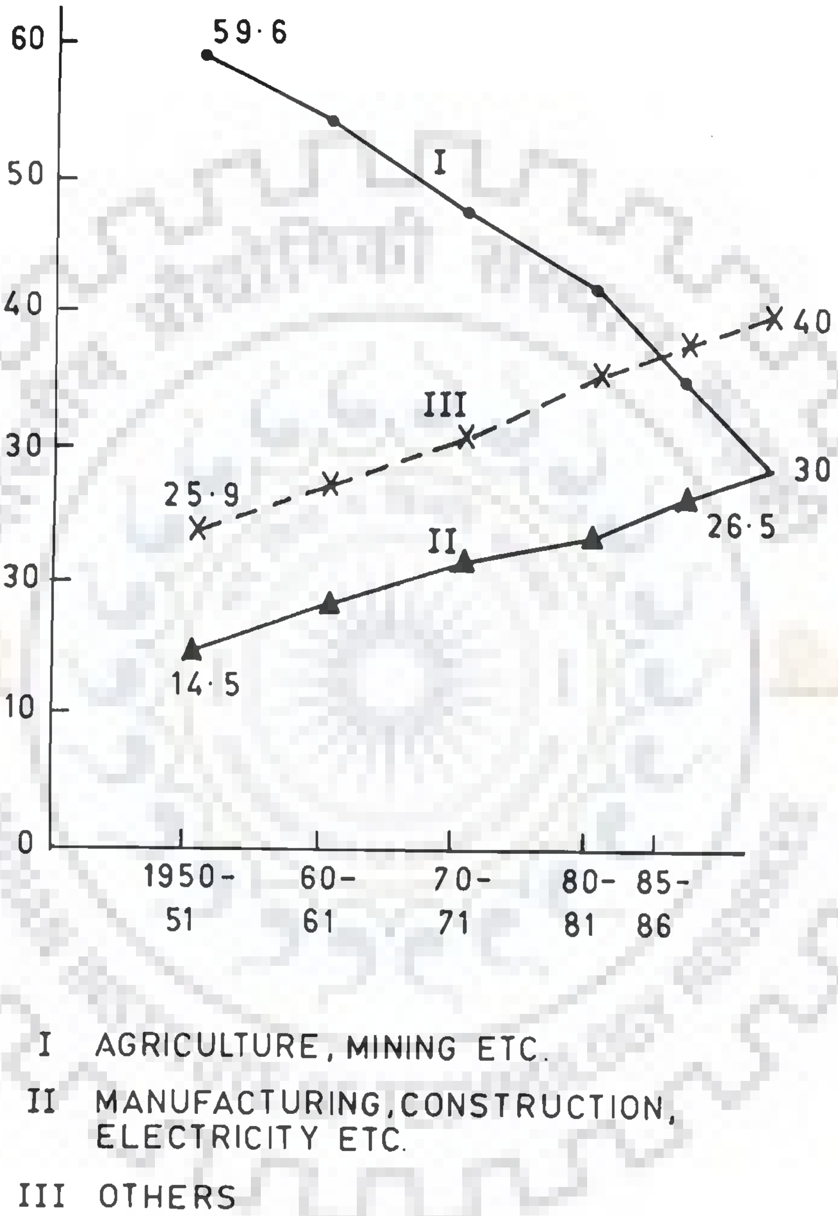
Development was suggested to reduce regional imbalances in the country and consequently, more attention was paid for the development of backward states through sectoral approach. In the Fourth Five Year Plan importance was given to the district level planning and it suggested experimental studies on growth centres. Thus, the problem was recognized but no serious attempts were made at regional levels. Except for a few case studies, no systematic attempt has been made to prepare and implement plans at the grass root level.

In a country like India, rural development is a critical element in the overall development of the economy. Various approaches and strategies of rural development have been tried over the past three decades. Some of these approaches/strategies have emphasized agricultural growth while others have stressed on developing the infrastructure. Educating the rural population has been one of the strategies of rural development. Development of the entire community has been the strategy in some others. However, all efforts for rural development have centred around increasing agricultural production. Even after knowing well the problem being faced in the rural development, the policy attempts have remained `soft' and `peripheral'. It is a well known fact that rural transformation is not possible until the land, water and energy problems are fully settled.

To achieve a higher rate of growth in the agricultural sector, it is necessary that the provision of agricultural infrastructure should be made on a vast scale - particularly irrigation, fertilisers and energy facilities for multiple cropping and improved technology, which can boost up production to achieve higher rates of long-term growth in agriculture.

1.1 Decline of Share of Agriculture in GNP.

It should be a matter of concern to the planners that there has been a steady decline of the share of agriculture in GNP (Fig. 1.1). This is a normal trend which occurs as economy develops and diversifies so that the industrial and services sectors play a more prominent role. In highly developed countries today maximum contribution is made by the service sector followed by manufacturing with agriculture far behind. Correspondingly the proportion of population directly engaged in agriculture has also sharply declined. For example the proportion is less than 5% in the USA. Due to high level of mechanisation this small fraction of the population can produce enough not only for domestic consumption but also a large surplus for export. In India, on the other hand while the share in GNP has fallen to less than 30%, the population occupied in agriculture is still about two third of the total. This means that two thirds of the country's population engaged in agriculture gets a share of less than one third of the national income - they are on the average half as well off as the minority engaged in other sectors. This should be a matter of serious concern as it can be a source of social discontent. It is imperative to think of a planning approach which would reverse this trend and improve the relative condition of the agricultural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I AGRICULTURE, MINING ETC.
II MANUFACTURING, CONSTRUCTION, ELECTRICITY ETC.
III OTHERS

FIG. 1.1

population. In view of the high population density, and large and still growing population of the country diversion of a large proportion of the population to non-agricultural sectors, as in Western countries, is not possible. Therefore, the aim has to be to increase the agricultural income through improved agriculture and associated activities within or close to the rural areas themselves. This is in accord with the vision of the father of the nation, Mahatma Gandhi. The present research work is an attempt to highlight that it could be feasible.

1.2 SCOPE OF WORK AND METHODOLOGY

The fulfilment of the objective of economic development of rural India as given above is illustrated by attempting case study of a primarily agricultural and industrially less developed district of Bijnor in U.P.

In this context, first an assessment is made of available land and water resources and existing agricultural practices in the district. A study is then carried out of the water resources which can be made available from the potential of surface and ground water resources. There is little scope for extending the net area under cultivation as the limited areas under forests and pasture land have to be maintained. But, there is scope for appreciable increase in gross cultivated area by encouraging multiple cropping on the same land. This can be done to the extent of optimal utilisation of the water resources which can be mobilised.

Another important aspect which determines income from agriculture is the cropping pattern. While it is quite true that from experience farmers know a lot about the cropping pattern which is advantageous to them, yet sometimes they continue to practice certain pattern purely from a force of habit. The Indian farmer is generally poor and rightly averse to making radical departures. At the same time if the benefit of a certain course of action is clearly demonstrated to him, he is eager to adopt it. The high yeilding varieties of wheat spread to all parts of wheat growing states within a decade from mid sixties.

Thus an optimised cropping pattern can be gradually promoted not by compulsion but by demonstration, persuation, and propagation and some inducements in power and electricity rates, land revenue etc. Based on this reasoning optimal corpping pattern for Bijnor district has been attempted and evolved through linear programming model which can increase the agricultural income by almost 80%.

The increased agricultural income will act as multiplier and result in a rapid growth of associated economic activity. More intensive agriculture will generate more employment and higher wages. Increased incomes will trigger a demand for more goods and services many of which can be provided within the district resulting in more employment and further chain reaction. Commodities which are surplus to the need of the people of the district will be sold outside and enable purchase of manufactured goods and other requirements not available in the district, from outside. Thus there would be a rapid change in economic well being and quality of life. This aspect has also been dealt with in the study.

As mentioned above the increased economic activity will have many facets like industry, housing, trading, banking, educational health, social and recreational etc. It is such a broad canvas that it would be futile to attempt to propose a planning approach for all these aspects. Some of these, in any case, are not quantifiable and will evolve gradually by themselves. However, the development of a road transport network is crucial for marketing the agricultural produce and ensuring regular farm supplies i.e. necessary inputs like fertilizers, seeds, plant and machinery. The services can also reach the rural sector only after the provision of all weather roads. Hence this aspect has been taken up for an in-depth study and detailed planning of a rural road network. In view of these facts, a methodology has been evolved for locating growth centres and linking them to each other and to a major urban centre. This approach has been demonstrated by application to Najibabad Tehshil of Bijnor District, Uttar Pradesh.

1.3 OBJECTIVE OF STUDY

The objective of the study is to evolve a procedure by which a process of self sustaining economic growth can be started in rural India. It has to start with enhancement of agricultural production and income through optimum use of land and water resources, followed by concomitant development of infrastructure, industrial activity and all round economic activity. The approach is illustrated by application to a typical district with predominantly agricultural economy. The same approach could however be used for any other district with adjustments for variation in local conditions.

C H A P T E R - 2

REVIEW OF LITERATURE

2.0 This Chapter is devoted to the available literature directly or indirectly concerned with Integrated Rural Development. For cohesiveness in presentation, the literature has been reviewed under the following heads.

1. Place of Agricultural growth in economic development
2. Impact of agricultural growth on regional development
3. Water requirement of crops
4. System engineering application to water resources problems
5. Earlier system planning and related studies
6. Rural road transport

2.1 PLACE OF AGRICULTURAL GROWTH IN ECONOMIC DEVELOPMENT

2.1.1 Gunnar Myrdal (1967) (33) made a very detailed and comprehensive study of the phenomenon of underdevelopment and poverty in his magnum opus `Asian Drama - An inquiry into the poverty of nations'. This study was published in 1967, thirty years ago. Some of `his findings have been overtaken by events and some predictions have not been exactly fulfilled. However it is still a study unmatched in depth as well as breadth and some of his views remain as valid today as they were when first published.

He stated that South Asia `Forms a third and very unfortunate category namely that of extensive landuse combined with a high man/land ratio. Naturally this constellation results in disastrously low levels of nutrition and real income. For not only is agricultural output per head of population low but almost three-fourth of the total labour force is tied up in the production of a meagre diet in which cereals usually account for two thirds of the calory intake. According to him higher agricultural output per unit of land is an essential condition for raising levels of living and for supporting industrialisation. Much of the discussion about drawing off an alleged surplus of manpower from agriculture as a precondition of economic expansion is beside the point. Even on the most optimistic assumption productive work opportunities outside the agricultural sector will not be capable of absorbing more than a small fraction of the natural increment in the population of working age in the decades immediately ahead. The so called surplus manpower must infact remain in agriculture and the foundation of economic advance must be laid by intensifying agricultural production. He further comments that "Even without radical changes in technology it should be possible to extract very much larger yields from the available land by raising the input and efficiency of the labour force". These profound observations of Myrdal form the basis of and fully justify the present study made by the author.

2.1.2 Shenoi - (1975) (48) has made a study of agricultural development in India. In the foreword the famous agricultural scientist M.s. Swaminathan states `During the coming years there is no option but to strive towards achieveing a vertical growth in our agriculture, since the scope for further horizontal expansion in area under different crops is very limited. He also stresses the relatively inefficient use of our water resources in agricultural production. Shenoi has reviewed upto the date of his publication all aspects and deficiencies of agricultural production in India including infrastructure, inputs and strategy for production.

2.1.3 Robert Chamberts - (1983) (11) made a study of rural development in India and other poor countries which show deep insight into the lack of preception of the administrators and investigators into the lives of the poor and the causes of their poverty. He brings out the unpalatable truth that `the outrage is not just that avoidable deprivation suffering and death are intolerable, it is also that these co-exist with affluence' Chambers quotes from Wartman and Cummings the following pertinent paragraph `while the food poverty - population problem is massive and complex and will be extremely difficult and time consuming to resolve the existence of new capabilities provides a magnificient opportunity, perhaps a fleeting one to deal with it effectively if governments have the wisdom and the will to act.

Chambers has discussed the dichotomy between the views of the political economist and the physical scientist as to the importance of factors sustaining rural poverty. The former lay greater emphasis on social and economic factors which maintain deprivation and inequality while the latter stress the physical factors on their lack resulting in low productivity and poverty.

He points out that infact a holistic view is required and progress achieved on all fronts if a dent is to be made in the entrenched poverty of the masses.

2.1.4 Ajit Kumar Singh - 1987 (50) made a specific study with respect to the agricultural development and rural poverty in Uttar Pradesh. He has attempted to analyse the developments till date in the agricultural sector and in poverty levels of the state which is one of the more backward states in the country. He draws attention to the high degree of stability in land utilisation and continuous decline in gross cropped area per capita of rural population because of rapid population growth. The cropping pattern remains dominated by food grain crops though within these there has been a rapid expansion in the area under wheat. He points out the rapid growth in irrigated area during the period of study which has played a critical role in the agricultural transformation in the state.

2.1.5 P. Krishna Babu (1988) (47) made a study of Regional Planning in India illustrating his approach by applying it to Konasheena region of East Godavari District in Andhra Pradesh. His study shows that the incomes in agriculture can be almost doubled with the use of best available technology in the region and judicious use of water. The employment of human labour in agriculture can be increased by about 30% thus making a significant contribution to resolving the problem of unemployment in villages. His study indicates an increase of about 20% in credit needs but only about 5% in demand for fertilizers.

The results of the present study are also similar with respect to increase in agricultural production and generation of employment. If this approach could be implemented throughout the country there would be indeed a rapid improvement in the quality of life of the rural poor.

2.1.6. Sukhmoy Chakravarty (1989) (9) has stated that India had to initiate agrarian industrial and demographic translitions symultaneously. According to him the historical experience of the presently industrialised countries as well as the newly industrializing countries in Asia such as South Korea and Taiwan shows that the process of structural transformation depends essentially on two factors. One is the sequence and speed with which the above mentioned transitions take place. The other is the extent of changes in the occupational structure of the population corresponding to the changes in the structure of production. He draws attention to the fact that while the share of agriculture in total GDP declined from 47% in 1965 to 30% in 1987 the share of labour force declined only marginally from 73% to 70% during the same period.

2.1.7 S.D. Sawant and C.V. Achuthan - (1995) (45) express their views on Agricultural growth as follows-sustained growth in agricultural production and productivity is essential for overall stability of the Indian economy. But that is not enough. The aggregate growth rate in agriculture has remained fairly stable and unchanged in the first two decades of post green revalution. What is really required at present stage of development of Indian agriculture is to step up agricultural growth over and above the rate already achieved in the past. An accelerated growth in agricultural production would not only contain widenning rural urban income disparity but also help in achieving a higher reduction in rural poverty.

Analysis of India's agricultural growth and crops and regions in the post green revolution period unfolds interesting dimensions of the new trends and patterns that emerged in the 1980s. One thing is clear that there must be an upsurge, a significant one, in the growth of aggregate production and productivity in Indian agriculture and it cannot be attributed to merely favourable weather. The fact that the role played by yield improvement in inducing higher output growth has been far more important than that of expansion in area indicates that the process of growth has been technologically more dynamic too.

2.1.8 Svendsen and Gulati - (1995) (55) bring out a rather disturbing feature about investment in the agricultural sector. According to the authors the real investments in irrigation on public account have been declining at the rate of 1.73% per annum since the beginning of the sixth five year plan. This declining tendency is a cause of concern because it is leading to a slow down in the expansion of irrigation base of the Indian agricultural sector. Without a corresponding slow down in population expansion we could be in trouble in the years ahead.

2.1.9 V.M. Rao (1996) (42) comprehensively reviews the development of Indian agriculture over the past few decades. According to him the following factors are critical in determining the impact of growth process on the poor. First the long term growth rate needs to be high and remain steady over time otherwise they may not consider it worthwhile to make serious efforts to participate in the growth process. Second, when growth is broad based and is spread widely over areas and crops not only would its accessibility to the poor be easy but, more important even the relatively lazy and passive among the poor would find income augmenting opportunities within their own familiar neighbourhoods. Third, labour absorbing growth would obviously have a greater impact on the poor than when growth needs only a small number of highly skilled workers.

Assessing the so called trickle down effect he states that while it brings some relief to the poor the rate and spread of growth observed so far is unlikely to have raised the large number of poor in the economy to a status of sustained viability above the poverty line. So long the growth scenario continues to be what it has been so far the poor are likely to remain poor, infact more are likely to join the ranks. Over the planning decades the differential between the per capita GDP in agriculture and that in non agriculture has markedly widened from 2.19 in 1950-51 to 2.69 in 1960-61, 3.46 in 197071, and 3.74 in 1980-81 and as high as 4.20 in 1990-91.

2.1.10 **M.V. Nadkarni (1996) (34)** has made a study of commercialisation of agriculture in India. As an indication of this trend he presents the data of changing crop pattern and growing diversification reproduced in table 2.1. It is seen that the proportion of area under foodgrains declined during 30 years from 1950-51 to 1980-81 by only 2.8 percentage points but within the following decade by 5 percent points. There was a corresponding increase in the proportion of area under non-food grain crops.

Concerning employment and quality of life Nadkarni quotes a study by Chadha which concludes as follows `As one moves from a backward agricultural economy to an agriculturaly developed economy not only do total man days of employment generally increase but even the net yearly earnings and therefore per day earnings improve considerably. The gains of agricultural development thus percolate down to the weaker sections in terms of higher annual earnings. The trickle down effect however becomes far more pervasive where the economy expands beyond agricultural development. Further, it is thus abundantly clear that a highly developed agriculture does have a decisive effect on rural poverty, the percolation mechanism is unassailably at work.

2.1.11 S.N. Misra (1997) (32) discuss the strategy of agricultural liberalisation and development in Ninth Plan. According to him the agrarian institutional form which is more conducive to maximisation of agricultural output growth and

Table : 2.1 Changes in Cropping Pattern, All India
(As percentage to total gross cropped area)

Crops	1950-51	1960-61	1970-71	1980-81	1990-91	1991-92
Rice	23.6	22.3	22.6	23.3	23.0	23.3
Wheat	7.6	8.5	11.0	12.8	12.9	12.8
Coarse creals	30.0	29.4	27.8	24.6	19.5	18.6
Total creals	61.1	60.2	61.4	60.7	55.4	54.7
Total pulses	15.6	15.5	14.0	13.2	13.5	12.5
Total foodgrains	76.7	75.7	75.4	73.9	68.9	67.2
Sugarcane	1.3	1.6	1.6	1.6	2.0	2.2
Condiments and spices	0.9	1.0	1.1	1.2	1.3	1.3
Fruits	0.6	0.7	0.9	1.1	1.4	1.5
Potatoes	0.1	0.2	0.3	0.4	0.5	0.6
Onions	0.1	0.1	0.1	0.1	0.2	0.2
Total vegetable	1.2	1.0	1.3	1.7	4.5	4.7
Total oilseeds	8.3	8.3	8.9	9.2	13.5	14.9
Cotton	4.3	5.0	4.7	4.5	4.1	4.2
Jute	0.4	0.4	0.4	0.5	0.4	0.5
Total fibres	5.1	5.7	5.5	5.4	4.7	4.8
Tobacco	0.3	0.3	0.2	0.3	0.2	0.3
Other crops	5.6	5.7	5.1	5.6	5.8	5.5
Total non foodgrains	23.3	24.3	24.6	26.1	31.1	32.8
Total gross	100	100	100	100	100	100
Cropped area in mil ha	131.9	152.8	165.8	173.1	185.9	182.7

employment remains the peasant proprietorship system as at present. For the same reason national food security and food scurity for the poor are better ensured under this system. It provides for comparatively better distribution of assets (Land and capital) and income from agriculture. Whereas ceilings on land ownership continue there ought to be no restriction on the size of operational holding. A free land lease market will also to some extent take care of the unviable holdings. The reformed tenancy legislations should have however, strict safety provisions for ownership rights so that there is no apprehension of loss of land due to leasing by owner of such holdings.

He considers that with the kind of institutional base envisaged by him an average growth rate of 4 to 4.5 percent of agricultural GDP seems to be quite feasible, provided necessary investment for agriculture takes place during the ninth plan and thereafter. An efficiency of capital use in agriculure is constantly improved.

2.2. IMPACT OF AGRICULTURAL GROWTH ON REGIONAL DEVELOPMENT

2.2.1 John Glasson - 1975 (20) In his valuable book on regional planning Glasson discusses the conceptual basis of regional planning. He goes on to analyse intra-regional and inter regional aspects including the spatial structure of regions and growth pole threory and central place theory. In a final section he illustrates his concept with the example of United Kingdom.

According to him major features of general planning include a sequence of actions which are designed to solve problems in the future. The planning problems vary but tend to be primarily economic and social, the planning period, the true horizon of the future also varies according to the type and level of planning, but all planning involves a sequential process which can be conceptualised into a number of stages.

He points out a fundamental distinction between physical planning and `Economic Planning'. Physical planning is the planning of an areas physical structure land use, communications, utilities and so on and has its origins in the regulation and control of town development which outstripped the ability of the market mechanism to cope. Economic planning is concerned more with the economic structure of an area and its over all level of prosperity. It works more through the market mechanism than physical planning, which relies heavily on direct controls.

2.2.2 L. Malassis - (1975) (30) discusses in detail the place of agriculture in the development process. According to him agriculture is the most important economic sector in the less developed countries and it is usually called upon to play a fundamental role in the overall socio-economic development process. The concept of integrated agricultural development means viewing agriculture not as a separate sector but rather as a branch of the economy completely integrated into the development process and contributing to the fulfilment of the objectives which society as a whole has set itself.

Agriculture and the overall economy, rural society and society as a whole are bound together by ties of interdependence. In certain circumstances agricultural growth helps set in motion overall economic growth, but since such growth causes an increase in the number of non agricultural jobs and in the demand for food stuffs as well as the production of agricultural implements, agriculture itself undergoes transformation.

In a particularly valueable chapter the author analyses the role of agricltural in bringing about development. According to him one can aim at balanced growth or unbalanced growth. Balanced growth depends on harmonized development of the different sectors of the economy and recognises that investment in infrastructure, productive investment and social investment are complementary.

According to many eminent thinkers the theory of balanced growth is unrealistic and from the point of view of investment policy impracticable. The different economic sectors do not all develop at the same rate or at the same time. There are `Leading Sectors' which play a major role during the take off period and at the different stages of development. Agriculture and the iron and steel and textile industries played a decisive part in the economic take off of the United Kingdom and France, as did the railways in the United States, Canada and Germany, wood and woodpulp in Sweden, armaments in Japan, dairy produce and meat in Denmark. At other stages of development the automobile chemical, electronics and other industries have all helped to stimulate overall development. Thus idea of key or leading industries involves historical and geographical considerations alike.

According to the author experience has shown that if agriculture is neglected it cannot fulfil the economic functions falling within its scope, and reduction or paralysis of overall growth may ensue.

2.3 WATER REQUIREMENT OF CROPS

The determination of water requirement of crops is an important aspect of crop planning with given land and water resources. There is a large mass of literature on the determination of water requirement of crops to meet the evapotranspiration demand of plant and its metabolic activities. Some of the important reference in this field are - Dastane - (1972) (15), Israelson and Hansen - (1950) (34), A.M. Michael - (1978) (31) The Water Management Manual (1985) (56) and `A Guide for Estimating Irrigation Water Requirement' Government of India, (1985) (2). Penman (1956) (37) evolved a method of estimating evapotranspiration from climatic factors, a modification of his approach has been adopted by FAO and Government of India (18).

A detailed review and discussion of this aspect has not been included as it is primarily in the scope of irrigation engineering and agricultural science. Regional planner needs to choose the most appropriate approach available for his area. Pan evaporation method with appropriate crop coefficients as taken from the concerned references has been used in computing the water requirement of selected crops.

2.4 SYSTEM ENGINEERING APPLICATION TO WATER RESOURCE PROBLEMS

Hall and Dracup - (1970) (22) have provided both the theoretical background and practical methodology for the application of systems Engineering methodology to Water Resources problems. They describe the scope and utility of Systems Engineering as follows.

`Treating the complex problem, the multiplicity of goals and alternatives and the very real possibility of having only one chance at developing the best course of action requires a logical procedure, which can rationally eliminate alternatives, reduce thousands of decisions to a relatively few, on the basis of rather formidable mass of information in various stages of scientific interpretation. Systems Engineering including both the art and science, offers practical possibilities for providing the necessary retionality, if not in toto, then atleast with respect to important substantial part of the water resources problem'.

The authors caution against the use of this powerful tool by those not well versed in the physical aspects of the phenomenon in hand in the following of words.

`Systems analysis is a very powerful tool capable of dealing with large scale problems involving millions of people and billions of dollars. It can lead to decisions which may prove to be quite irreversible in an economic and social sense. As such, systems analysis is a very dangerous tool in the hands of those lacking full understanding of the water resources systems and the multiplicity of objectives. It would seem axiomatic that water resources systems engineering should be practiced by the most competant professional water resources engineers assisted by competant experts in operations research rather than vice versa.

The concept of a best decision set or policy implies criteria where by the effect of any feasible policy on the desirable and undersirable outputs can be gauged. This criterion is called the objective. The `objective function' is any statement by which the consequences of the system can be determined given the policy, the initial values of the state variable, and the system parameters. However, usage has generally limited the term to the determination of those quantitative objectives which are fully comensurate.

There are a number of procedures for solving problems in systems analysis and optimisation. Out of these for several types of problems linear programming provides the most convenient and useful approach.

In many problems where costs or gains are to be optimised the objective function and the constraints take a particularly simple form. These problems involve decisions such as the selection of a particular number of units of a commodity at a fixed cost or profit per unit. The objective function is thus a simple linear algebraic equation.

If the constraints also can be expressed as linear algebraic equations or inequalities involving nonegative decision variables the result is a particular type of optimisation, problem known as `linear programming. Stated in general terms this is to maximise'.

$$V(X_1 \ldots Xn) = C1\ X1 + C_2\ X_2 \ldots\ldots CnXn = V$$

subject to

$$g_1\ (X1 \ldots.)\ Xn = a_{11}\ X_1 + a_{12}\ X_2 + \ldots\ a_{2n}\ X_n \leq b_1$$

$$g_2\ (X1 \ldots.\ Xn) = a_{21}\ X_1 + a_{22}\ X_2 + \ldots.\ a_{2n}\ Xn \leq b_2$$

$$g_m\ (X1, \ldots..Xn) = aml\ X1 + am_2\ X_2 + \ldots.\ a_{mn}\ X_n \leq b_m$$

The above equations state the general linear programming problem. Where the number of variables is small a solution can be found by hand calculations but normally it is necessary to use a digital computer. Standard programme packages are now available for solution of linear programming problems.

2.5 EARLIER SYSTEM PLANNING AND RELATED STUDIES

2.5.1 Extensive Studies were carried out on all aspects of optimum utilisation of water and crop planning in Gomti Kalyani Doab under Water Resources Development Centre in Roorkee during the 1970's. The results of the studies have been published in a series of reports by Sarbeswar Das (1974) (14), Yoganarasimhan et al (1981) (59) Ford Foundation Research Group (1982) (21), (1982) (13). In reports by Sabeswar Das and Yoganarsimahan the Water requirements of different crops have been worked out on basis of pan evaporation data using crop co-efficients as recommended by the Ministry of Agriculture, Government of India. Detailed calculations have been shown for the cost of cultivation of each of the selected crops. The costs of inputs include those of human and animal labour, seeds, fertilizers, plant protection, special operations where needed and of irrigation water. These costs were based not only on available data at that time but also on extensive field studies. They thus provide a valuable data base for working out the cost of cultivation after making due adjustments for changes with time and location. Similarly these studies include the gross and net benefits from each crop at the rates prevailing at that time. For Bijnor district the average productivity of crops grown there has also been given in the statistical handbook of the district published in June 1993 (53).

2.5.2 Raghuvanshi and Samal - (1983) (39) have carried out a study on the impact of irrigation on farm income and employment on Salawa distribsutory of Upper Ganga Canal in Meerut district. The methodology consisted of selecting three villages each in head, middle and tail reaches of Debthwa distributary which takes off from Salawa Distributary. Data was collected from selected farm households in these villages including cropping pattern, invesment in capital assets and labour utilization. Valuable information is given about the input output ratio and profitability of important irrigated crops.

Input output analysis revealed that irrigated sugar cane, berseem and wheat gave the best income per hectare. In comparison unirrigated crops earned a much lower net income.

2.5.3 Another paper by **Paul, Raghuvanshi and Chauhan (1988) (35)** analyses socio - economic impact of irrigation on cropping pattern , productivity and resource use efficiency using data from Saharanpur District of Western U.P. The methodology adopted is similar to that used in the previous study on the Dubatwa distributary. The study reveals that irrigation has brought about significant changes in cropping pattern with a sharp increase in sugarcane area. Further during the last two decades there has been a sharp increase in tubewell irrigation and correspondingly a proportionate decrease in canal irrigation. The yield of the three major crops namely sugarcane, wheat and paddy has grown significantly during this period. This has resulted in increase of net income to the farmers and input output ratio. An important finding is that additional employment has been generated to the extent of thirty labour days per hectare directly on the farm.

2.5.4 Numerous studies have been carried out in India, USA and other countries using the methodology of linear programming to optimize cropping pattern, land and water use. **Asit K Biswas (1984)** (7) discusses the use of systems analysis for water management in developing countries. According to him though the use of systems analysis and the application of computer technology for water resources development and management processes have increased significantly in many developed countries the progress in developing countries leaves much to be desired. He advocates greater utilization of these techniques in developing countries.

2.5.5 **Avdhesh Chandra et al (1988)** (12) discuss the relationship of pan evaporation with meteorological parameters. They propose statistically derived equations between panevaporation and air temperature, relative humidity, wind, velocity and the number of bright sunshine hours. These equations can be useful where direct pan evaporation measurements are not available but there is a record of meteorological factors.

2.5.6 **Bari and Gidley (1988)** (5) discuss the problem of the gap between theory and application of mathematical optimization methods. Their study suggests a complete algorithmic frame work for unifying two seemingly unrelated ideas. The generation of many solutions to obtain a reasonable coverage of range of choice in decision space and the selection of only a few but most diverse solutions dicarding the redundant and hence the uninteresting ones.

2.5.7 **Akhanda and Sale - (1989)** (3) have applied a linear programming model to maximize command area and yield of Teesta Barrage project. Results of the model application reveal that for optimal command area and yield, crop staggering with early transplantation should be adopted. The model also predicts the critical periods of irrigation development when the demand for irrigation water matches flow from Teesta river. More land could be brought under irrigation by providing additional water during these critical periods.

2.5.8 Acharya et al (1990) (7) have reported a study on optimal conjunctive use planning in Mahi command area. A static deterministic linear programming model having constraints of crop water requirement, land, water availability from various sources, seasonal water availability, and restriction of total water withdrawal from a given source in a particular season was adopted for the study. The study identified three crops namely maize, wheat and sorghum for optimal crop planning. As suggested by the model output a net annual return of Rs. 4010/- per hectare can be obtained by adoption of optimal cropping plan. A cropping intensity of 285% could be obtained.

2.5.9 Dhawan (1990) (17) discusses the role of cropping pattern in irrigation planning. According to him if we wish to acertain the crop pattern likely to emerge in a new command area, the simplest guide is the existing crop pattern on irrigated lands in similar agro - climatic commands. He states that too much importance need not be given to advance crop planning as such forecastes may differ substantially from the actual crop pattern that finally emerges. He advocates free choice of the farmer in choosing cropping pattern and suplementing canal water supply from his own pumped wells if he finds it beneficial.

2.5.10 Senapati (1991) (47) reports a case study of optimal crop planning for a distributary of Kendra Para canal system in Orissa. He has selected a crop combination of eighteen crops and with the available water and land constraints, he has shown a possibility of achieveing 286% cropping intensity and a net return Rs. 1594/- per hectare.

2.5.11 **Pawar et al (1992) (36)** have made a study on crop sequencing under constraints of irrigation water. The study on water requirement with varying crop sequences was under taken during the period 1984-85 to 1986-87. On basis of monetary returns and under optimum moisture condition the study revealed that the growing of groundnut during Kharif season with sub optimum irrigation followed by sorghum with optimum irrigation during rabi season gave maximum monetary return of Rs. 2268/- per hectare. It involved two irrigations for groundnut during Kharif season followed by sorghum with three irrigations. The water requirement for this sequencing was 697 mm.

2.5.12 **Morales et al - (1992) (26)** present a simulation model for conjunctive use of irrigation water from a single multipurpose reservoir and an aquifer and the allocation of cropped areas within an irrigation district. The model considers cropping patterns, profits for the farmers in the irrigation district, monthly reservoir and aquifer operating schedules for a one year planning horizon, and hydro power generation.

The model yielded the annual profit, the total requirement of water, fertiliser, pesticide, seed, equipment and labour, the monthly schedule of reservoir releases and aquifer withdrawls that satisfy the water reqauirement of cropped areas, and the amount of hydro power generated by reservoir releases. Solutions to the model allowed an evaluation of the effects of annual inflows on profits, and provided an indication of the levels of inflow that can be used for planning the operation of the district.

2.5.13 Javaid Afzal et al (1992) (25) developed a linear programming model to optimize the use of different quality waters by alternative irrigations rather than by blending. In a situation of poor quality ground water and limited good quality canal water, the model decides how much land to put under each crop and how much ground water to abstract and apply to each crop in each time period. The model increases the area under cultivation while maximising the net returns.

2.5.14 Bahauddin and Hussain - (1995) (6) report a case study of optimal surface irrigation under conditions of limited water supply in Sri Ram Sagar project. They conclude that under condition of limited water supply irrigation must be given during critical stages of crop growth. They find both kharif and rabi paddy to be unrewarding as their productivity per unit of water is comparatively low and senisitivity to short supplies is high. They have selected eight other crops which have smaller water consumption and carried out studies with water availability of 60% to 90% at the project head. Thus the cropping pattern can be adjusted to the available storage in the reservoir.

2.5.15 Sarma (1996) (43) discusses the problems involving integrated development of irrigated agriculture. He draws attention to the fact that lack of co-ordination between the various agencies concerned in irrigation and agriculture inhibited optimization of yields on irrigated lands. This was sought to be remedied by setting up Command Area Development

Agencies and Water and Land Management Institutes, in the states. In his opinion though these organizations have been in position for over two decades in most parts of the country the desired results have not been obtained. He recommends that serious thought be given to this problem to minimize the gap between potential created and area irrigated, maxmizing productivity per unit of water and optimizing utilization of the large capital invested on irrigation so far and to be invested in future. Though he records the findings that there is hardly any additional benefit to show in CADA areas as compared to non-CADA areas he has not made any concrete suggestions to improve the situation.

2.5.16 Sinha (1996) (49) discusses the physical problem resulting in poor agricultural and economic growth in Bihar and highlights the necessity of effective and integrated development and utilization of Bihar`s water resources. The state of Bihar suffers from both the occurrence of floods,the incidence of drought. This paradoxical syndrome has been analysed region-wise and compared to the all India situation Bihar has a lower cropping intensity and lower yields than other north Indian states and consequently continues to be the poorest state in India. The author finds that more productive agriculture is imperative for the economic emancipation and prosperity of Bihar. In the prevailing conditions, irrigation is a necessity for realising this goal. Adequate surface and ground water resources are available for the purpose.

2.5.17 Perreira et al (1996) (38) discuss sustainability of Irrigated agriculture particularly in European context. Sustainable Development meets the needs of the present population without compromising the ability of future generations to meet their needs. The present 5.3 billion world population is projected to increase to 9 billion over the next forty years. Correspondingly world food production must more than double in the next few decades. Fortunately there is potential for doing so. Actual cereal yield in the developed countries is now 4 tonnes/ha. while in developing countries it is only 2.3 tonnes/ha. Irrigated land accounts for 18% of cultivated land but produces 33% of world food supplies. Thus to meet the expanding food demand there is need for increasing the average yields and for expanding irrigated area.

The authors emphasize the need for research on sustainability of irrigated agriculture. They suggest that the environmental approaches should not be external but integrated with technologies methodologies and tools, required for irrigated agriculture and the sustainable use of water resources in agriculture.

2.6 REVIEW OF LITERATURE ON RURAL ROAD TRANSPORT

Several authors have brought out the importance of providing a Rural Road network in economic development. Among these may be mentioned Prof. A.S. Ashby as quoted by Shenoi (1975) (48) Levy et al (1981) (28), Robert Chambers (1983) (11), Chakrovarty (1989) (10) Sarna (1989) (44) and Francisco and Routray (1992)

(19). Their views have been quoted later in Chapter 8 pertaining to methodology for development of a Rural Road Network. They justify the importance given to the planning of Rural Road Network for Bijnor district as a part of its integrated development.

2.6.1 Considerable work has been done on devising approaches to planning of Rural Roads. **Swaminathan et al 1981 (54)** present an approach based on systems engineering toward a systematic development of a Rural Road Network. A scientific approach borrowed from `Graph Thery' has been proposed for preparation of Master Plan for rural roads at the district or block levels. In the proposed methodology flow of traffic in a rural road network has been considered analogous to the flow of current in an electric circuit. The entire road transportation system can be divided into four parts namely (1) market centres attracting traffic from various villages (ii) main roads inter connecting the market centres, (iii) villages of various population levels generating traffic to and from the market centres, and (iv) village roads interconnecting the various villages and providing connection to the nearest market centre.

Market centres are considered as high intensity concentrated electric charges and main roads as cables with high intensity current flowing through them. Villages are also considered as small concentrated charges. The final optimized rural road network can then be generated by the concept of `Minimal Spanning Trees' borrowed from Graph theory. The authors developed and described a stepwise proceedure for generating these minimal spanning trees.

2.6.2 Mahendru et al (1983) (24) rightly point out that in planning rural road networks at micro level where decision has to be taken to link individual settlements, conventional transportation planning process based on travel demand will require enormous travel data for all settlements which would be impractical. In any case even if travel data could be collected and origin destination matrix formed in most cases the intensity of trips would be so low that it would be hardly possible to justify any road link on this basis.Rural road network planning requries a different approach.

The authors suggest a different and new approach which enables the planner to generate, analyse and evaluate alternative rural road link-age patterns. A set of options is ,then available to the decision making authority with full analysis amd evaluations to facilitate the final selection for implementation. Concepts of settlement inter actions, demographic force of inter action,link effieiency , route efficiency and network efficiency have been developed and used to generate, analyse and evaluate alternative rural road link age patterns. The methodololgy developed has been illustrated by application to Behat Block in Distric Saharanpur of U.P.

In this approach using developoment goals and objectives a series of alternative linkage patterns can be developed. Simple evaluation methodology using network parameters has been devised which enables comparison between alteranatives in a simple manner without necessitating collection of massive traffic data.

2.6.3 **Kumar and Tilotson (1989) (27)** present a planning methodology for rural roads underIndian conditons. This methoadology aims at generating a basic rural road network in which each village finds a road connection for a bigger centre of activities. For identifying the best network among alternatives optimisations is done by minimising the total cost or the investments for a given level of effectiveness. For this purpose an iterative process has been developed which star ting from any network, connecting all villages reduces the objective function to a minimum, by making changes in the links of the starting network. The whole methodology is computer based to extend its utility and application. The data requrements can be partly met from published census record and maps but do include assessment of construction cost and travel cost along the various links.

2.6.4 **Srinivasan and Mahesh Chand (1987) (51)** argue that in order to derive full benefits of investment to be made in rural road development it becomes essential to adopt a scientific method of selection of villages to be linked rather than adopting the criterion of population alone. Village links need to be selected in such a way that the costs are minimised and the benefits maximised.

The authors have defined a transport priority index for village selection. Three alternative methods of TPI have been used and compared. The rating method used by them is similar to the one adopted by the author in the present thesis. In selecting multiple links for villages a concept of Village Affinity Index (VAI) has been used. Their approach involves a study of traffic intensity on the existing road network. The methodology developed has been illustrated for Malappuram District in Kerala.

2.6.5 Srinivasan et al (1990) (52) in a subsequent paper describe a planning study of the rural road network in Palghat district of Kerala. A methodology, that could be useful in similar situations for the purpose of planning improvement and strengthening of existing road network is given.

The studies reviewed have some relevance for the present study. However, all the reviewed studies have focussed only one aspect of agricultural growth, cropping pattern etc.

These have either considered the place of agriculture in economic development or impact of agricultural growth in a localised manner, while the present study attemted to incorporate all these aspects. The study covered not only the infrastructure in its totality but also gauged reactions to multiplier effect and emerging needs and mounting pressure of population explosion.

This aspect was not hitherto attempted in a technology dynamic context like the present one because the reviewed studies generally considered one aspect in isolation of the other.

CHAPTER - 3

DESCRIPTION OF THE STUDY AREA

3.0 LOCATION

District Bijnor is situated on the left bank of River Ganga in Moradabad division of U.P., between 29° 2` and 29° 5`, north latitude and 78° 59' and 78° 6' east longitude. To the north east of the district is the hill region of Garhwal. In the east the Phika river for the greater part of its course constitutes the boundary separating the district from Nainital and Moradabad. Besides Ganga on its western boundary, other rivers crossing the district are Ram Ganga, Khoh, Malin, Gangan and a few other smaller streams (Fig. 3.1).

3.1 HISTORY

According to legend Bijnor was founded by the Raja Ben who is supposed to have ruled this area during the days of Mahabharat. Some mounds near Binjor are named after it. These have, however, not been explored so far. There is some conjecture that the Kingdom of Motipulo mentioned by Hwen Tsang was in this region. Along with the rest of India the region came under Muslim rule in early 14th century. The Moguls tried to wrest this region from the Afghans but did not achieve full success. In the early eighteenth century the Nawab of Sambhal who controlled this area became quite powerful. The Nawab took part in the 1857 rebellion but was defeated by the English forces. This was accomplished by a force formed at Roorkee under the command of Brigadier Jones who marched through Rihelkhand to

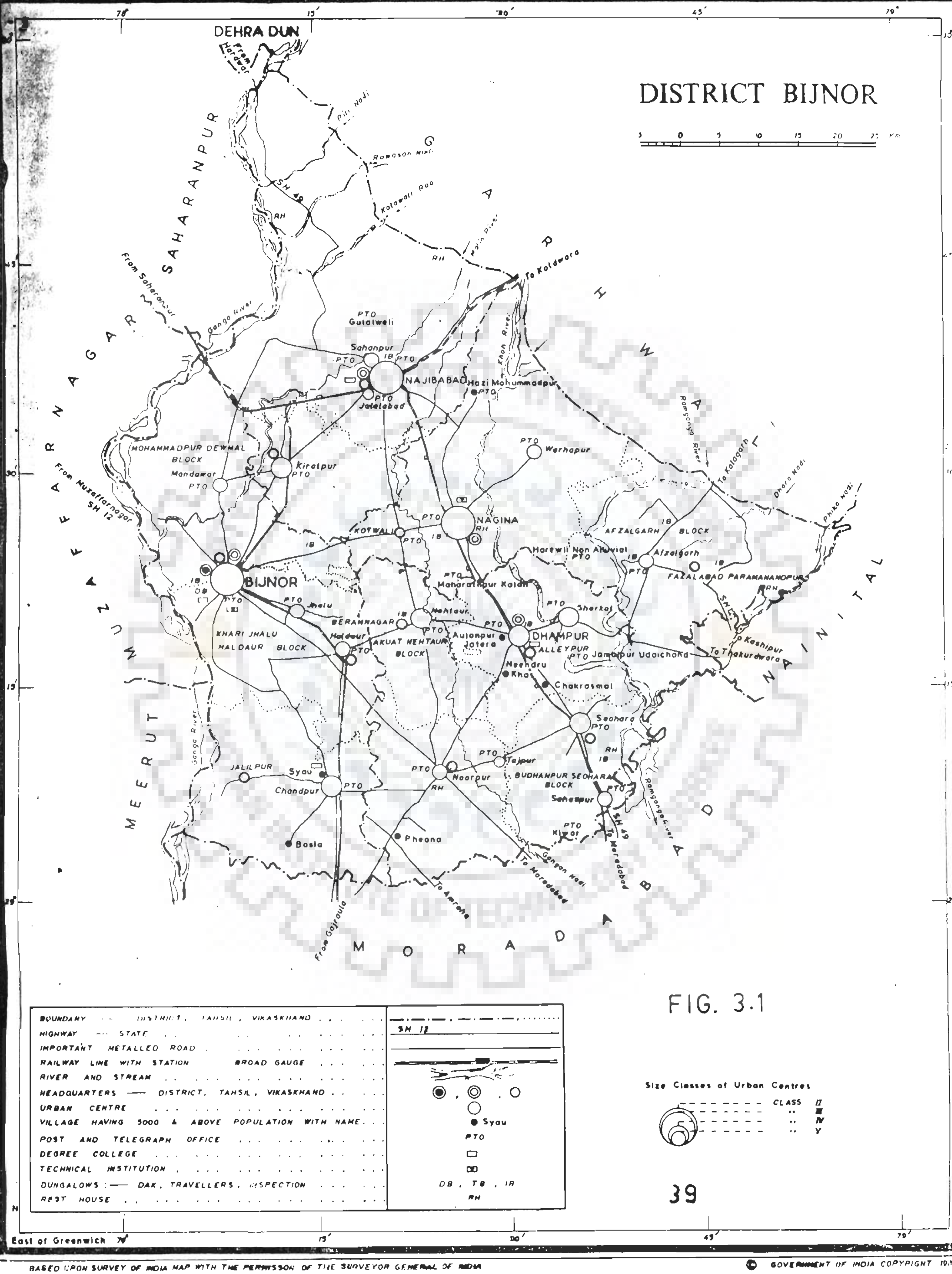


FIG. 3.1

BASED UPON SURVEY OF INDIA MAP WITH THE PERMISSON OF THE SURVEYOR GENERAL OF INDIA

Bareilly. Under British rule Bijnor was formed as a District headquater.

3.2. TOPOGRAPHY AND CLIMATE

Bijnor has fairly diverse physical aspects but by far the larger portion of the district is open and is intensively cultivated country. The surface is broken by several rivers and their tributaries. The level country with riverine depressions extends northwards to a broad belt of forest area. The forest forms a fringe along north eastern border and where the district narrows to its northern apex, the forest occupies the entire breadth. In the extreme north one can see the extension of Shivalik chain while towards the east Bhabar characteristics are present. As a whole the northern belt is moist and fertile with luxuriant growth of small trees, shrubs and grasses. At the foot of Chandi hills the elevation is about 290 m which drops to 270 m at Najibabad on the southern outskirt of the forest. Bijnor town is at an elevation of about 235 m.

Owing to its geographical position Bijnor suffers from less intense summers than other districts in the plains. The proximity of the Himalayas and the presence of many streams render the district moist and cool but sandy soils, good ground slopes and an adequate drainage system preserve it from unhealthy dampness. The hot western winds have a comparitively short duration. The average maximum temperature in the shade seldom exceeds 38°C. The minimum temperature in winter may go down to 4° C. The average annual rainfall generally varies from 1000 to

1100 mm. The climate including rainfall and evapo-transperiation are discussed in greater detail in Chapter - 4,5.

The forests occupy 46,680 hectares which is a very small proportion accounting for 9.6% of the area. In these forests the main variety of trees are sal, sebhal, dhak, sain, tendu and haldu. Sheesham trees which provide valuable timber are distributed throughout the plains.

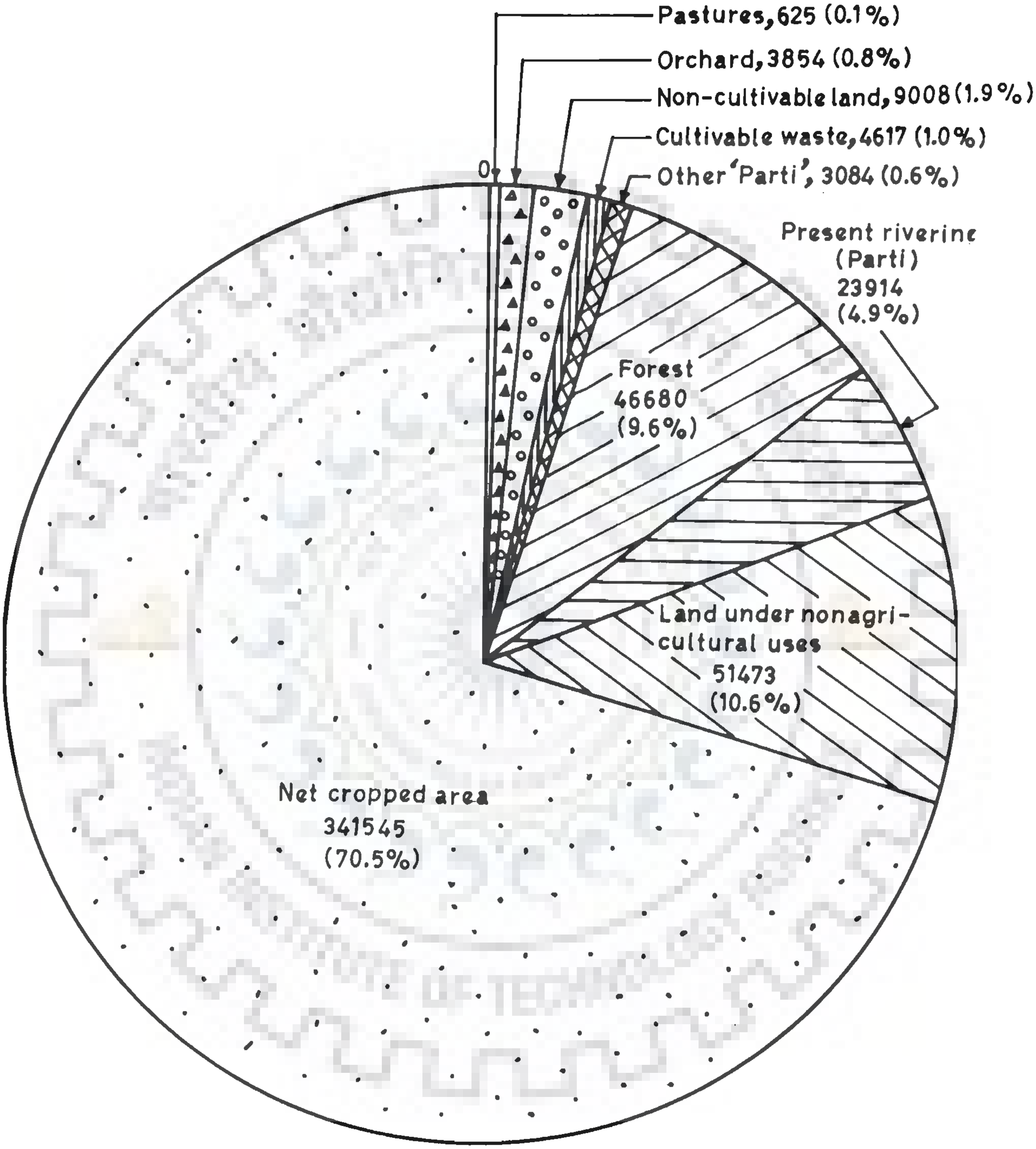
The northern forest belt harbours wild elephants, leopards, hyenas, jackals and wild pigs. Occasional sightings of tigers have also been reported. Numerous species of water birds can be seen in Raoli Jhil and other water bodies.

3.3. LAND AND POPULATION

The total geographical area or land area of the district is 4,84,800 hectares. Out of this 3,41,545 hectares 70.5% is net cropped area. Forest covers 46,680 hectars which is a rather low 9.61% Riverine or fallow land is 23,814 hectares or 4.9% while 51,473 hectares i.e 10.6% is put to non-agricultural uses. The rest of the area consists of orchards, pasture land, unculturable land and culturable waste. The land use pattern i.e. distribution of land in different categories is shown in a sector diagram in figure (3.2).

The total population of the district according to 1991 census was 24.55 lakh which gives a density of 520.7 per sq km. Out of the total population males were 13.12 lakh and females 11.43 lakhs. Thus there was a highly adverse sex ratio with 871

LAND USE, DISTRICT BIJNOR 1990-91



Total Area, 484800 ha (100.00%)

FIG. 3.2

women per 1000 men. This is worse than the national average of 934.

The rural population is 18.39 lakhs or 74.9% and the urban population is 6.16 lakhs which is 25.1% of the total. The population of the scheduled castes is 5.07 lakh but there are only 2000 persons belonging to S.T. The two togther form 20.7% of the total population. Hindus form 59.16% of the population and Muslims 39.45%. Sikhs are 1.16% and the other religious denominations have very small numbers.

The literacy rate is 41.6% for men and 26% of women which results in a 31.8% overall literacy rate. These percentages are based on total population not excluding young children and babies.

The average family size was reported to consist of 6.5 persons in rural areas and 6.6 persons in urban areas. It is somewhat suprising that there is no difference between urban and rural areas. It is indicative of a traditional way of life both in towns and villages, with most families including one or more grandparents, besides the parents and children.

3.4 ECONOMY

3.4.1 Infrastructure - Transport

The district is well served by railways. Main broad gauge line from Howrah to Amritsar passes through the district. The total track length in the district is 189 km and there are 27 railway stations located within the district. All urban centres in the district are on railway line.

No national highway passes through the district. State highways have a length of 1132.2 km. The total metalled road length comes to 1955 km. Besides this there are some brick paved link roads. The availability of metalled road per 1000 sq km is 450.7 km while per lakh of population it is 101.6 km. Both these figures are better than the average of state of UP but still lower than those recommended by Indian Roads Congress.

3.4.2 Electricity

The total consumption of electricity in the year 1991-92 was 565.72 million kwh out of which 9.15% was used for domestic and commercial purpose, 17.49% for industry and 72.7% for agriculture. The small remainder is for urban water supply and micellaneous uses. The percapita consumption of electricity for 1991-92 was 230.4 units per year which is considerably better than the state of UP and even for the country as a whole for that year. In all 1669 villages accounting 78.2% of the inhabited villages in the district are electrified. All urban centres have ofcourse the facility of electric power.

3.5 IRRIGATION

About 45.5% of the total area sown in the district is irrigated, most of it from ground water. Canals contribute to irrigation of only 1.7% while tubewells provide 85.9% and open wells 12.1%. The remainder is from ponds, ditches etc. More details about irrigation are presented in Chapter 4.

3.5.1 Agriculture and Allied Sector

The economy of the district is predominantly agricultural. About 65% of the work force are engaged as cultivators or agricultural labourers. Sugarcane has become the predominant crop in the district accounting for 46.2% of the total cropped area. Wheat occupies 35% and paddy 16.3%. The remaining area has pulses, cotton, groundnut and others. Details of cropping pattern are given in the Chapter 5. According to the latest available data there were a total of 256,323 holdings in the district. The number of holdings and their areas as well as percentages for both are given in table 3.1.

It will be seen that the majority of holdings i.e. 57.5% are less than one hectare in size. The average size of the holding was 1.37 hectares in 1985-86 and must have reduced further in common with the general trend in the country. There is a high pressure on land and a great deal of unemployment or underemployment. It is essential to raise productivity and provide more employment through intensive agriculture and processing of agricultural products.

3.5.2 ANIMAL HUSBANDRY

Animal husbandry is an important part of the economy of the district. Cattle are used for drought power, for agriculture and for milk and its products. Sheep and goat are kept for meat and milk while a small number of horses and mules are also used for transport. There are a fair number of pigs also which are kept as a source of meat. According to latest livestock census (1988) the number of the main livestock are as follows.

Table 3.1 DISTRIBUTION OF LAND HOLDINS IN BIJNOR DISTRICT

Size of holdings	Less than 1 ha.				1 to 2 ha.				2 to 3 ha.				3 to 5 ha.				More than 5 ha.				Total	
No. and % area	No.	% of total	Area	% of total	No.	% of total	Area	% of total	No.	% of total	Area	% of total	No.	% of total	Area	% of total	No.	% of total	Area	% of total	No.	Area
	147474	57.53	58626	16.27	52944	20.66	70530	20.05	23407	9.13	55246	15.71	21360	8.33	81105	23.06	11138	4.34	86275	24.51	256323	351732

Table 3.2 **LIVESTOCK DATA**

Type of Livestock	Numbers
Cows and Bullocks	4.15 lakhs (6.8% cross breed)
Buffaloes	3.95 lakhs
Goats	58.8 thousand
Sheep	15.8 thousand
Pigs	33.6 thousand
Horses and Mules	7600
Other animals	74.5 thousand
Total	10.0 lakhs

Besides these animals, there are about 1.5 lakh of chickens kept as poultry for eggs and meat. Though the number of cattle is large, possibly too large to be economic, there is a great deal of scope for improvement in breed particularly in case of milch cattle. About half of the cow and buffaloe population is kept for milk but their yield is rather low. Improvement of breed and provision of nutritious fodder can bring about considerable improvement in milk yield and income of farmers. Thus, breeding, feeding and management can help to improve the milk yield. Veternary services are available through twenty eight hospitals and dispensaries and 26 service centres. At these service centres and additionaly at twelve centres and 42 subcentres artificial insemination facility is available for cattle. There is also one animal breeding farm.

3.6 INDUSTRY

The district is not endowed with mineral resources and industrially it is not well developed. According to 1987-88 data there were 438 units registered under the Indian Factories Act but out of them only 251 were actually working. They employed about 25,000 persons and produced goods worth Rs. 18.08 lakhs.

Khadi and Cottage Industries supported by Khadi Udyog add 2739 units while small scale industrial units numbered 504. The small scale industry is predominantly based on handicrafts like brassware, handloom etc. Others include agricultural implements, khand sari, gur and sugar edible oils, brassware, toys and pottery. The only major industry in the district is sugar industry. There are several sugar mills including those at Bijnor, Chandpur, Dhampur, Najibabad and Seohara. There is one cotton mill at Nagina, a distillery at Seohara, and a straw board mill at Dhampur. There is a very considerable scope for industrial development in the district starting with processing of agricultural and dairy produce, manufacturing of value added products and also manufacturing of agricultural inputs and consumer goods for which there will be a rapidly increasing demand with growth in income.

3.7 AMENITIES

The most important amenity from the point of view of welfare of the people are education, health and water supply.

3.7.1 Educational Facility

In 1991-92 the number of recognised educational institutions was as below :

Table 3.3 Number of Educational Institions

Junior Basic school	1076
Senior Basic school	139 (including 58 for girls)
High school and intermediate	95 (including 18 for girls)
Degree colleges	6

It is observed that there has been no increase in the number of these institutions in the last ten years. As will be seen from the following table 3.4, the number of students in basic schools has not increased and has in some cases gone down. The number in highschool and intermediate school as well as colleges has increased but seems to have reached a plateau from 1989-90 onwards.

Table 3.4 : Number of students in recognised institutions according to grade

Year	Classes 1 - 5		Classes 6 - 8		Classes 9 - 12		College level	
	Total	Girls	Total	Girls	Total	Girls	Total	Girls
1989-90	152315	75950	166786	41213	46533	11248	4336	2065
1990-91	151219	76301	167597	42467	47504	11605	4508	2194
1991-92	116188	61602	131789	30014	48224	10461	4116	1981

The following trends are noticable. At the primary level upto class 5 girls form 50% or more of the students population. This declines sharply to about 25% at the next level of 6 to 8 and a little more to about 20% at the stages of classes 9 to 12. Somewhat suprisingly the proportion increases to about half at the college level. This may be due to the boys taking up technical or professional courses or going into employment. Another important reason perhaps is a larger proportion of girls in comparison to boys qualifying in the Board examination at class XII.

A plot showing number of educational institutions, and number of students is given in Figs. 3.3 (i) and (ii).

The position with respect to professional educations is given in Table 3.5.

It is noticable that while the available seats in the polytechnics have been filled in all the three years the full number of vacancies available in ITI's have not been taken up. The district could certainly do with another polytechnic particularly catering to the needs of girls and computer education.

With respect to educational facilities the situation is typical of similar districts in the state. The villages which have some kind of educational facility cover 67.3% of the rural population of the district. Considering that many of the schools in rural areas function only eratically while one third of

ALL EDUCATIONAL INSTITUTIONS
Distt. Bijnor

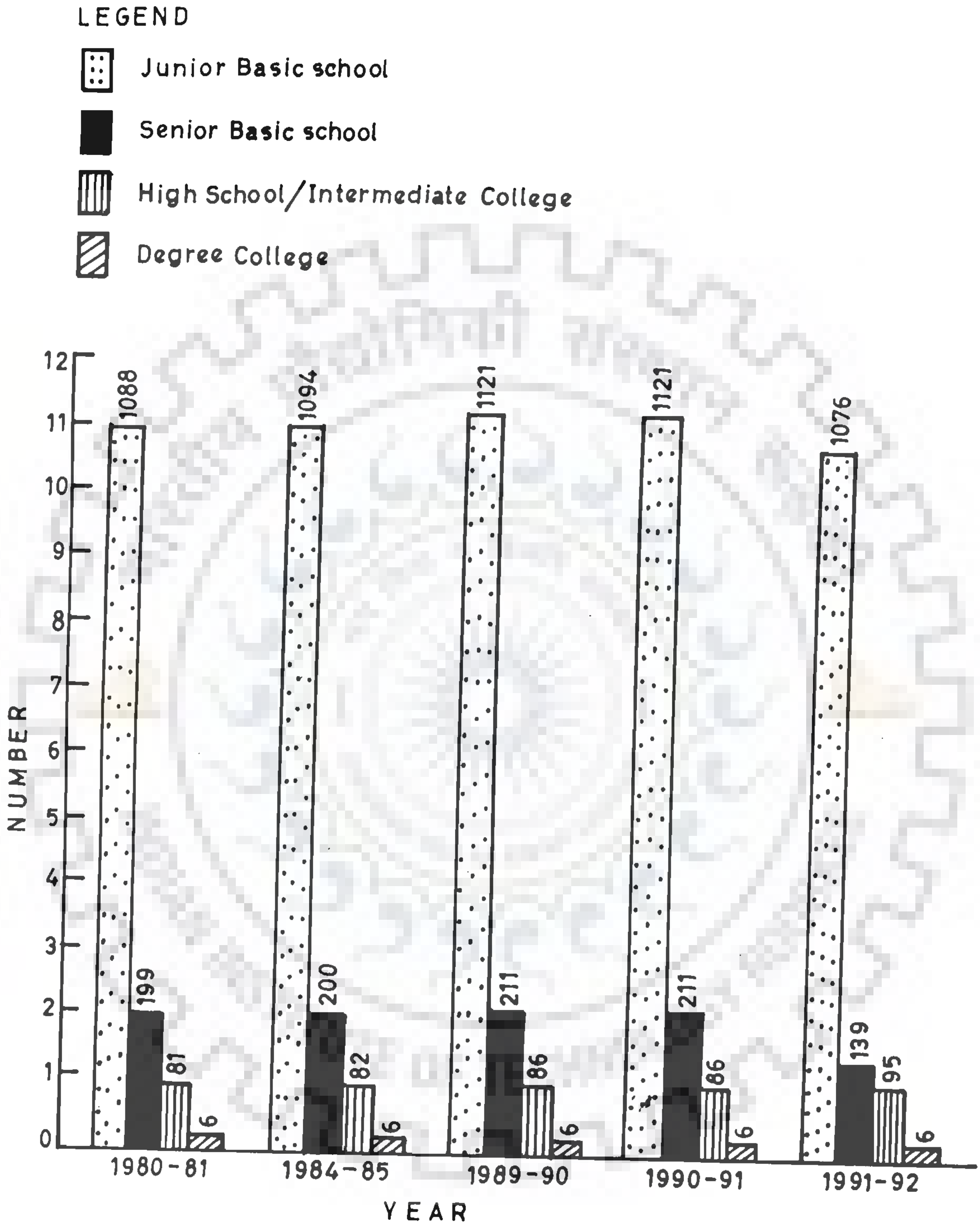


FIG.3.3(i)

TOTAL NUMBER OF STUDENTS
Distt. Bijnor

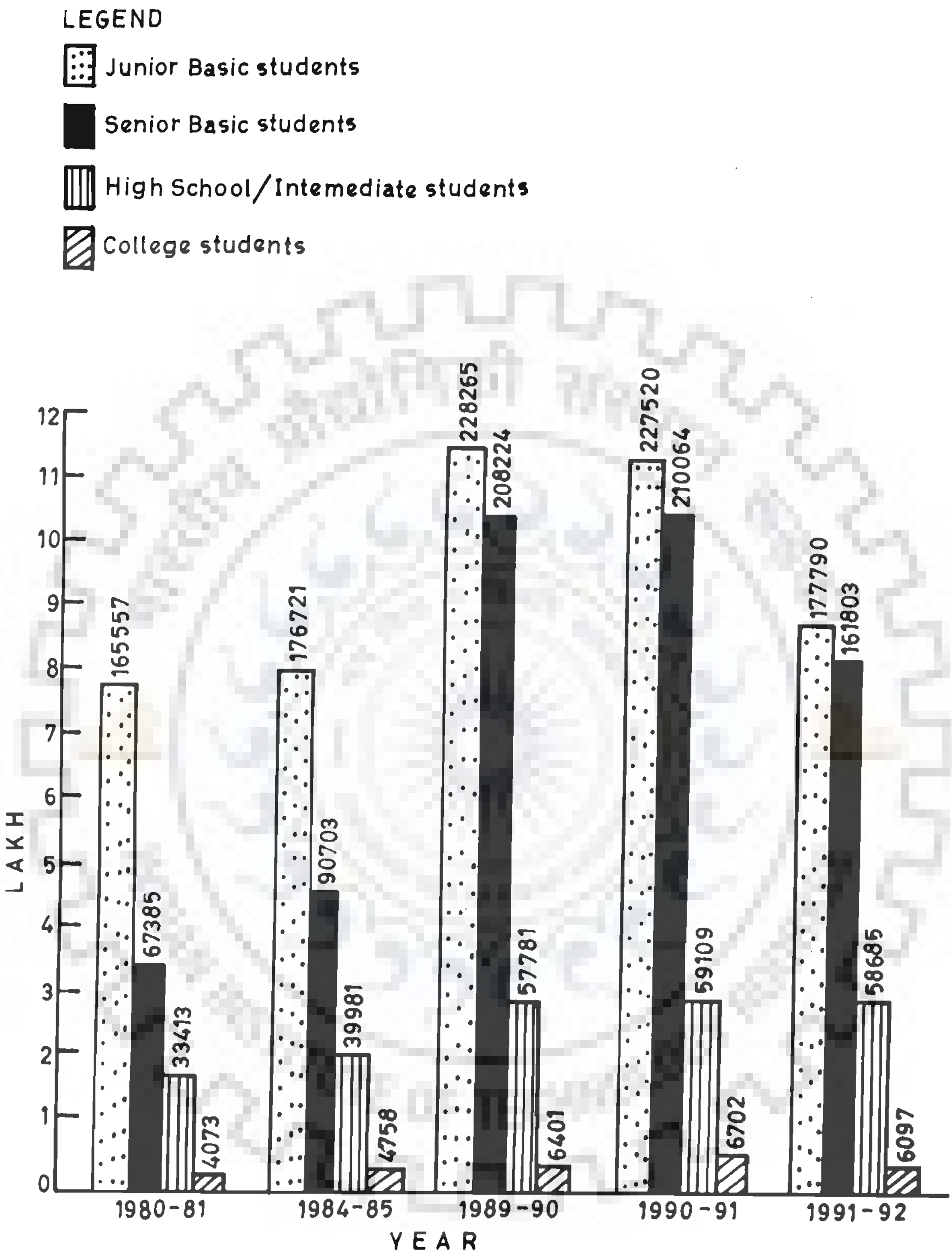


FIG.3.3 (ii)

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Table 3.5 : Facilities for Professional Education

Item	1989-90	1990-91	1991-92
1	2	3	4
I Polytechnic			
1.1 Number	1	1	1
1.2 Number of seats	60	60	60
1.3 Admissions	64	56	56
II Industrial Training Institues			
2.1 Number	3	3	3
2.2 Number of seats	597	597	636
2.3 Admissions	521	551	487
III Teachers Training Institutions			
3.1 Number	4	4	4
3.2 Number of seats	906	906	906
3.3 Admissions			
3.3.1 Males	651	715	747
Females	146	165	171

population has no local facility at all a great deal of leeway remains to be made up to achieve the declared aim of universal primary education. Plans for economic development can only succeed with a literate and well informed population. The expenditure on education has to be treated as investment in human resource development, atleast at par with that in development of physical resources.

3.7.2 Medical Facilities

The availability of public health and family planning centres can be divided into two categories-one based on modern or Allopathic system and the other as indigenous Ayurvedic, Yunani and Homeopathic systems. The availability of allopathic hospitals and dispensaries is given in Table 3.6.

Table 3.6 : Allopathic Hospitals and Dispensaries in the District including Primary Health Centres

Sl.No.	Item	1989-90	1990-91	1991-92
1.	Govt. Public	56	61	61
2.	Govt. special	5	5	6
3.	Local bodies	5	5	5
4.	Aided	--	--	--
5.	Aided private	1	1	1
6.	With grants	2	2	2
	Total	69	74	75

Besides these there are 11 Ayurvedic, 9 Yunani and 11 Homeopathic hospitals and dispensaries. There are 49 centres and 313 sub centres for family planning and mother child welfare.

Medical facilities are available to 31% of the rural population. There are over 400 villages in which the nearest medical facility is at a distance of more than 5 km. Improvement and further extension are also a priority requirement. Benefits of economic development will continue to get neutralised or diluted unless the rate of growth of population can be rapidly and sharply curtailed. Sread of education particularly among girls and extension and activisation of family welfare services are the two essentials for achieving this objective.

3.7.3 Drinking Water

It is reported that potable water supply is available to all the population of the district. In the villages, it is generally through handpump, tubewells used for irrigation or from open wells.

3.7.4 Other Amenities

Banking - In 1991-92 there were 87 branches of nationalised banks and 81 branches of other banks in the district. Out of these 51 and 36 respectively were in urban areas while 36 and 45 served rural areas. The number of branches in rural areas is clearly inadequate.

3.8 POSTAL FACILITIES

There are 31 urban and 232 rural post offices in the district. The number of telegraph office is 24. The number of telephone connections in 1992 was 5003 but it has rapidly expanded since then.

3.9 CONCLUDING REMARKS

The above discussion presents the general characteristics of the physical and human resources in the district and their state of development. The district is more or less typical of industrially less developed districts in northen India primarily dependent on agriculture and associated activities for its economy. Considerable change has been brought about during 46 years of planned development particularly after the "Green Revolution" of mid sixties. Further stimulus for growth and better quality of life has to be provided by further increase in agricultural productivity and financially more rewarding cultivation. These will then stimulate industrial and commerical growth provided that the social and human aspects are not neglected. The development plan proposed in this research work is based on this line of thinking within the limitation of the amount of work that can be accomplished by an individual. Selected aspects have been treated in detail while for others only broad directions have been indicated.

CHAPTER - 4

WATER RESOURCES POTENTIAL OF THE DISTRICT

4.0 SOURCES OF WATER SUPPLY

The sources of water supply can be considered in three categories. One is the natural rainfall which has a seasonal pattern, but is variable within the season and also from year to year. On a long term basis there is a statistical reliability about the pattern of rainfall but there can be no reliable prediction of likely rainfall in a given period of a given year. Thus irrigation is necessary to supplement natural rainfall, to meet the deficiency during the part of the year when the rainfall is normally insufficient to meet the crop requirement, to make up the deficiency which may often occur for a part of the monsoon season and also for intensive multiple cropping and growing of high water demand cash crops.

The rainfall pattern in Bijnor district is typical of north Indian plains averaging between 1000 and 1100 mm per year. Almost 90% of the rainfall occurs during the four months from June to September.

4.1 RAINFALL DATA

Railfall is being recorded/observed at Madhya Ganga Barrage site during the monsoon season from 1985 onwards. Rainfall data is also available from record, maintained by ADM (Planning) at Bijnor. The primary data obtained from them is given in Tables 4.1. and 4.2 respectively.

For purpose of the study mean of the data available from the two sources has been used for the monsoon months while the data obtained from district planning office alone has been used for non-monsoon months. The monthly rainfall figures adopted for the study on the above basis are given in table 4.3.

4.2 SURFACE WATER AVAILABILITY

Eastern Ganga canal has been introduced into the district only a few years ago. Irrigation development on the canal system is still being done. It has to be noted that this canal is purely a Kharif canal as the available flow in the river during winter or Rabi season is fully committed for older sytems, Upper and Lower Ganga canals. So far even the available potential of kharif irrigation from Eastern Ganga Canal has not been utilised fully as the network of distributaries and minors has not been completely built. It may be expected that the full potential of canal irrigation will be achieved within the next few years and should certainly be taken into account in future crop planning.

The capacity of Eastern Ganga Canal is 137.44 m^3/S as shown in table 4.4. The ultimate total input of water from this canal would be 116,170 ha.m.

Based on measured data seapage losses from the various parts of the system which is unlined, may be taken as follows.

Main/branch canal	4%
Distributarties	8.5%
Minors	16.5%

Hence seepage loss from the canal system,

= (4% + (8.5% of 0.96) + (16% of 87.5) = 26.65%

of volume at entry or 1,16,170 x 0.2665 = 30,960 ha.m.

Hence water available at outlet head = 1,16,170-30,960 =

85,210 ha.m.

Seepage loss from water courses may be taken as 20% of water at outlet head or 0.20 x 85,210 = 17042 ha.m.

Hence total seepage loss including that in water courses =

30,960 + 17042 = 48002 or say 48000 ha.m.

The potentially available canal supplies have been included in the monthly water availability constraints equations. In these equations the quantity available as per table 4.4 has been taken into account while the canal losses are accounted for while converting Field Irrigation Requirement (FIR) into Gross Irrigation Requirement (GIR).

4.3 GROUND WATER

Ground water reservoir is recharged from rainfall, seepage from irrigation channels and from irrigated fields. As the district does not receive extensive canal irrigation most of the recharge would be from rainfall. For long term sustainability of groundwater utilisation the annual draft should not exceed the annual recharge.

4.3.1 Recharge from Rainfall

The following emperical formulae have been commonly used for estimating ground water recharge from rainfall. The formulae and the recharge worked out for Bijnor district from each of them are given below.

Table 4.1 : Rainfall Fortnightly (Barrage)

Month & Date/ year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Average
Upto June 15	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	
											70.8
30/6	70.2	136.80	--	47.00	3.00	50.00	52.00	27.00	223	28	
July											
15/7	9.38	48.85	22.0	157.36	16.00	179.00	70.00	85	30	124.50	
31/7	119.21	69.40	5.0	115.69	146.00	70.00	77.00	85	149	458.5	226.3
	128.59	118.25	27.0	273.05	162.0	249.0	147.0	170	179.0	583.0	
August											
18/8	166.76	5.00	18.20	357.95	95.00	276.00	82.00	265.0	60.0	191.0	
31/8	120.65	65.10	48.90	151.00	238.00	44.0	251.00	282.0	18.0	363.0	344.3
	287.41	70.10	67.10	508.95	333.00	320.00	333.00	547.0	78.0	554.0	
September											
15/9	32.82	40.00	26.10	---	288.00	259.00	60.0	99.0	213.0	2.0	
30/9	108.06	168.40	--	247.00	8.00	45.0	22.0	--	10.0	0.0	159.5
	140.88	208.40	26.10	247.00	296.00	304.00	82.0	99.0	223.0	2.00	
October											
15/10	Nil	--	--	-		-	-	-		-	Nil
31/10	Nil										Nil
Total	627.08	533.55	120.20	1076.0	794.00	923.00	614.00	843.00	703.00	1167.00	

Table 4.2 : Monthly rainfall data (ADM Planning)

Sl. No.	Month	1990	1991	1992	1993	1994	Average
1	Jan	--	3.60	38.48	23.79	28.87	18.94
2	Feb	141.72	33.08	16.50	25.48	40.80	30
3	Mar	28.68	29.94	--	26.07	0.44	17.03
4	Apr	4.76	3.58	--	--	7.20	3.11
5	May	57.82	3.81	9.44	38.41	8.12	23.52
6	June	51.24	155.85	28.84	198.58	145.44	116.00
7	July	551.85	92.40	288.51	226.73	457.18	323.33
8	Aug	399.95	296.09	435.16	120.46	394.66	329.26
9	Sep	306.55	110.06	101.14	446.07	--	192.76
10	Oct	10.65	--	--	--	--	2.13
11	Nov	10.06	27.18	15.12	--	--	10.47
12	Dec	22.29	31.03	--	--	--	10.66
Total		1585.57	785.86	933.19	1105.59		

Note : (Omit 1990 as abnormal)

Table 4.3 : Adopted monthly rainfall

Month	Rainfall (mm)
January	18.94
February	30.00
March	17.03
April	3.11
May	23.52
June	116.00
July	275.00
August	337.00
September	176.10
October	2.13
November	10.47
December	10.66
Total	1019.96 say 1020 mm

Table 4.4 : Canal Water Input :

Month	No.of running days	% capacity	Discharge m^3/S	Water input ha.m
June	23	20%	27.48	5,460
July	31	100%	137.40	36,800
August	31	100%	137.40	36,800
September	21	100%	137.40	31,170
	9	50%	68.70	
October	7	50%	68.70	5,940
	8	20%	27.50	
			Total	1,16,170 ham

a) IRI Roorkee formulae

$$I = 3.47\ (P-38)^{2/5}$$

where I is the infiltration or recharge and P is the annual precipitation in cms. Taking P as 102 cms

$$I = 3.47\ (102-38)^{2/5} = 18.31\ cm$$

b) IPRI Amritsar formula

$$I = 3.98\ (P - 40.6)^{1/2}$$

or $I = 3.98\ (102 - 40.6)^{1/2}$

$= 31.2$ cm

c) Formula derived through Tritium tracing studies in Western U.P.

$$I = 0.40\ Pe^{-0.046c}$$

In this formula e is the base of Naperian logaritham or 2.72 and C is the average clay percentage in top soil. From the nature of the soil in the district a reasonable figure to adopt for C would be 15%. With these values.

$$I = 0.40 \times 102 \times 2.72^{(-0.046 \times 15)}$$

$= 20.5$ cms

In these three values the figure of IPRI Amritsar is out of conformity with the other two and is too high. Also greater reliance is placed on studies carried out in U.P. The values generally adopted in river alluvia are 15 to 20% and the Central Working Group of Planning Commission adopted 20% for Indo - Gangetic Alluvium (1987) (40). On this basis mean of the two values from (a) and (c) i.e. 19.5 cm is adopted.

Hence rainfall recharge

= Land area x infiltration

= 4,84,800 x 0.195 = 94,536 ham say 94,540 ham.

4.3.2 Seepage from Canals and Cannal Irrigated Fields : As computed earlier the total seepage loss from irrigation channels comes to 48,000 ham. It would be safe to assume that 75% of this or 36,000 ham will replenish groundwater.

Assuming field application efficency of 70% and that 75% of the loss replenishes the ground water recharge from canal irrigated fields is = (85210 - 17042) x 0.30 x 0.75

= 15, 338 ham or say 15, 300 ham

Hence, total seepage from canal irrigation contributing to groundwater = 36,000 + 15300 = 51,300 ham

Hence total annual ground water recharge

= 94,540 + 51,300 = 145,840 ham

Allotting 15% of groundwater to non-agricultural priority uses like domestic and industrial water supply 85% of this should be available for irrigation. However there will be additional seepage from fields irrigated by increased ground water in the new situation. This has to be obtained by trial.

If we assume total groundwater available for irrigation in the new situation as 167,000 ham and field losses again as 30% the infiltration from ground water irrigated fields will be

0.3 x 167,000 = 50,100 ham

Adding this to the earlier calculated potential of 145840 ham the total comes to 195,940 ham. Taking 85% as available for irrigation the availability will be 1,66,550 ham which practically coincides with the assumed value. Hence the availability of groundwater for irrigation may be taken as 166,500 ham. This has been adopted in crop planning studies.

4.3.3 Pumping Capacity and Annual Draft

The number of wells of different types and the estimated monthly pumping capacity and annual draft is given in table 4.5.

Table 4.5 : Annual Draft and Pumping Capacity

Types of wells	Number	Annual draft per well ham	Total annual draft ham	Pumping capacity l/s	No. of hours per month	Monthly pumping capacity ham
Deep tube wells	638	14	8932	30	16x25=400	2756
Shallow tubewells and pumping from ponds etc. (Diesel)	48987					
(Electrical)	21130					
Total	70117	1.50	105176	10	8x25=200	50484
Open pucca wells	189	0.50	90	small		
			1,14,148			53248
Say Total			1,14,200 ham			53250 ham

The estimated annual draft comes to 114,200 ham and monthly pumping capacity to 53,250 ham. Assuming that about 85% of the pumping capacity will be available for irrigation it has been stipulated that monthly irrigation demand should be limited to 45,000 ham. The existing pumping capacity is infact more than adequate to make use of the annual groundwater potential of 166,550 ham as worked out earlier. Additional pump wells should not be needed except perhaps for local adjustments.

In conclusion it is found that the annual water resources potential of the district can be taken as follows.

From canals	-	116,170 ham (during monsoon months only)
Total annual groundwater	-	166,550 ham (subject to not more than 45,000 ham in any given month)

C H A P T E R - 5

EXISTING CROPPING PATTERN AND CROP WATER REQUIREMENT

5.1 EXISTING CROPPING PATTERN

While selecting the various crops from which an optimum cropping pattern should be evolved a primary factor would be the existing cropping pattern. The cropping pattern as it exists takes into account the characteristics of climate and soil which are basically invariable. It also represents the evolved wisdom of the farmers which deserves much greater credit than is generally given to it. At the same time there is a scope for finding one or more patterns of cropping which makes optimal use of land and water resources and would give increased income to the farmers.

The existing cropping pattern for the year 1991 as given in District Statistical Hand Book (53) (1992) is given in table 5.1 and the distribution of main crops shown in Fig. 5.1. It will be seen that the dominant crops are sugarcane 42.6%, paddy 16.3% and wheat 30%, the three all together accounting for 92.5% of the total cropped area. After studying the crops (table 5.1) seventeen crops listed in table 5.2 are selected for optimisation. All these crops are already being grown in the study area. The other crops which are being grown on small areas are minor and do not have much scope for development. Vegetables and fruit orchards while valuable and useful for home consumption as well as marketing are excluded from the study as it is presumed that the existing area of orchards which is additional to the crop area is not likely to change significantly.

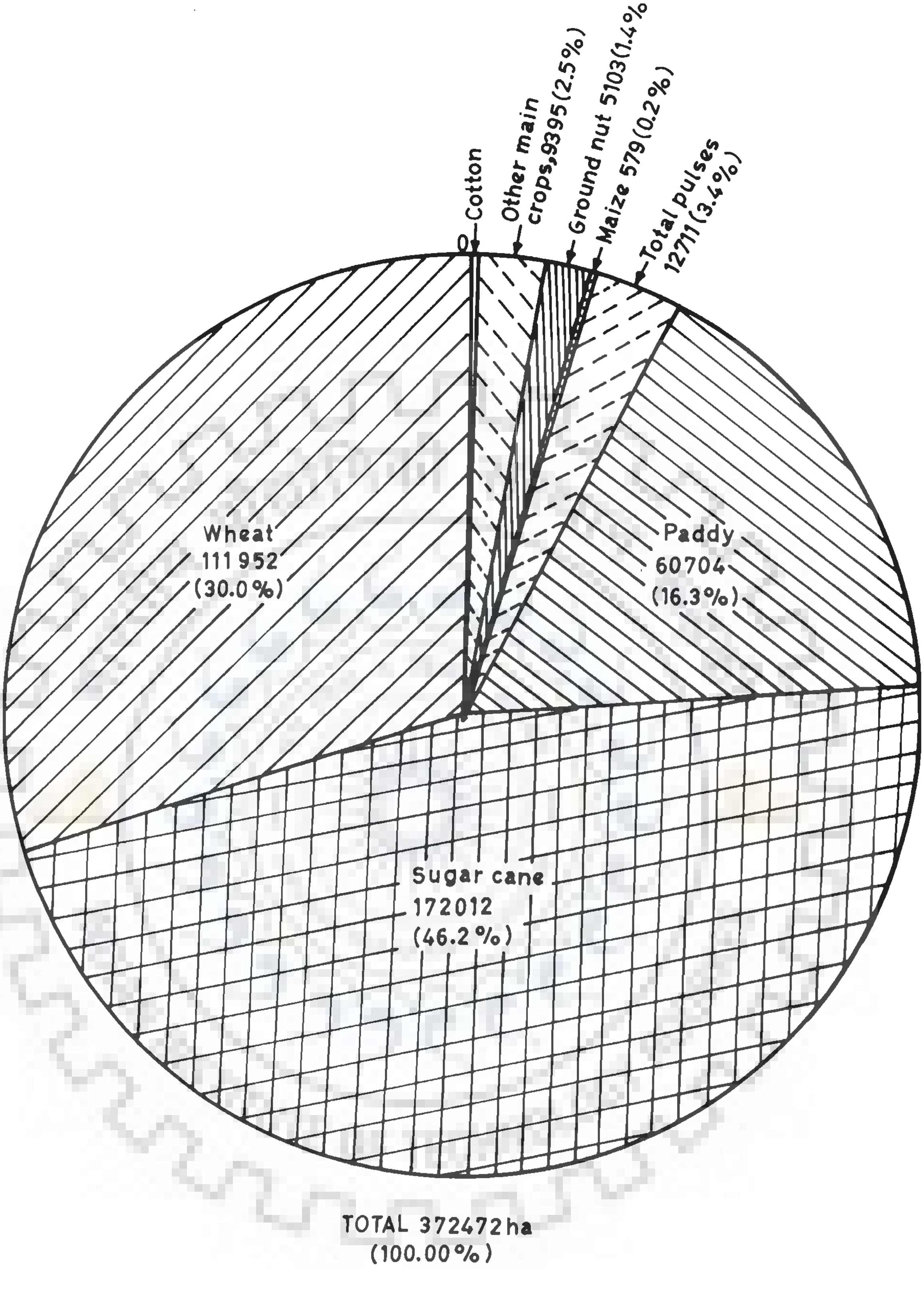


FIG.5.1: AREA UNDER MAIN CROPS.

In table 5.2 the sowing and harvesting time adopted for computation of crop water requirement have been given. There is always a certain spread in sowing and harvesting time for all crops. These dates are adopted as average of typical current practice in the district.

5.2 SOIL - WATER - PLANT RELATIONSHIP

5.2.1 Soils as Medium for Plant Growth

The matter of interest for an agronomist is establishing inter-relationship in the plant-water-soil system. For the healthy growth of plant, soil has an important role to play through which the Plant is supplied with plant nutrients, moisture and air through the root system of plant. The absorption of salts and plant nutrients takes place through the root hairs and the growing young root zones and root tips. Plants get energy from the oxidation of organic matter in the roots by cellular respiration which helps in drawing nutrients from soil. Hence oxygen is vital for plant growth and oxygen supply to root zones must be unrestricted. If the soil pores in the root zone of plant are completely filled with water and there is no room for air the plant will not survive just as it will not survive in the absence of water.

The soil structure should be such that it should contain grains of different sizes for the development of sound root system and to facilitate easy entry of air and water. The soil should contain certain minimum level of organic matter to facilitate tilling to have desirable water holding capacity and to supplement the nitrogen requirements of plant.

Crop rotation is an important aspect of agriculture. it maintains adequate amount of organic matter in soil, improves the water holding capacity of soil, prevents erosion and checks the depletion of plant nutrients. Suitable crop rotation improves crop yields, prevents certain crop disease and weed growth.

5.3 SOIL - WATER RELATIONS

5.3.1 Kinds of Water in Soil

The soil acts as a medium from which water is obtained for plant growth. The soil pores and spaces between particles are interconnected with each other forming cavities for the storage of water and air. When water is applied continuously to the completely dry soil, it goes on occupying the pore spaces expelling the air in them till all the pore spaces large or small are filled with water. In such a state the soil is saturated. After such a state is attained, any additional quantity of water added to soil moves downward as free water by the influence of gravity and is termed as `gravitational water'. When the supply of water is discontinued the water from the larger pore spaces continues to drain out for some days and the space gets occupied by air. The remaining water in comparatively smaller pore spaces is held by capillary forces and is called the `capillary water'. This water can move in any direction but mostly in the direction of greatest tension at a slower rate than free water.

The amount of water present in the soil is further reduced by evaporation from land surface and utilisation by growing plants. A stage may come when the water present in soil is so tightly held by capillary tension that it can not be utilised by plants. This residual water is called `hygroscopic water'. The plant at this stage of soil water starts wilting.

Of the three forms of water gravitional, capillary and hygroscopic, the irrigation engineer and agronomists are more interested in the first two forms. As gravitational water is short term and transitional, most of the plant needs are met from capillary water.

Besides the above three forms of water, a fourth form of soil water held by chemical force is called the `combined water'. It can neither freeze nor evaporate at ordinary temperatures and can only be expelled by heating the soil to ignition point.

5.3.2 Soil Moisture Tension

Soil moisture tension is the force per unit area that has to be exerted to remove water from the soil and is measured in atmospheres. One atmosphere is an average air pressure at mean sea level at 21° C temperature which is equivalent to 1036 cm. height of water or 76 cm of mercury. One bar is equivalent to 10^6 dynes/cm^2 or 0.987 of an atmosphere. One millibar is 1/1000 of a bar. Different soils will hold different amounts of water at the same moisture tension. Sand may completely drain at a given soil moisture tension while clay will still hold some water. As moisture content reduces, soil tension increases, it can attain very high values in clayey soils.

5.3.3 Available Soil Water to Plants

A knowledge of the available water to plants is essential for suggesting improved technique for application of irrigation water and designing irrigation systems.

`Field capacity' of a soil is the upper limit of moisture range held against gravity after free drainage has taken place for a certain period usually taken as one to three days. At this stage the larger pore spaces are filled with air and the microscopic pores are filled with water and the water movement at this stage is very slow. The field capacity depends on the porosity as well as capillary tension in the soil.

The `permanent wilting point' is the soil water content below which the plant can no longer extract enough moisture for its growth and wilts permanently unless water is added to the soil. It is the lower limit of soil moisture range for plant use. The permanent wilting point depends on the nature of the crops as well as soil texture.

The soil moisture tension for salt free water at field capacity ranges from 0.1 to 0.7 atmospheres depending on the soil texture. At the permanent wilting point the soil moisture tension ranges from 7 to 32 atmospheres depending on soil texture, kind and condition of plant, amount of soluble salts in water and climatic environments.

The quantity of water between field capacity and permanent wilting point is considered as the available water holding capacity (AWHC) of the soil which is available to plant for its use. Figure 5.2 shows the general relationship between soil moisture characteristics and soil texture. For heavier soils it can be seen from the figure that the water content at field capacity is higher but so is that at wilting point which is not available for plant use. The available water for plant use is maximum for silty loam soils.

The water content at any time should not be allowed to fall down to wilting point as it considerably reduces plant growth and crop yield. It is the normal practice to apply water to attain field capacity when the water content of the soil falls to about 50% of the available water holding capacity. Soil moisture in excess of the field capacity is wasteful and even harmful to plant growth and there is generally a decline in crop yield if saturation conditions are maintained for any length of time. This is not applicable to paddy.

5.4 PLANT MOISTURE RELATIONSHIP

Water acts as a solvent for gases and minerals to provide essential foods to plant. It is reagent for photo-synthesis and maintenance of turgidity.

Plants get their soil moisture supply by capillary movement of water to plant roots and by root elongation into moist soil. Osmotic pressure helps the roots to absorb water from the soil.

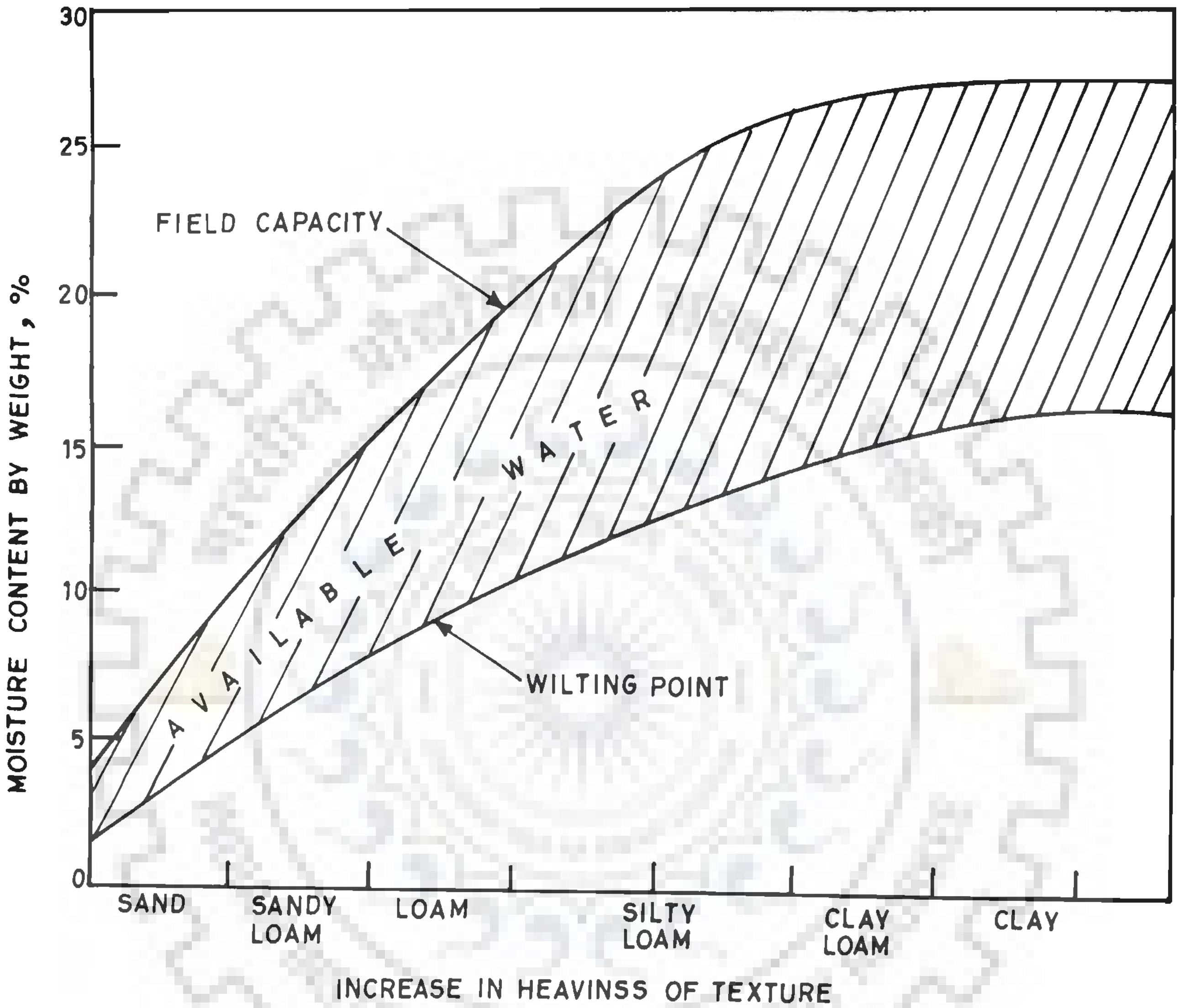


FIG. 5.2 : GENERAL RELATIONSHIP BETWEEN SOIL MOISTURE CHARACTERISTICS AND SOIL TEXTURE.

As water extraction by plants continues, soil moisture tension increases in the soil near the points where extraction takes place and the moisture from the surrounding lower tension zone moves towards the zone of absorption.

5.5 CONSUMPTIVE USE OF WATER

While water performs a number of useful functions in plant growth less than 2% of it is actually retained by the plant. The rest which is practically all the water taken up by the plants performs its task and is then released to be evaporated mainly through the leaves. This process is called transpiration.

Consumptive use or evapotranspiration is the quantity of water used by a crop in transpiration and building up of tissue and that evaporated from adjacent soil or from intercepted precipitation on the plant foliage in any specified time. Consumptive use can be determined on a daily basis or for a specified period or for a growing season as a whole. Consumptive use depends on the stage of growth of the crop. It is low at the begining of the growing season, gradually incareases, as plant foliage develops, attains a maximum value during flowering and maturing period and then declines rapidly towards the end of the growing season. Fig. 5.3 illustrates the general pattern of consumptive use requirements of plants during their growing season.

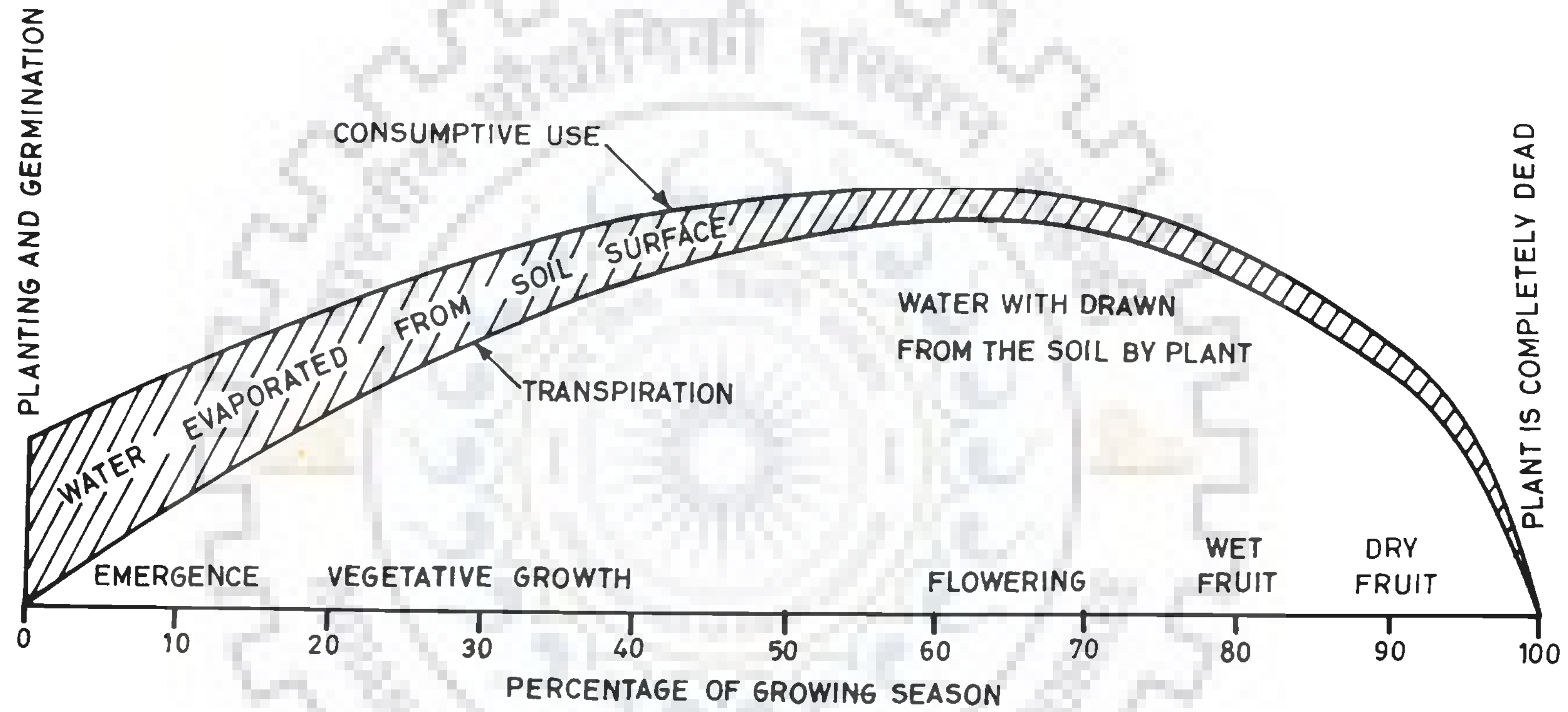


FIG.5.3: TYPICAL CONSUMPTIVE USE CURVE FOR ACROP DURING GROWING SEASON.

5.5.1 Factors Affecting Consumptive Use

The main factors governing consumptive use are the mean temperature, and daylight hours during the growing season. Other climatic factors involved are humidity and wind movement. The nature of the crop, its stage of growth and the moisture available in the root zone also affect the consumtive use.

If there is no constraint on moisture availability in the root zone then the consumptive use equals potential evapotranspiration or PET. If water supplied to the soil is less than the PET there will be less actual evapotranspiration but the plant would be subjected to periodic soil stress depending upon the quantum of the shortage. If this stress is considerable and sustained, or at critical stages of plant growth like crown rooting or flowering there may be a sharp reduction in crop yield. Attempt has therefore, to be made to maintain sufficient moisture level in the soil to protect it from damaging stress.

Consumptive use is measured as volume per unit area. Thus it can be measured as ham (one metre depth on one hactare area or 10,000 cum) per hactare or simply as depth of water in cm or mm. The depth of water has the physical meaning that if the total quantity were to stand on the surface without percolation or evaporation it would come upto that depth.

The consumptive use requirement of a crop may be supplied partly by effective precipitation and partly by irrigaion. To find the irrigation requirement it is therefore, necessary to estimate the consumptive use as well as effective precipitation.

5.6 EFFECTIVE PRECIPITATION AND IRRIGATION REQUIREMENT

Out of a given precipitation that part which is available for plant use is called effective precipitation. This consists of the moisture stored as available water in the soil within the root zones of the crops grown. The water which flows away as surface run off or percolates below the root zones is not utilisable by the current crop on the field. Heavy storms particularly following each other at a close interval may result in considerable run off and percolation losses. Thus the nature and intensity of rainfall are the main factors determining effective precipitation.

The `net irrigation requirement' in the field is obtained by deducting the effective precipitation from the consumptive use over a given period.

The `Field irrigation requirement' (FIR) will be obtained by dividing the net irrigation requirement by the field irrigation efficiency i.e. the percentage of water applied to the field which is available for actual consumption by the crops. This depends on the method of irrigation, nature of soil, frequency of irrigation and the care taken by the farmer during irrigation. By the usual methods of flow irrigation the field efficiency obtained varies from 60 to 80%. The irrigation water requirement at any other point of the system is obtained by accounting for conveyance losses from the field upto that point. This may be done by dividing the FIR by a conveyance efficiency factor or by actually computing the conveyance losses through the system.

5.7 DETERMINATION OF CONSUMPTIVE USE

It has been found that potential evapotransperation (PET) for a crop can be corelated to pan evaporation which means measured evaporation from a standard pan filled with water and open to the atmosphere. This can be taken from actual measured data or if these are not available derived from several available equations based on climatic factors. The pan evaporation data for various stations in India is published by the Meteorological Department. For the present work measured values are not available within Bijnor district but there are two observation stations one at Roorkee and the other at Bareilly which are on two sides of the district and in the same climatic region. Therefore, the mean of the pan evaporation at Roorkee and Bareilly have been taken for determining crop water requirements. The mean monthly pan evaporation along with mean monthly rainfall are shown in Table 5.3. It will be seen that except for the months of July, August and September the Pan-evaporation exceeds the rainfall.

For workingout the crop requirement in a given month the pan evaporation has to be multiplied by a crop co-efficient. As mentioned earlier the crop coefficient depends on stage of growth and to some extent on the nature of the crop. The Department of Agriculture, Government of India have published recommended values for important crops based on actual field measurements. Typical crop coefficient cureves used in these calculations are shown in Fig. 5.4 (i) to 5.4 (v).

Based on the crop calendar given in Table 5.2, the rainfall and pan evaporation data in Table 5.3, and the crop coefficients plotted in figures 5.4(i) to 5.4(v), the water requirement of the seventeen adopted crops have been worked out and have been shown in Tables 5.4 to 5.18. In these tables the field irrigation efficiency has been taken as 80% for rice and 70% for other crops. Special requirement e.g. percolation loss in case of rice and pre-sowing irrigation where needed have been taken separately. Further the full monthly rainfall is taken to be effective, as it is considered that there is not much scope for deep percolation during rainfall and most of the runoff from one field finds its way to other fields.

The abstract of field irrigation requirements for the 17 crops under study is given in Table 5.19.

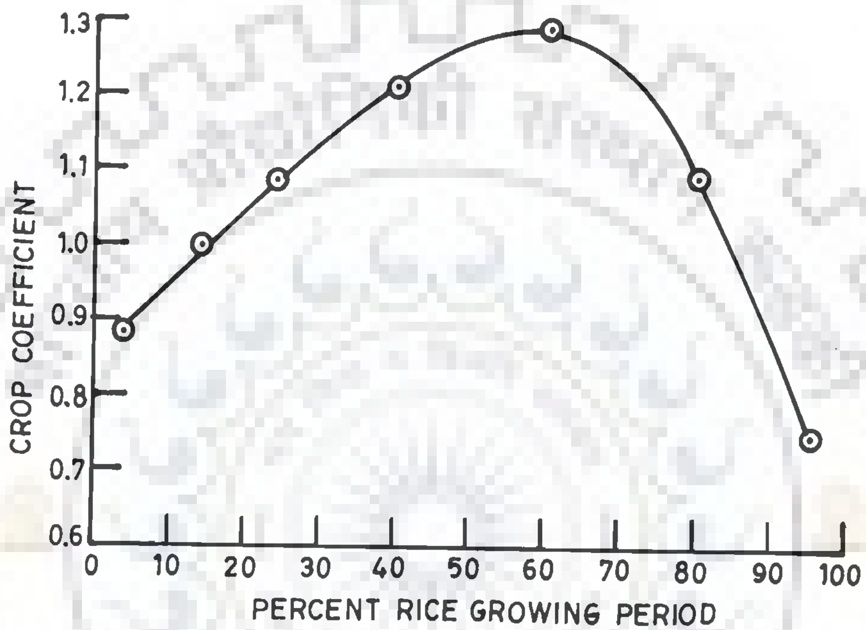
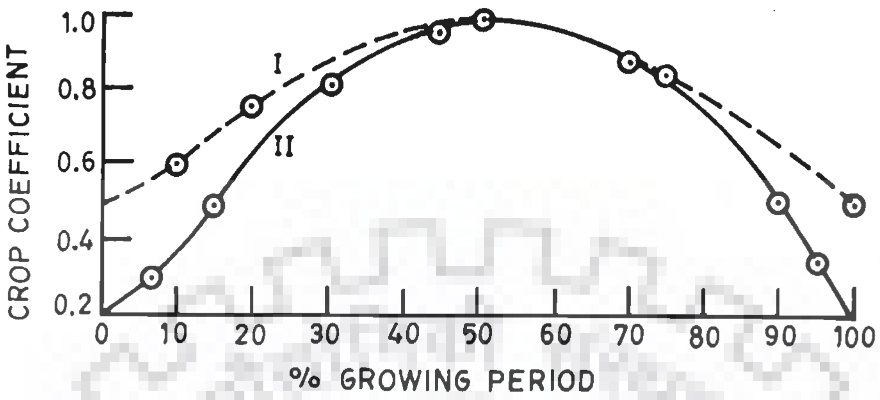

1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
CROP COEFFICIENT
0
10
20
30
40
50
60
70
80
90
100
PERCENT RICE GROWING PERIOD

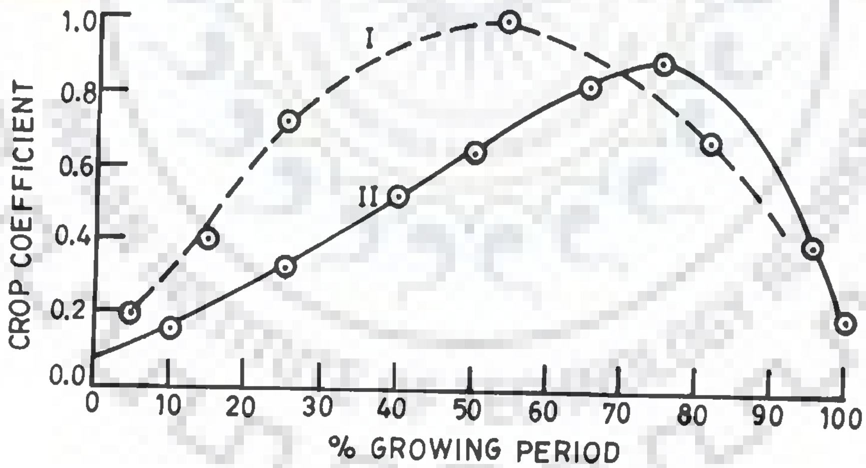
FIG.5.4 (i)



I. SUGAR CANE

II. MAIZE, COTTON, POTATOES, PEAS, SUGAR BEET

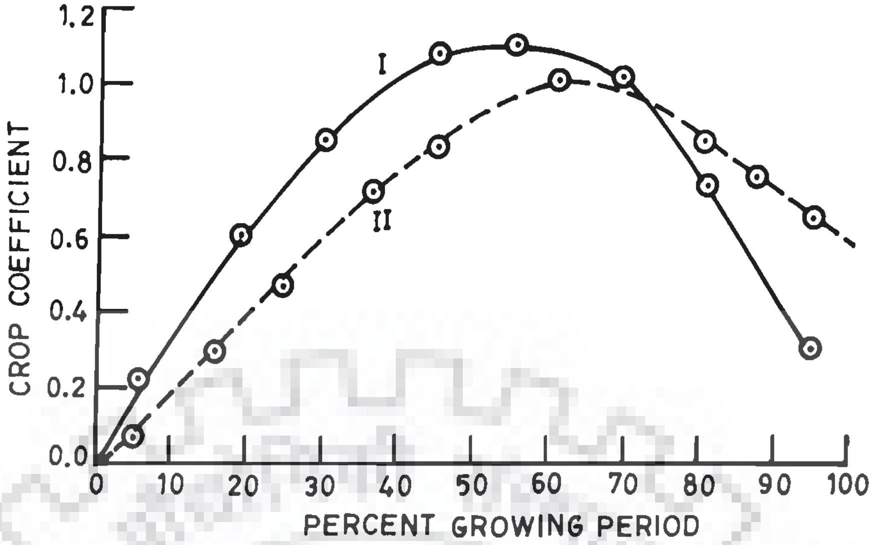
FIG. 5.4 (ii)



I. ZAID, FODDER, MOONG, URD

II. WHEAT, GRAM AND OTHER SMALL GRAINS

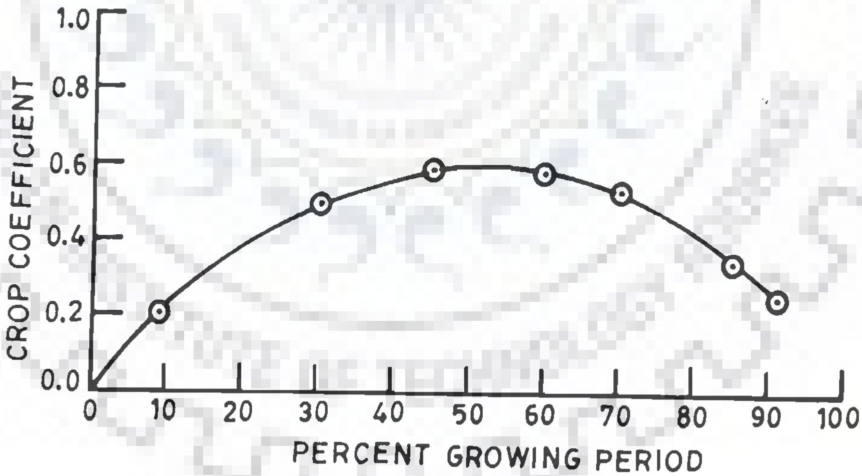
FIG. 5.4 (iii)



I . ARHAR

II . GROUND NUT

FIG. 5.4 (iv)



MUSTARD, RAPESEED, BERSEEM

FIG. 5.4 (v)

Table 5.1 : Existing Cropping Pattern

Sl. No.	Crop	Total Area (ha)	Irrigated area (ha)
1	2	3	4
	Cereals		
1.	Rice	60,704	34,435
2.	Wheat	111,952	91,390
3.	Barley (Jau)	713	211
4.	Jowar	125	1
5.	Bajra	343	Nil
6.	Maize	579	97
7.	Other cereals	81	1
	Pulses		
8.	Urd	3415	927
9.	Moong	642	567
10.	Musoor	5328	837
11.	Gram	1773	516
12.	Peas	686	399
13.	Arahar	865	30
	Oil Seeds		
14.	Mustard/Rapeseed	2641	1578
15.	Alsi	7	1
16.	Til	1011	112
17.	Groundnut	5103	8
	Other Crops		
18.	Sugarcane	172012	147202

1	2	3	4
19.	Potatoes	481	451
20.	Tobacco	5	5
21.	Jute	5	nil
22.	Cotton	16	3
23.	Sanai (Sanhemp)	77	1
24.	Soyabeen	65	26
	Fodder Crops		
25.	Kharif fooder (Chari)	35,699	406
26	Rabi fodder (Berseem)	7.937	7,209
27	Zaid fodder	3,887	3,620

Table 5.2 : Crops Selected for Optimisation with Crop Calendar

Sl. No.	Crops	Season	Sowing time	Harvesting time
X1	Rice	Kharif	Ist July	15th Nov.
X2	Maize	Kharif	15th June	10th Oct.
X3	Urd	Kharif	Ist July	30th Sept.
X4	Groundnut	Kharif	15th May	15th Oct.
X5	Kharif fodder (Chari)	Kharif	--	--
X6	Wheat	Rabi	15th Nov.	31st March
X7	Potatoes	Rabi	Ist Oct.	15th Feb.
X8	Mustard	Rabi	15th Nov.	28th Feb.
X9	Rapeseed	Rabi	Ist Sept.	15th Dec.
X10	Gram	Rabi	Ist Oct.	15th March
X11	Peas	Rabi	Ist Dec.	15th March
X12	Musoor	Rabi	Ist Nov.	31st March
X13	Berseem	Rabi	15th Oct.	30th April
X14	Moong	Zaid	Ist May	10th July
X15	Zaid fodder	Zaid	Ist May	10th July
X16	Sugar cane	year round	Ist March	28th Feb.
X17	Arhar	In both seasons	Ist July	28th Feb.

Table 5.3 : Mean Monthly Pan Evaporation and Rainfall

Month	Pan Evaporation Roorkee mm	Pan Evaporation Bareilly mm	Mean Pan Evaporation mm	Mean Monthly rainfall mm
Jan.	42.8	48.8	45.8	18.94
Feb.	62.4	70.6	66.5	30.00
March	110.4	124.7	117.5	17.03
April	152.7	166.5	159.6	3.11
May	198.9	208.5	203.7	23.52
June	192.0	196.0	194.0	116.0
July	135.3	129.4	138.3	275.0
Aug.	123.8	115.5	119.6	337.0
Sept.	121.6	122.6	122.1	176.1
Oct.	99.4	110.1	104.7	2.13
Nov.	55.5	64.2	59.8	10.47
Dec.	38.5	45.3	41.9	10.60
Total	1333.8	1402.8	1368.3	1019.96 mm

Table 5.4 : Water Requirement for Rice (X_1)

Dates	No.of days to mid point	% of growing season	Pan Evn. mm	Crop coefficient	Consumptive use	Percolation loss + Spl. requirement	Effective rain fall mm	NIR CU+ percolation loss-effective rain fall	PIR NIR/ 0.8 mm	GIR at channel head PIR/0.7 mm
1	2	3	4	5	6	7	8	9=(6+7)-8	10	11
July 1-31	16	11.6	138.3	0.96	132.8	186+250+75 = 511	275	368.8	461.0	658.6
Aug 1-31	47	34.1	119.6	1.16	138.7	186	337	--	--	--
Sept. 1-30	77	55.3	122.1	1.28	156.3	186	176.1	166.2	207.8	296.8
Oct. 1-31	108	78.3	104.7	1.10	115.2	186	--	301.2	376.5	537.8
Nov. 1-15	131	94.9	29.9	0.75	22.4	Nil	--	22.4	28.0	35.0
138 days								858.6	1073.3	1528.2

Table 5.5 : Water Requirement for Maize (X_2)

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
June 15-30	8	6.8	97	0.3	29.1	58.0	--	--	50 pre-sowing requirement
July 1-31	31	26.7	138.3	0.73	100.95	275.0	--	--	
Aug. 1-31	62	58.4	119.6	0.97	115.43	337.0	--	--	
Sept. 1-30	92	79.3	122.1	0.75	91.57	176.1	--	--	
Oct. 1-10	112	96.5	34.9	0.32	11.17	0.71	10.46	14.94	21.34
Total 116 days								14.94	71.34

Table 5.6 : Water Requirement for Urd (X_3)

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
July 1-31	16	17.4	138.3	0.5	69.15	275	--	--	--
Aug. 1-31	47	51.1	119.6	0.98	117.2	337	--	--	--
Sept. 1-30	77	83.7	122.1	0.63	77.30	176.1	--	--	--
Total days 92									

Table 5.7 : Water Requirement for Groundnut (X_4)

Dates	No.of days to mid point	% of growing season	Pan evaporation	Crop coefficient [illegible]	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
May 15-31	8	5.2	101.8	0.08	8.14	11.76	--	--	75 pre-sowing
June 1-30	31	20.2	194.0	0.04	77.6	116.0	--	--	--
July 1-31	62	40.5	138.3	0.76	105.1	275.0	--	--	--
Aug. 1-31	92	74.7	119.6	0.91	108.83	337.0	--	--	--
Sept. 1-30	123	80.4	122.1	0.85	103.7	176.1	--	--	--
Oct. 1-15	145	94.7	52.35	0.53	27.74	2.13	25.6	36.58	52.26
Total days 153								36.58	127.26

Table 5.8 : Water Requirement for Wheat (X_6)

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
Nov. 15-30	8	5.8	29.9	0.11	3.29	5.23	--	--	75 mm Land preparation & presowing
Dec. 1-31	31	22.6	41.9	0.45	18.86	10.66	8.2	11.71	16.74
Jan. 1-31	63	46.0	45.8	0.60	27.54	18.94	8.6	12.28	17.55
Feb. 1-28	92	67.15	66.5	0.83	55.19	30.0	25.19	36.00	51.40
March 1-31	122	89.0	117.5	0.60	70.50	17.03	53.47	76.4	109.1
Total 137 days					169.09			136.39	269.79

Table 5.9 : Water Requirement for Potatoes (X_7)

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
Oct. 1-31	16	11.6	104.7	0.37	38.74	2.13	36.61	52.3	74.71+75=149.71 (75 mm presowing)
Nov. 1-30	46	33.3	59.8	0.82	49.03	10.47	38.56	55.08	78.68
Dec. 1-31	77	55.8	41.9	0.96	40.22	10.66	29.56	42.22	60.31
Jan. 1-31	108	78.3	45.8	0.82	37.55	18.94	18.61	26.58	37.97
Feb. 1-15	130	94.20	33.25	0.32	30.14	15.00	15.14	21.62	30.89
Total days 138								197.8	357.56

Table 5.10 : Water Requirement for Mustard (X_8)

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient mm	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm	
Nov. 15-30	8	7.7	29.9	0.16	4.78	5.23	--	--	+ 50 presowing	
Dec. 1-31	31	29.5	41.9	0.51	20.95	10.66	10.29	14.7	21	
Jan. 1-31	62	59.04	45.8	0.59	27.02	18.94	8.08	11.54	16.4	
Feb. 1-28	90	85.7	66.5	0.35	23.77	30.00	--	--	--	
Total days 105									26.24	87.4

Table 5.11 : Water Requirement for Rapeaseed (X_9)

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient mm	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
Sept. 1-30	15	14.1	122.1	0.29	35.41	176.1	--	--	50 presowing
Oct. 1-31	46	43.4	104.7	0.57	59.68	2.13	57.55	82.21	117.44
Nov. 1-30	76	71.7	59.8	0.55	32.89	10.47	22.42	32.03	45.74
Dec. 1-15	91	85.8	20.45	0.36	7.36	5.33	2.03	2.90	4.14
Total days 106								117.14	217.33

Table 5.12 : Water Requirement for Gram (X_{14})

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
Oct. 1-31	16	9.6	104.7	0.15	15.7	2.13	13.5	19.28	27.54+50 mm field preparation
Nov. 1-30	46	27.7	59.8	0.33	19.73	10.47	9.26	13.23	18.9
Dec. 1-31	77	46.3	41.9	0.60	25.14	10.66	14.48	20.68	29.54
Jan. 1-31	108	65.0	45.8	0.82	37.56	18.94	18.62	26.6	38.00
Feb. 1-28	136	81.9	66.5	0.84	55.86	30.00	25.86	36.94	52.77
March 1-15	158	95.1	58.75	0.4	38.04	8.51	29.53	42.18	60.26
								158.91	227.01+50

Table 5.13 : Water Requirement for Peas (X_{11})

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
Dec. 1-31	16	15.2	41.9	0.44	18.43	10.66	7.77	11.1	15.8+75 presowing
Jan. 1-31	47	44.7	45.8	0.87	39.84	18.94	20.9	29.85	42.64
Feb. 1-28	75	71.4	66.5	0.84	55.86	30.00	25.86	36.94	52.77
March 1-15	97	92.3	58.75	0.45	41.53	8.51	33.02	47.17	67.38
Total days 105								125.06	253.50

Table 5.14 : Water Requirement for Masoor (X_{12})

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
Nov. 1-30	15	9.9	59.8	0.35	20.93	10.47	10.46	14.94	21.34+50=71.34 (50 mm presowing)
Dec. 1-31	46	30.5	41.9	0.80	33.52	10.66	32.86	46.94	67.05
Jan. 1-31	77	51.0	45.8	0.99	45.34	18.94	26.40	37.71	53.87
Feb. 1-28	105	69.3	66.5	0.87	57.85	30.00	27.85	39.78	56.82
March 1-30	136	90.0	117.5	0.3	35.1	17.03	18.07	25.81	36.87
Total days 151								163.8	285.95

Table 5.15 : Water Requirement for Berseem (X_{13})

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	PIR mm	GIR mm
Oct. 15-31	8	12.9	52.3	0.3	15.69	1.05	14.64	20.9	29.9 No field preparation water needed
Nov. 1-30	31	50.0	5.98	0.6	35.90	10.47	25.43	36.3	51.9
Dec. 1-31	62	100.0	41.9	0.25	10.5	10.66	--	--	--
Jan. 1-31	93	50.0	45.8	0.6	27.50	18.94	8.56	12.2	17.5
Feb. 1-28	121	100.0	66.5	0.25	16.6	30.00	--	--	--
March. 1-31	152	50.0	117.5	0.6	70.50	17.03	53.47	76.4	109.1
April 1-30	182	100.0	159.6	0.25	39.90	3.11	36.79	52.6	75.1
Total days	197							198.4	283.5

Note : Three cuttings on Dec. 31, Feb. 28 and April 30, percentage growing season taken accordingly

Table 5.16: Moong Zaid and Zaid Fodder (X_{14}, X_{15})

Dates	No.of days to mid point	% of growing season	Pan evapora-tion	Crop coeffi-cient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
May. 1-31	16	22.5	203.7	0.67	136.50	23.50	113.0	161.4	230.6+75 field pre-paration
June 1-30	46	64.8	194.0	0.90	174.6	116.0	58.6	82.8	118.4
July 1-10	67	94.4	46.0	0.40	18.4	92.0	--	--	--
Total days	71							244.2	340.0 + 75 424 mm

Table 5.17 Water requirement of Sugar Cane (X_{16})

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
March 1-31	16	4.4	117.5	0.52	61.10	17.03	44.07	62.95	89.93+75 for field preparation
April 1-30	46	12.6	159.6	0.63	100.55	3.11	97.44	139.2	198.85
May 1-31	77	21.7	203.7	0.76	154.81	23.52	131.29	187.55	267.93
June 1-30	107	29.3	194.0	0.86	166.84	116.0	50.84	72.63	103.76
July 1-31	138	37.8	138.3	0.94	130.0	275.0	--	--	--
Aug. 1-31	169	46.3	119.6	0.96	142.82	337.0	--	--	--
Sept. 1-30	199	54.5	122.1	0.96	117.22	176.1	--	--	--
Oct 1-31	230	63.0	104.7	0.92	96.32	2.13	94.19	134.55	192.21
Nov. 1-30	261	71.5	59.8	0.88	52.62	10.47	42.15	60.29	86.13
Dec. 1-31	291	79.7	41.9	0.78	32.68	10.66	22.02	31.45	44.93
Jan. 1-31	322	88.2	45.8	0.65	29.77	18.94	10.83	15.47	22.1
Feb. 1-28	350	95.9	66.5	0.57	37.91	30.00	7.91	11.3	16.14
Total days 365								715.39	1021.98 + 75 1096.98

Table 5.18 Water requirement of Arhar (X_{17})

Dates	No.of days to mid point	% of growing season	Pan evaporation mm	Crop coefficient	CU mm	Effective rainfall mm	NIR mm	FIR mm	GIR mm
July 1-31	16	6.5	138.3	0.23	31.8	275	--	--	--
Aug 1-31	47	19.3	119.6	0.61	72.95	337	--	--	--
Sept. 1-30	77	31.6	122.1	0.86	105.00	176.1	--	--	--
Oct. 1-31	108	44.4	104.7	0.98	102.6	2.13	100.47	143.53	205.04
Nov. 1-30	138	56.8	59.8	0.99	59.2	10.47	48.73	69.61	99.44
Dec. 1-31	169	69.5	41.9	0.91	38.13	10.66	27.47	39.24	56.06
Jan. 1-31	200	82.3	45.8	0.69	31.60	18.94	12.66	18.08	25.83
Feb. 1-28	228	93.8	66.5	0.30	19.95	30.00	--	--	25.83
Total days 243								270.46	386.37

Table 5.19 : Field Irrigation requirement in cms (Abstract for all crops

Sl.	Crop	Duration	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
X_1	Rice	July 1- Nov.15	--	--	--	--	--	--	46.1	--	20.78	37.65	2.80	--	107.33
X_2	Maize	June 15-Oct.10	--	--	--	--	--	5.0	--	--	--	1.49	-		6.49
X_3	Urd	July 1 -Sep.30	--	-	--	--	--	--	--	-	-	--	--	--	NIL
X_4	G.Nut	May 15- Oct.30	--	--	--	--	7.5	--	--	--	--	3.66	--	--	11.16
X_5	Chari	-- -	--	--	--	--	--	--	--	--	--	--	--	--	NIL
X_6	Wheat	Nov.15- Mar.21	1.23	3.60	7.64	--	--	--	--	--	--	--	7.5	1.17	21.14
X_7	Potatoes	Oct.1 - Feb.15	2.66	2.16	--	--	--	--	--	--	--	12.73	5.51	4.22	27.28
X_8	Mustard	Nov.15- Feb.28	1.15	--	--	--	--	--	--	--	--	--	5.00	1.47	7.62
X_9	Rapeseed	Sep.1- Dec.15	--	--	--	--	--	--	--	--	5.0	8.22	3.20	2.90	16.71
X_{10}	Gram	Oct.1- Mar.15	2.66	3.69	4.22	--	--	--	--	--	--	6.93	1.32	2.07	20.89
X_{11}	Peas	Dec.1- Mar.15	2.98	3.69	4.72	--	--	--	--	--	--	--	--	8.61	20.00
X_{12}	Masoor	Nov.1- Mar.31	3.77	3.98	2.58	--	--	--	--	--	--	--	1.49	4.69	21.51
X_{13}	Berseem	Oct.15- Apr.30	1.22	--	7.64	5.26	--	--	--	--	--	2.69	3.63	--	19.84
X_{14}	Moong	May 1- July 10	--	--	--	--	23.64	8.28	--	--	--	--	--	--	31.92
X_{15}	Zaid Fodder	May 1- July 10	--	--	--	--	23.64	8.28	--	--	--	--	--	--	31.92
X_{16}	Sugarcane	Mar. 1- Feb.28	1.55	1.13	6.03	13.92	18.76	7.26	--	--	--	13.46	6.03	3.15	78.76
X_{17}	Arhar	July 1- Feb.28	1.81	--	--	--	--	--	--	--	--	14.35	6.96	3.92	27.04

CHAPTER - 6

OPTIMISING OF CROPPING PATTERN AND RESULTING BENEFITS

6.0 Optimisation of cropping pattern involves initial selection of a group of crops which can be grown in an area with given climatic conditions, soil, topography social needs and technological level of the farmers. Taking all these considerations in view seventeen main crops were selected for Bijnor district as listed in table 5.2. The crop calendar and monthly crop water requirement as well as monthly irrigation requirement have been worked out in the previous chapter. The next step is to try to evolve such a combination of these crops that it is of maximum benefit to the farmers.

While the objective seems to be simple the solution is quite complex as there can be an unlimited number of variations and a solution by trial and error is not feasible practically. Such a problem can however be conveniently solved using mathmetical tools and digital computer.

The basic methodology is to ensure economic optimality subject to physical and technological constraints by an optimisation model. The objective function in such a model defines economic optimality while the other requirements have to be specified in the form of constraints. An unconstrained economic optimisation will not be a feasible solution as it may select only a few most remunerative crops neglecting the requirements of internal consumption, storage, marketing of the marketable surplus of the produce, the need for fairly well spread utilisation of labour and water and the preferences of the community. Hence a linear programming model is used to arrive at an optimal as well as a feasible solution through a prudent specification of constraints.

6.1 PROBLEM FORMULATION

With respect to water either a fixed yield model or a model making use of water production function can be used. In the former case it is assumed that the water requirement of the crop is to be fully met during the growing season resulting in optimal production. In the latter case the quantity of water to be applied to each crop is varied from sub optimal to optimal resulting in corresponding variation in yield. In this way water allocation between different crops is further refined to give maximum returns per unit of water. This technique is more effective and useful in areas of water scarcity. With adequate availability of ground water supplemented by Eastern Ganga Canal during Kharif season Bijnor district cannot be categorised as a water scarcity area. Hence in the present study fixed yield model has been used as production function model could possibly give only marginal advantage but would greatly add to the complexity of the solution.

6.1.1 Objective Function

The objective function could be defined in several ways. In the present study the objective is the maximisation of net monetary benefits during one year. This can be written as -

$$\text{Maximise} \quad Z = \Sigma X_i * B_i$$

where X_i is the i^{th} crop and B_i the net benefit for that i^{th} crop

6.2 DETERMINATION OF NET BENEFITS OF CROP

The net benefits for the selected seventeen crops have been estimated by assessing the cost of production and the gross return obtained by sale of the product. The net benefits are then the difference between gross benefits and cost of production.

The main items of production cost are human labour, bullocks or tractor power, seeds, fertilizers, plant protection, irrigation, land revenue, interest on capital and special operations, where necessary. Interest charges on fixed assets of the farmer like land and machinery have not been taken into account. Fertilizer application has been assumed at recommended levels. In computing water cost it has been taken into account that for Rabi crops water will have to be mostly pumped water while for Kharif crops canal water will also be available. The cost of inputs, labour and the market prices of the products have been taken from actual surveys as prevailing during hte year 1995-96 when most of this work was done. Admittedly costs and prices are subject to variation but it is considered that the relative order of benefits of the different crops will remain basically unchanged. The cost and net benefit calculations of the crops are given in tables 6.1 to 6.14. Abstract for all the crops is given in Table 6.15.

6.3 OPTIMISATION MODEL

A linear programming model has been adopted to obtain optimum crop combination for maximum net benefits with the available land and water. That is -

Maximise $Z = \Sigma X_i * B_i$

where X_i is the ith crop and B_i the net benefit for that ith crop.

$$Z = 4,800X_1 + 4075X_2 + 6340X_3 + 9,160X_4 + 4000X_5 + 6,790X_6 + 8050X_7 + 4,900X_8 + 4150X_9 + 4,180X_{10} + 3,510X_{11} + 4970X_{12} + 6,370X_{13} + 3050X_{14} + 2,800X_{15} + 11,850X_{16} + 6060X_{17}$$

Constraints -

The following constraints are general and obligatory -

1. Total cropped area not to exceed available area in any month or $\Sigma X_i * a_{it} \leq A_t$

   where a_{it} represents the fraction of month for which the crop is in the field, and A_t is the total available area for cultivation.

2. Monthly water requirement not to exceed available pumping capacity plus canal water input in that month.

   $$\Sigma X_i * \Delta it \leq W_t$$

   where Δit is the monthly water requirement for the ith crop and W_t is the maximum water availability in that month.

3. Annual ground water withdrawal not to exceed replenishment.

$$\sum_{t(1 \text{ to } 12)} W_{gt} \leq 1,66,500$$

where ΣW_{gt} is the ground water pumpage during 12 months of the year.

4. Non-negativity constraints

$X_i \geq 0$

$W_t \geq 0$

Besides these crop area constraints were imposed to progressively arrive at a realistic and practical cropping pattern. As has been the experience in all such optimisation experiments, purely economic criteria result in a small number of most profitable crops. However, it is necessary, where possible to maintain self sufficiency in food and fodder to avoid transport costs. Marketability, processing facilities, preservation and storage, risk factors have all to be taken into account. Very drastic changes in established cropping pattern will not be possible, and even substantial changes will be difficult and slow.

For the present cropping pattern, the annual FIR for irrigated area has been worked out in Table 6.16 and comes to 1,75,980 h.m. The existing availability of ground water has been estimated as 1,09,850 or say 1,10,000 ha.m. The existing canal input may be taken as 7,500 ha.m. during Kharif only. Thus, the present water availability is about 2/3rd of the full water requirement for the area reported as irrigated. This is bound to reflect on productivity and net benefits.

Net benefits for the existing cropping pattern are worked out in Table 6.17. It is reasonable to assume yields on sub-optimally irrigated land as 75% and net benefits as 70% of optimally irrigated land. On this basis, the net benefits for the 17 crops with existing cropping pattern and irrigation comes to Rs. 2280 million.

As a matter of interest, the result of the first trial with no imposed constraint besides obligatory is shown in Table 6.18. It gives only three crops, the full area under groundnut during kharif and equally divided between wheat and potatoes during Rabi. A cropping intensity of 200% and overall net benefits of Rs. 6,262 million are obtained. It needs hardly be pointed out that this cropping pattern is not practicable. Numerous trials were made with imposed constraints to arrive at practicable cropping pattern while maintaining as high a profitability as possible.

The results of two such trials E and G are given in Table 6.19. Both combinations give almost identical net benefits of Rs. 4,107 million and cropping intensity of 200% (counting year round crops twice). The net benefits from these trials are 1.8 times the present estimated benefits.

It can be seen that the study definitely points towards reduction in sugar cane area and substitution by crops of shorter duration and less water consumption. In study E, large increases are in urd, groundnut, potatoes, and moong, while in study G, they are in maize, urd, groundnut, and potatoes. Three of the crops are common in both, and give a clear direction in which the cropping pattern should move. Study G makes a less drastic reduction in sugarcane and may thus be considered more realistic. This change will take time but is not as difficult as it seems. Rapid increases in wheat area at the cost of other crops in late sixties and seventies show the adaptability of Indian farmers. Some signs of growth in pulses and oil seeds area are already visible.

Computer output of studies E and G are attached at Appendix I and II respectively.

The study indicates that by optimum utilisation of land and water resources it would be possible to increase the agricultural income of the district by almost 80%. This will by itself have a profound impact on the standard of living of the people. Consequential development of infrastructure and industrial and service sectors have to be planned simultaneously and will further greatly enhance economic benefits and well being.

Table 6.1 : Benefit Calculations of Crop/Ha. - Crop Rice

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	100	2500/-
2.	Bullock/tractor	Day/hr	80	16	1280/-
3.	Seeds	Kg	10	30	300/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	150	525/-
	b) Potassium Ko	kg	4.50	60	270/-
	c) Phosphorous	kg	3.00	40	120/-
	d) F.Y.M				
5.	Irrigation (FIR)				250/-
6.	Nursery preparation				200/-
7.	Special operation		LS		200/-
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				
	c) Overhead cost		LS		750/-
	d) Implements				
	Cost of cultivation				6395/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	35	300	10,500/-
	By product	35	20	700/-
	Gross benefits/ha			11,200/-
	Net Benefits/ha			4,805

Rs. 4800/

Table 6.2 : Benefit Calculations of Crop/Ha. - Crop Maize

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	70	1750/-
2.	Bullock/tractor	Day/ hrs	80	10	800/-
3.	Seeds	Kg	8	40	320/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	60	210/-
	b) Potassium Ko	kg	4.50	30	135/-
	c) Phosphorous	kg	3.00	20	60/-
	d) F.Y.M				
5.	Irrigation (FIR)				100/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection		LS		600/-
	c) Overhead cost				
	d) Implements				
	Cost of cultivation				3975/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	25	300	7,500/-
	By product			500/-
	Gross benefits/ha			8,000/-
	Net Benefits/ha			4,075

Table 6.3 : Benefit Calculations of Crop/Ha. - Crop Urd

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	50	1250/-
2.	Bullock/tractor	Day/ hrs	80	10	800/-
3.	Seeds	Kg	25	20	500/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	20	70/-
	b) Potassium Ko	kg	4.50	40	180/-
	c) Phosphorous	kg	3.00	25	60/-
	d) F.Y.M				
5.	Irrigation (FIR)				--
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				
	c) Overhead cost		LS		500/-
	d) Implements				
	Cost of cultivation				3360/-

II Benefits/Ha.

	Qnty/ha	Rate Rs/quintal	Amount Rs.
Main product	8	1200	9,600/-
By product	100	1.0	100/-
Gross benefits/ha			9,700/-
Net Benefits/ha			6,340/-

Table 6.4 : Benefit Calculations of Crop/Ha. - Crop Groundnut

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	125	3125/-
2.	Bullock/tractor	Day/hr	80	6	480/-
3.	Seeds	Kg	10	120	1200/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	100	350/-
	b) Potassium Ko	kg	4.50	30	135/-
	c) Phosphorous P_2O_5	kg	3.50	50	150/-
	d) F.Y.M				
5.	Irrigation (FIR)				200/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				600/-
	c) Overhead cost		LS		800/-
	d) Implements				
	Cost of cultivation				7040/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	18	900	16,200/-
	By product			
	Gross benefits/ha			16,200/-
	Net Benefits/ha			9,160/-

Table 6.5 : Benefit Calculations of Crop/Ha. - Crop Wheat

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	125	3125/-
2.	Bullock/tractor	Day/ hr	80	20	1600/-
3.	Seeds	Kg	8	120	960/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	120	420/-
	b) Potassium Ko	kg	4.50	60	270/-
	c) Phosphorous P_2O_5	kg	3.00	30	90/-
	d) F.Y.M				
5.	Irrigation (FIR)Rabi		LS		500/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value		LS		600/-
	b) Plant protection				
	c) Overhead cost				
	d) Implements				
	Cost of cultivation				7565/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	35	350	12,250/-
	By product	35	60	2,100/-
	Gross benefits/ha			14,350/-
	Net Benefits/ha			6,785/-

Say 6,790/-

Table 6.6 : Benefit Calculations of Crop/Ha. - Crop Potato

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	200	5000/-
2.	Bullock/tractor	Day	80	10	800/-
3.	Seeds	Qtl	150	12	1800/-
4.	Farm yard Manure	Carts	40	30	1200/-
5.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	125	438/-
	b) Potassium Ko	kg	4.50	125	563/-
	c) Phosphorous P_2O_5	kg	3.00	250	750/-
6.	Irrigation (FIR)Rabi				800/-
7.	Nursery preparation				
8.	Special operation		LS		100/-
9.	Miscellaneous				
	a) Rental value		LS		600/-
	b) Plant protection				
	c) Overhead cost				
	d) Implements				
	Cost of cultivation				11,951-

II Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
Main product	200	100	20,000/-
By product			
Gross benefits/ha			20,000/-
Net Benefits/ha			8,049/-

Say 8050/-

Table 6.7 : Benefit Calculations of Crop/Ha. - Crop Mustard

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	50	1250/-
2.	Bullock/tractor	Day/hr	80	10	800/-
3.	Seeds	kg	15	5	75/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	50	175/-
	b) Potassium Ko	kg	4.50	20	90/-
	c) Phosphorous P_2O_5	kg	3.00	20	60/-
5.	Irrigation (FIR)Rabi				150/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection		LS		500/-
	c) Overhead cost				
	d) Implements				
	Cost of cultivation				3,100

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	10	800	8,000/-
	By product			
	Gross benefits/ha			8,000/-
	Net Benefits/ha			4,900/-

Table 6.8 : Benefit Calculations of Crop/Ha. - Crop Gram

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	40	1000/-
2.	Bullock/tractor	Day/hr	80	6	480/-
3.	Seeds	kg	8	50	400/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	40	140/-
	b) Potassium Ko	kg	4.50	60	270/-
	c) Phosphorous P_2O_5	kg	3.00	40	120/-
5.	Irrigation (FIR)Rabi		LS		500/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection		LS		500/-
	c) Overhead cost				
	d) Implements				
	Cost of cultivation				3,410

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	15	500	7,500/-
	By product	15	6	90/-
	Gross benefits/ha			7,590/-
	Net Benefits/ha			4,150/-

Table 6.9 : Benefit Calculations of Crop/Ha. - Crop Peas

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	60	1500/-
2.	Bullock/tractor	Day/hr	80	6	480/-
3.	Seeds	kg	6	80	480/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	40	140/-
	b) Potassium Ko	kg	4.50	60	270/-
	c) Phosphorous P_2O_5	kg	3.00	40	120/-
5.	Irrigation (FIR)Rabi		LS		500/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection		LS		500/-
	c) Overhead cost		LS		500/-
	d) Implements				
	Cost of cultivation				3,990/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	15	500	7,500/-
	By product			
	Gross benefits/ha			7,500/-
	Net Benefits/ha			3,510/-

Table 6.10 : Benefit Calculations of Crop/Ha. - Crop Masoor

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	60	1500/-
2.	Bullock/tractor	Day/hr	80	10	800/-
3.	Seeds	kg	28	40	1120/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	25	70/-
	b) Potassium Ko	kg	4.50	40	180/-
	c) Phosphorous P_2O_5	kg	3.00	20	60/-
5.	Irrigation (FIR)Rabi		LS		500/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				
	c) Overhead cost		LS		500/-
	d) Implements				
	Cost of cultivation				4,730/-

	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
II				
	Main product	12	800	9,600/-
	By product	100	10	100
	Gross benefits/ha			9,700/-
	Net Benefits/ha			4,970/-

Table 6.11 : Benefit Calculations of Crop/Ha. - Crop Barseem

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	50	1250/-
2.	Bullock/tractor	Day/hr	80	6	480/-
3.	Seeds	kg	25	20	500/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	150	525/-
	b) Potassium Ko	kg	4.50	50	225/-
	c) Phosphorous P_2O_5	kg	3.00	50	150/-
5.	Irrigation (FIR)Rabi		LS		500/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				
	c) Overhead cost		LS		500/-
	d) Implements				
	Cost of cultivation				4,130/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	300	35	10,500/-
	By product			
	Gross benefits/ha			10,500/-
	Net Benefits/ha			6,370/-

Table 6.12 : Benefit Calculations of Crop/Ha. - Crop Moong

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate Rs.	No.of Units	Value in Rs.
1.	Human labour	Day	25	60	1500/-
2.	Bullock/tractor	Day/hr	80	8	640/-
3.	Seeds	kg	20	20	400/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	20	70/-
	b) Potassium Ko	kg	4.50	40	180/-
	c) Phosphorous P_2O_5	kg	3.00	20	60/-
5.	Irrigation (FIR)Rabi		LS		600/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				
	c) Overhead cost		LS		500/-
	d) Implements				
	Cost of cultivation				4,150/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	8	900	7,200/-
	By product			
	Gross benefits/ha			7,200/-
	Net Benefits/ha			3,050/-

Table 6.13: Benefit Calculations of Crop/Ha. - Crop Sugarcane

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate in Rs	No.of Units	Crop Ist yr. value Rs.	Crop II Yr. value Rs.
1.	Human labour (including harvesting)	Day	25	275	6875/-	3437/-
2.	Bullock/tractor	Day/hr	80	30	2400/-	600/-
3.	Seeds	kg	70	20	1400/-	--
4.	Fertilizer					
	a) Nitrogen N_2O	kg	3.50	200	700/-	700/-
	b) Potassium Ko	kg	4.50	50	225/-	225/-
	c) Phosphorous P_2O_5	kg	3.00	80	240/-	240/-
5.	Irrigation (FIR)Rabi				2000/-	2000/-
6.	Nursery preparation					
7.	Special operation				600/-	600/-
8.	Miscellaneous					
	a) Rental value					
	b) Plant protection				1000/-	1000/-
	c) Overhead cost					
	d) Implements					
	Cost of cultivation		Total		15,440/-	8,802/-

II	Benefits/Ha.	Qnt/ha	Rate Rs/ha	Amount	Qntl. ha	Rate Rs/ha	Amount
	Main product	500	50	25,000	450	50	22,500
	By product			200			200
	Gross benefits/ha			25,200			22,700
	Net Benefits/ha			9,760			13,948

First crop benefit = 9760

Second crop bebefit = 13948

Total benefits for two years = 23,708 Average benefit = 11,850

Table 6.14: Benefit Calculations of Crop/Ha. - Crop Arhar

I Cost of Cultivation Rs./Ha.

	Input Break-up	Unit	Rate in Rs	No.of Units	Value in Rs.
1.	Human labour (including harvesting)	Day	25	60	1500/-
2.	Bullock/tractor	Day/hr	80	10	800/-
3.	Seeds	kg	15	15	225/-
4.	Fertilizer				
	a) Nitrogen N_2O	kg	3.50	20	70/-
	b) Potassium Ko	kg	4.50	30	135/-
	c) Phosphorous P_2O_5	kg	3.00	20	60/-
5.	Irrigation (FIR)Rabi		LS		750/-
6.	Nursery preparation				
7.	Special operation				
8.	Miscellaneous				
	a) Rental value				
	b) Plant protection				
	c) Overhead cost		LS		500/-
	d) Implements				
	Cost of cultivation				4,040/-

II	Benefits/Ha.	Qnty/ha	Rate Rs/quintal	Amount Rs.
	Main product	10	1000	10,000/-
	By product	20	5	100/-
	Gross benefits/ha			10,100/-
	Net Benefits/ha			6,060/-

Table 6.15 : Net benefits and benefit per unit of water

Sl. No.	Crop	Adopted prdouc-tivity T/ha	Gross income Rs/ha	Net benefit Rs./ha	Water depth FIR m	Net benefit/ unit of water Rs./ha.m
X_1	Rice	3.5	11,200	4800	1.07	4,486
X_2	Maize	2.5	8,000	4075	0.065	62,692
X_3	Urd	0.8	9,700	6340	nil	nil
X_4	Groundnut	1.8	18,000	9160	0.112	81,786
X_5	Kharif Fodder	--	--	4000	nil	nil
X_6	Wheat	3.5	14,350	6790	0.211	32,180
X_7	Potatoes	20.0	20,000	8050	0.273	29,487
X_8	Mustard	1.0	8,000	4900	0.076	69,474
X_9	Rapeseed	1.0	7,500	4150	0.167	24,850
X_{10}	Gram	1.5	7,590	4180	0.209	20,000
X_{11}	Peas	1.5	7,500	3510	0.200	17,550
X_{12}	Masoor	1.2	9,700	4870	0.295	16,847
X_{13}	Berseem	3.0	10,500	6370	0.198	32,172
X_{14}	Moong	0.80	7,200	3050	0.319	9,561
X_{15}	Zaid Fodder	--	--	2800	0.319	8,777
X_{16}	Sugarcane	50.0	23,973	11,850	0.715	16,573
X_{17}	Arhar	1.0	10,100	6,060	0.270	22,444

Table 6.16 : Water requirement existing cropping pattern

Sl.No.		Irrigated area ha	Unirrigated area ha	Total area ha	Avg. prod. ton/ha	Annual field irrigation req. m	Water req. for irrigated area (ha/m)
X_1	Rice	34,435	26,269	60,704	2.73	1.073	36,948.8
X_2	Maize	97	482	579	0.89	0.065	6.3
X_3	Urd	927	2,488	3,415	0.54	--	--
X_4	Groundnut	8	5,095	5,103	0.78	0.112	0.9
X_5	Kharif Fodder	406	35,293	35,699	--	--	--
X_6	Wheat	91,390	20,562	111,952	2.3	0.211	19,283.3
X_7	Potatoes	451	30	481	1.88	0.273	123.1
X_8 X_9	Mustard Rapeseed	1,578	1,063	2,641	0.73	0.12	189.4
X_{10}	Gram	516	1,257	1,773	0.61	0.209	107.8
X_{11}	Peas	399	287	686	1.04	0.200	79.8
X_{12}	Masoor	837	4,491	5,328	0.48	0.215	180.0
X_{13}	Berseem	7,209	728	7,937	--	0.198	1,427.4
X_{14}	Moong Zaid	567	75	642	0.45	0.319	180.9
X_{15}	Zaid Fodder	3,620	265	3,887	--	0.319	1,154.8
X_{16}	Sugarcane	147,202	24,810	172,012	45.0	0.790	116,289.6
X_{17}	Arhar	30	835	865	0.62	0.270	8.1
						Total	175,980.1

Table 6.17 : Net Benefits - Existing Cropping Pattern

Sl. No.	Crop	Irrigated area (ha)	Net Benefit Rs./ha.	Total Benefit for irrigated area mill Rs.	Un-irrigated area	Net Benefit Rs./ha.	Total for Unirrigated area Mill Rs.
X_1	Rice	34,435	4,800	165.288	26269	2400	63.046
X_2	Maize	97	4,075	0.395	482	2038	0.982
X_3	Urd	927	6,340	5.877	2488	3170	7.887
X_4	Groundnut	8	9,160	0.073	5095	4580	23.351
X_5	Kharif Fodder	406	4,000	16.24	293	3000	105.879
X_6	Wheat	91,390	6,790	620.538	20562	3395	69.808
X_7	Potatoes	451	8,050	3.631	30	4025	0.121
X_8	Mustard	1,578	4,900	7.101	1063	2250	2.392
X_9	Rapeseed	--	4,150				
X_{10}	Gram	516	4,180	2.157	1257	2090	2.627
X_{11}	Peas	399	3,510	1.400	287	1755	0.504
X_{12}	Masoor	837	4,970	4.160	4491	2485	11.160
X_{13}	Berseem	7,209	6,370	45.921	728	3685	2.638
X_{14}	Moong	567	3,050	1.729	75	1525	0.114
X_{15}	Zaid Fodder	3,620	2,800	10.136	267	1400	0.374
X_{16}	Sugarcane	147,202	11,850	1744.344	24810	5925	147.00
X_{17}	Arhar	30	6,060	0.182	835	3030	2.530
			Total	2629.172			440.458

Note : Total benefits for irrigated area taken on basis of full optimal irrigation, and for unirrigated area taken as 50% for all other crops and 75% of chari (i.e. Juar, fodder) comes to Rs. 3069.6 mill. Actually irrigation water available is only 65% of optimal. Assuming 70% benefits for sub-optimally irrigated area, these come to Rs. 1840 million and total benefits to Rs. 2280 mill. This is the realistic figure.

Table 6.18 : Optimal crop pattern - no crop area constraints

Sl.No.	Crop	Net benefit Rs./hac	Area ha	Total benefit Rs.
X_4	Groundnut	9160	3,41,500	3128.14
X_6	Wheat	6790	1,70,750	1159.34
X_7	Potatoes	8050	1,70,750	1974.54
			6,83,000	6262.02

Table 6.19 : Net Benefit Studies G and E

		Study E			Study G	
Sl. No.	Crop	Net benefit Rs/ha.	Area ha.	Total benefit Rs.mill	Area ha	Total benefit Rs.mill
X_1	Rice	4800	50,000	240	60,000	288.0
X_2	Maize	4075	1,000	4.08	58,787	339.6
X_3	Urd	6340	78,000	494.52	30,000	190.20
X_4	Groundnut	9160	30,000	274.80	30,000	274.80
X_5	Kharif Fodder	4000	36,000	144.00	36,000	144.00
X_6	Wheat	6790	150,000	1018.5	145,949	990.99
X_7	Potatoes	8050	50,000	402.5	50,000	402.50
X_8	Mustard	--	--	--	--	--
X_9	Rapeseed	4150	17,500	72.63	1,551	6.44
X_{10}	Gram	4180	2,000	8.36	2,000	8.36
X_{11}	Peas	3510	1,000	3.51	1,000	3.51
X_{12}	Masoor	4970	6,000	29.82	6,000	29.82
X_{13}	Berseem	6370	13,000	82.81	13,000	82.81
X_{14}	Moong	3050	40,500	123.53	703	2.14
X_{15}	Zaid Fodder	2800	4,000	11.20	4000	11.20
X_{16}	Sugarcane	11850	100,000	11.85	120,000	1422.00
X_{17}	Arhar	6,060	2,000	12.12	2,000	12.12
			Total	4,107.38		4107.79

CHAPTER - 7

IMPACT OF INCREASED AGRICULTURAL PRODUCTION ON ECONOMY

7.0 INTRODUCTION

Before discussing the impact of increased agricultural production on overall economy, it would be pertinent to examine the present state of agriculture and the reasons for its backwardness in relation to more advanced economi es. From this would logically follow, the measures required for a more rapid stimulation of growth than has been possible so far.

India gained her independence from almost 200 years of British rule in 1947. Out of these for the first hundred years India was governed by a commercial entity, the East India Company, whose candidly professed objective was to earn profits for its share holders, not to administer the territory for the welfare of the governed. It was a period of explicit and ruthless exploitation, the deliberate destruction of India's craft based manufactures and exports, and forcing a larger proportion of the population to subsist on land. On land, the poor agriculturist was crushed by heavy taxation and insecure tenancy under the parasitic zamindari system imposed by the British through permanent settlement of Lord Cornwallis.

In 48 years from 1860 to 1908, India experienced twenty famines and droughts, eight of them in Ganga Basin. The Ganga basin, the granary of India till the middle of 18th century had by the middle of 19th century, become agriculturally backward and impoverished. Blyn's study of agricultural trends in India from 1891 to 1947 shows that in Greater Bengal (comprising present day Bengal, Orissa, Bihar and Bangladesh) there was a decline of 0.06% per year in aggregate acreage. The growth rate of yield for all crops for British India during the period was a meagre 0.01% but in Greater Bengal it was minus 0.34% and in U.P. minus 0.05%.

This was the period in which the first industrial revolution was taking roots in Europe; India under foreign rule was deliberately excluded from it. What would have happened under Indian rulers is difficult to conjecture - but looking at Thailand and Japan, it would be a reasonable assumption, that we would perhaps not have been worse off, than we were in 1947, with expectancy of 30 years of life at birth.

7.1 POST INDEPENDENCE STRATEGY

Based on Nehru's conviction that planned development was essential for India's growth, the Planning Commission was established in 1950. From the very beginning, policy makers were faced with `a historically unprecedented situation in the sense that structural transformation of a backward society with a very low technological base was sought to be achieved within the framework of political democracy with full adult suffrage'. (Chakravarty 1980) (9), Secondly Nehru decided in favour of mixed economy, neither allowing free play to market forces, which tend to promote disparity and can be ruthless to the weaker sections, nor imposing a state monopoly. In spite of distortions which entered later, few would question that it was the right decision at the time. Thirdly it was appreciated, after Mahalanobis drew pointed attention to it, that the limiting factor to development was not only inadequate levels of domestic savings but also the inadequacy in production of capital goods. This led to over emphasis on import substitution and to some distortions in economic growth. The current emphasis is on faster growth through technological upgradation, expansion of infrastructure and policy reforms aimed at liberalisation, removal of controls and increasing competitiveness.

The basic objective of planned economic development in our country has been to achieve rapid structural transformation in order to improve the standard of living of the vast majority of our population. This process involves three types of simultaneous transitions namely, agrarian, industrial and demographic. The success of this process depends on the speed with which the above mentioned three transitions take place and the extent of changes in occupational structure of the population corresponding to changes in the structure of production.

It can be seem from Fig.1.1, and Table 7.1 that the share of agriculture declined from 47% in 1965 to 30% in 1987, while that of industry increased from 22 to 30% and that of services sector increased from 31 to 40% during the same period. On the other hand the share of labour force declined only marginally from 73 to 70%, while increase in labour force engaged in industry and services sector was marginal. In other words, though there has been a substantial change in the structure of output (GDP) in the Indian Economy, this has not been accompanied by a corresponding change in the occupational structure of labour force. The high rate of population growth from 361 million in 1947 to an estimated 960 million in 1997, (an average 2% compound growth rate) has resulted in a high rate of growth in labour force, and deterioration in per capita availability of cultivated land from 0.42 ha in 1951 to about 0.16 ha in 1997. The situation in U.P. is even more adverse than the national average. In order to overcome the serious constraints on land, our agricultural development strategy has had to lay stress on role of large scale investment in irrigation, research and extension along with public policies relating to agricultural prices and subsidies on inputs.

Table 7.1 : (After Chakravarty)

Structural changes in Production and Labour Force in India 1965 to 1987, (percent)

Distribution	Year	Agriculture	Industry	Services
G.D.P	1965	47	22	31
	1987	30	30	40
Labour Force	1965	73	12	15
	1987	70	13	17

This strategy has enabled the country to achieve a substantial increase in food production, from an average of 52 m tonnes in 1950's to 195 m tonnes now, an increase of 3.5 times, which has given us a fair measure of food security, freedom from dependence on imports, and resilience to face adverse weather conditions. Yet, increase in population has limited increase in per capita grain availability from 480 gms per day to 508 gms/day; in fact the per capita availability of pulses has declined form 71.8 gms in 1957 to 37 gms now. Considering that pulses are the main source of proteins for vegetarians and low income groups, this is a matter of concern. Availability of milk and its products has no doubt increased, but they are priced beyond the means of half the population. It is an unpleasant truth that the standard of nutrition of Indians in lower income groups has declined after five decades of independence. About half the children in India are found to suffer from malnutrition. In comparison per capita per day food grain availability is 883 gms in China, 783 gms in Indonesia and 583 gms in Egypt. In prosperous countries like USA it exceeds 2 kg.

However, this strategy, though improving productivity of land, has not helped in increasing employment opportunities in agriculture to the required extent.

The basic socio-economic indicators (1990-91) for India, Bangladesh and Nepal are given in Table 7.2. The latter two countries are among the few which rate lower than India in HDI. The HDI, for UP is an apalling 0.07 and for Bihar 0.11 against 0.309 for India.

Table 7.2 : Basic Socio - Economic Indicators (1990-1991)*

	Nangladesh	India	Nepal
Population (million	109.90	862.70	18.50
Population growth rate (percent)	2.03	1.80	2.10
Density (per sq km)	740.00	263.00	128.00
Crude birth rate (per 1000)	31.60	27.50	29.60
Crude death rate (per 1000)	11.00	9.40	NA
Infant mortality rate (per 1000)	111.00	90.00	102.00
Total fertility rate (per woman)	4.23	4.00	5.60
Life expectancy (years	51.80	59.10	52.20
Adult literacy (percent)	35.30	48.20	25.60
Adult literacy-female (percent)	22.00	39.00	13.00
Adult literacy-male (percent)	47.00	64.00	38.00
Females as percentage of males	94.00	93.00	95.00
Urbanization (percent)	16.00	27.00	10.00
Daily per capita calorie supply (percentage of requirements)	88.00	101.00	94.00
Population with access to health services (1987-90)	74.00	NA	NA
Population with access to safe water (1988-90)	78.00	75.00	37.00
Population with access to sanitation (1988-90)	12.00	13.00	6.00
Public expenditure on education (% of GNP 1988-90)	2.20	3.20	2.90
Public expenditure on health (percentage GNP 1988-90)	0.90	3.20	0.70
Per capita GNP (US $)	210.00	360.00	170.00
Human Development Index (HDI)	0.189	0.309	0.170
Ranking in HDI	147.00	134.00	152.00
Population below poverty line (percent, 1990)	86.50	48.00	60.70

from Converting Water into Wealth

Sources : UNDP, Human Development Report, 1992 and 1993
Statistical year book of Bangladesh, 1992 (57)
Census Index 1991

NA - Not available

Note : Poverty indices computed nationally, based on calorie intake only, are lower in all the three countries. UNDP index takes into account other basic necessities of life.

7.2 THE SETTING FOR DEVELOPMENT

The land and population statistics for Bijnor District have been given in Chapter 2. These are representative of an agrarian district in Western U.P., better than other regions of U.P. but more adverse than the average for India as shown in Table 7.2.

7.2.1 Institutional Change

Immediately after independence, high priority was accorded to agrarian reorganisation. In the first phase, the aim was to abolish all forms of intermediary or feudal land rights with a view to give land to the tiller. In the second phase the attention was focussed on the consolidation of holdings. In the third phase, it was hoped to achieve a more equitable distribution of land by imposition of land ceilings and redistribution of surplus land to the land less, and to promote co-operative farming. Very limited success has been achieved in this last objective and with the changed outlook of liberalisation or in plain words of capitalistic production and economy, little can be expected in future.

(a) Zamindari Abolition and Tenancy Reforms. The U.P. Government passed. `The Uttar Pradesh Zamindari Abolition and Land Reforms Act' in 1951. It was one of the most progressive measures of land reform introduced anywhere in the country (Singh 1987) (50). The Act abolished all intermediary rights in land and brought the actual tiller of the soil in direct contact with the state. Among other progressive features of the Act were prohibition of sub-letting, prevention of subdivision of holdings below a minimum size, a ceiling on future acquisition of holdings and vesting of common land in the village community.

The main achievement of land reforms in U.P. was the rationalisation and simplification of tenurial rights and the removal of the parasitic class. The conferment of permanent and heritable right on the tiller removed the motivational hurdle for raising producitivity. The impact on productivity is difficult to assess, the negative factors have been low levels of literacy and health care. Nevertheless, there is no doubt that a sound land tenure system is a pre condition for agricultural growth.

In practice, prevention of sub letting has been largely a failure. In fact, the leasing of land in the form of crop sharing has been increasing even though the share croppers have to pay a heavy rent, often as much as half of the produce. Paradoxically, the technological changes brought about by green revolution have encouraged this trend. Small holdings can ill afford to maintain bullocks or tractors, to invest in quality seeds and fertilisers and have to buy water from their neighbours at high rates. They are thus either forced to lease or sell their own land or to take extra land on crop sharing basis.

(b) Consolidation of Holdings - Holdings in U.P. are not only small but were also highly fragmented. Though effort was initiated from 1918-19 and Act was passed in 1939, progress was very slow till 1953-54 with consolidation of only 1.84 lakh ha. The U.P. Consolidation of Holdings Act was passed in 1953 which provided for consolidation on a comprehensive and compulsory basis. Under this Act very good success has been achieved, an area of 61 lakh ha having been consolidated till 1982-83. This is one of the more successful achievements of U.P. Govt.

(c) Land Ceilings and Co-operative Farming - The `Imposition of Ceilings on Land Holdings, Act', of U.P. was passed in 1960. The ceiling on fair quality of land for upto 5 family members was 16 ha. The maximum limit for larger families was 25.6 ha. There were further exemptions for various categories of land. The Act proved to be almost totally ineffective. The land ceiling Act was amended in 1972 in which the family of the tenure holder has been taken as the unit and the ceiling has been fixed at 7.3 ha of irrigated land. In addition 2 ha. were allowed for each major son subject to a maximum of 6 ha. The number of exempted categories was reduced. Against an estimated surplus of 2.96 lakh ha in U.P. by end of 1962 only 1.05 lakh ha could be taken possession of and 0.94 lakh ha settled on landless. Even if the full target could be achieved it would make very little impact on the landless labourers, as their numbers are far too large.

The programme of co-operative farming was encouraged in the early years of planning but has made no head way and little impact on farming practices in U.P.

7.3 LAND DISTRIBUTION

The Zamindari system having been abolished, the pattern of ownership of land in India is predominantly small, privately owned farms. Most of the holdings are uneconomically small, and the holding size in U.P. is even much smaller than for the country as a whole as can be seen from the following Table 7.3.

Table 7.3 Distribution of Land Holdings

Holding size	Percentage of House holds		Percentage of Land	
	India	U.P	India	U.P
Below 2 ha	49	83.40	24	42.67
2 to 10 ha	21	16.04	53	51.8
More than 10 ha	3	0.47	23	6.0

Even in the category below 2 ha. 40% of the house holds own less than 0.4 ha and account for only 3.9% of land in U.P. For Bijnor Distt. the holdings below 2 ha are 78.2% occupying an area of 36.7%, from 2 to 5 ha. the holdings are 17.5% occupying an area of 38.8% and more than 5 ha 4.3% with an area of 24.5%. The pattern in Bijnor more or less conforms to that of U.P. Almost three quarter of the area is in holdings, of less than 5 ha. Thus increased productivity has to take this into account - it will have to follow the pattern of Japan, Korea, Taiwan and Indonesia not that of USA, Canada, or Australia. This means intensive effort at better seeds, scientific irrigation, balanced fertilizer and manure application, pest control but not large scale mechanisation.

7.4 INFRASTRUCTURE

The characteristics of land and its ownership have been given in Chapter 3 and articles 7.2 and 7.3. The next step is to take a look at infrastructure requirements. These will be considered in the category of physical inputs and human resource requirements.

7.4.1 Irrigation

The most important input without which no progress is possible, is irrigation. India has monsoonic climate with rainfall limited to 3 to 4 monsoon months. Intensive agriculture with high yields would be impossible without Irrrigation. Numerous studies have been made on the benefits, economic and social, of Irrigation. A few only need to be quoted here. The impact of irrigation may be considered under the following headings.

(i) Increased cropping intensity - While there is very little scope for increase in net cropped area, the gross cropped area can be increased with availability of water. In Binjor District the present cropping intensity (counting sugar cane once) is about 128%. With proposed crop planning it comes to 164%. Since sugar cane occupies the land for most of the year, if sugar cane is counted twice, the intensity with proposed cropping pattern rises to 200%.

(ii) Increased yields -The yield per hectare of all crops rises significantly with irrigation, particularly when co-ordinated with other inputs. A striking analysis carried out by B.D.Dhawan (1986) (16) for four states in the country shows that average yields in canal irrigated lands are 3.8 times and tube well irrigated land 7.5 times those in unirrigated land. He has also shown that in Gandak and Sarda Sahayak commands which have several drawbacks, there has been an increase in production by 127% and 148% respectively. There are several other studies for different parts of the country which give similar results.

For Bijnor Distt. with optimal use of water and revised cropping pattern the production of cereals (wheat, rice maize) increases from 4.23 lakh tons to 8.68 lakh tons, or 205%, that of pulses from 6.48 thousand tons to 36.26 thousand tons or 560% and of oil seeds from 5.91 thousand tons to 55.55 thousand tons or 940%. The sugar cane productivity, increases but due to proposed reduction in area from 1,72,012 ha to 120,000 ha the production goes down from 7.74 lakh tons to 6.0 lakh tons or to 77.5%. This is in over all economic interest of the farmers.

(iii) Stabilisation of Production - Based on Study of trends between 1970 and 1983 in 11 states Dhawan has found (quoted in World Bank study (1991) (58) that the coefficient of variation in cropped area was 1.9 in irrigated and 2.9 in non-irrigated lands, while that of yield was 4.3 in irrigated and 9.3 in unirrigated lands. Consequently the impact of adverse weather conditions is greatly reduced.

(iv) Crop diversification - Irrigation results in greater increase in production of higher value crops and more cash crops for the farmers.

(v) Impact on employment and Income - Studies have shown that employment increases by 30% to 50% and wage rates also rise after introduction of Irrigation (Robert Chambers 1983). (11).

There is reduced migration, more permanent shelters and less families with absentee father or parents. This leads to better care and education for children.

S.D. Sharma (1991) (46) reports in detail on the many faceted benefits recorded in irrigated areas. He has reported increased employment from 40 to 60% in states of Maharashtra and Rajasthan. He also reports significant improvements in household income, consumption and asset formation. In Dantiwala and Rajasthan canal commands the average household income was 1.5 and 2.2 times respectively for irrigated than for unirrigated households. He also finds better education and social mobility in irrigated areas.

There is a sharp reduction in poverty levels after introduction of irrigation. This is conclusively demonstrated from the following figures based on a study by Rao et al (1988) quoted by World Bank Review (1991) (41).

Table 7.4

Percent Gross Area with Irrigation	Percentage of Population below poverty line
Below 10	68.8
20 to 30	45.6
Above 50	26.5

Fortunately, Bijnor Distt. is well endowed with water potential. Thus with skillfull harnessing of water resources, the optimal crop planning proposed can be based on meeting the consumptive use requirement of all the crops. This will result in all the benefits described above to the people of the district. There is a direct increase of 15.9 million mandays in Bijnor Distt. due to increase in irrigated area. This implies employment for 79,500 labourers for 200 days in the year (Tables 7.5 - 7.6).

7.4.2 Quality Seeds

Modern crop technology is based on improved seeds capable of yielding, in the case of cereals 2 to 4 times the average yields of traditional cultivation. This capability is based on the capability of the new High yielding varieties (HYV) to absorb larger quantities of chemical fertilisers without lodging or falling over of the plants. The plants are bred to have shorter heights and thicker stems. Other qualities aimed at are better disease resistance, shorter growing season, and better qualities like nutrition or taste. It is the introduction and wide spread

Table 7.5 : Agricultural Labour for Existing Pattern

Crop	Irrigated Area, ha.	No.of mandays ha.	Total mandays thousands	Unirri-gated area,ha	No.of man-days ha	Total man-days/ha
Rice	34,435	100	3443.5	26269	50	1313.45
Maize	97	70	6.09	482	35	16.87
Urd	927	50	46.35	2488	25	62.20
Groundnut	8	125	1.0	5095	63	320.985
Kharif, fodder	406	20	8.12	293	20	5.86
Wheat	91,390	125	11423.250	20562	63	1295.406
Potatoes	455	200	91.0	30	100	3.00
Mustard	1578	50	78.9	1063	25	25.575
Rapeseed Gram	516	40	20.64	1257	20	25.14
Peas	399	60	23.94	287	30	8.61
Masoor	837	50	41.85	4491	25	112.275
Barseem	7209	50	360.450	728	25	18.20
Moong	567	60	34.02	75	30	2.250
Zaid fodder	3620	50	181.0	267	25	6.675
Sugarcane	147202	275	40480.55	24810	138	3423.780
Arhar	30	60	1.8	835	30	25.050
		Total	56242.46			6666.32

Grand total 62,908.78 thousand man days

Table 7.6 : Agricultural labour and fertilisers for optimal pattern

Crop	No.of mandays	Area ha.	Total/No. mandays thousands	Fertiliser quantity kg/ha	Total tonnes
Rice	100	60,000	6000.00	250	15000.00
Maize	70	58,797	4115.80	110	6467.67
Urd	50	30,000	1,500.00	85	2550.00
Groundnut	125	30,000	3,750.00	180	5400.00
Kharif, fodder	20	36,000	720.00	nil	nil
Wheat	125	145,949	18,243.60	210	30649.20
Potatoes	200	50,000	10,000.00	500	25000.00
Mustard Rapeseed	50	1,551	77.55	90	139.59
Gram	40	2,000	80.00	140	280.00
Peas	60	1,000	60.00	140	140.00
Masoor	50	6,000	300.00	85	510.00
Barseem	50	13,000	650.00	250	3250.00
Moong	60	70,302	42.18	80	56.24
Zaid fodder	40	4,000	160.00	nil	nil
Sugarcane	275	120,000	33,000.00	330	39600.00
Arhar	60	2,000	120.00	70	140.00
		Total	78,819.13		1,29,162.00

Additional mandays due to optimal cropping pattern, 78819.13 - 62908.78 = 15,910.35 thousands use of HYV which has resulted in a dramatic inrease in the production of wheat and rice in particular, and other crops in general.

There are six important links needed to produce and reach improved seeds to the farmers (Shenoi 1975) (48).

1) Genetic engineering for evolving better seeds - This is the function of ICAR and state level institutes and Agricultural universities. Initiated into the technique by Nobel Prize Winner Norman Borlaug for wheat in 1960's, Indian Scientists have adapted to it thoroughly and contributed commendably in respect of most crops.
2) Production of foundation seeds for multiplication - This is done initially by the same Institutes, but then also by approved farms, mostly in the public sector e.g. Suratgarh Farm.
3) Production of certified seed for sale to farmers. This is done in Institutional or Public sector organisations but more so in progressive farmers farms on contract. Strict supervision is maintained by the certifying agency.
4) Seed processing packing and storage
5) Quality control and certification and, finally
6) Seed distribution and marketing

Considerable progress has been made in all these steps. Distribution and marketing is often hampered by poor transport. Some of the new varieties are in short supply and the farmer has to pay exorbitant prices for them.

In Bijnor distt. almost 80% of wheat area and 60% of rice is under HYV varieties. For sugar cane also, mostly improved varieties are being used. There is considerable scope for further extension in case of rice, pulses, oil seeds and maize.

7.4.3 Fertiliser Supply and Services

Balanced use of chemical fertilisers is central to sustained growth rate in agricultural production. There are some voices cautioning against the use of chemical fertilisers and forecasting long term poisoning of land. That their fears are largely misplaced is proved by farms in Germany, USA etc. which have been using chemical fertilisers for almost a century and have not suffered any ill effects. Of course, it is necessary to use organic manure, animal dung or green manure also to maintain porous soil structure and supply micro-nutrients. But the quantity of main chemicals taken out from the soil by intensive cropping of high yielding varieties simply cannot be replaced by organic manure alone. Fertilisers make the largest single contribution to additional production, as much as 50 to 70%. For one rupee worth of fertilisers added, three ruppes worth of additional yield should be obtained - thus they greatly enhance the profit of the farmer. It may be stressed again, that availability of irrigation is sine qua non - a prior requirement for application of chemical fertilisers.

In India the use of chemical fertilisers has taken off from 1961-62 when the consumption was a mere 3.94 lakh tons. It rose to 26.5 lakh tons in 1971-72 and 91 lakh tons in 1987-88. The present consumption is estimated at 130 lakh tons. Above 80% demand is met from indigenous production and the rest has still to be imported. There are no sources of potash in the country, and it has to be almost entirely imported.

For optimum returns it is necessary to use the necessary quantities and combination of fertilisers after testing the soil. use of excess fertilisers is wasteful and pollutes the water ways on being washed into them by rain. The preconditions for getting the best response from fertiliser use are (Shenoi 1975) (48).

a) The fertiliser used should meet the nutritional deficiency of the soil
b) It should meet the nutritional requirement of the crop
c) The fertiliser product should suit the soil and the crop, and
d) There should be an optimum combination of other improved inputs (seeds, water, pesticides) and cultivation practices

Fertilisers are sold to farmers in India at subsidised rates. As the procurement prices for the produce are based on these subsidised rates, the beneficiary is not so much the farmer as the consumer.

The fertiliser consumption in Bijnor district in 1991 was as below

Nitrogen	43,460 mt (metric tonnes)
Phosphorus	8,631 mt
Potash	2,718 mt
Total	54,809 mt

It comes to an average of 132.5 kg/ha over the entire cropped area of 4.137 lakh ha, which is considerably larger than 72 kg/ha for India as a whole. For the proposed cropping pattern, the fertiliser requirement is worked out as 1.29 lakh tonnes which comes to 230 kg/ha on cropped area of 5.61 lakh ha. It is seen that fertilizer consumption in Bijnor is already quite high by National average due to dominance of sugar cane as dominant cash crop but needs further to be increased by 75%.

7.4.4. Plant Protection

In high yield agriculture now being promoted, the importance of plant protection measures increases greatly. Firstly, the more succulent plant growth attracts more pests and nourishes more weeds. While some resistance to pests and diseases has been genetically built into exotic varieties, they are still susceptible to pests and diseases and require protective measures. Secondly, the farmer makes higher investments in cultivation of HYV's which has to be protected.

The loss suffered in the field due to pests, diseases, rodents, weeds and parasites etc. may be as high as 20%, which represents a colossal amount. The benefit cost ratio for seed treatment has been reported to be as high as 10 to 45, while that for preventive sprays is about 3. In many agriculturally advanced countries, the value of pesticides is estimated to be 33% of fertilisers while in India, it does not exceed 10% (Shenoi, 1975). All pesticides are harmful to the environment, and already there are protest groups opposing use of chemical pesticides. Some, which were found dangerous have been banned. Research work is in progress all over the world to promote biological protection. Some success has been achieved with products based on Indian neem tree. While pesticides have to be used with restraint, and gradually replaced with more environment friendly methods, giving them up now is not practical.

There are reported to be 714 stores for pesticides in Bijnor District, which indicates reasonably good distribution network. Data of quantitative consumption is not available.

7.4.5 Farm Credit Service

Modern agricultural technology requires heavy investment in current inputs. eg. as shown in Chapter 6, sugar cane requires input cost of about Rs. 12,125/- and wheat of about Rs. 7560/- per ha. Most Indian farmers can not raise such amounts from their own savings, in fact the vast majority have hardly any savings at all. Hence availability of other inputs will be of no benefit to them unless credit is also made available on reasonable terms. Ideally, the quantum of credit should be related to a good crop plan for the farm, the security required should be within the capability of the farmer and the period of repayment should be within the farmer's paying capacity. The farmer should also be provided with guidance to make best use of the loan money.

Nationalised Banks are required to offer loans on preferential rates to weaker sections of society, particularly small farmers. Co-operative societies are also supposed to meet the credit needs of the farmer and are granted assistance by the Government. All pervading corruption greatly reduces the effectiveness and benefits of these measures. Private loans at relatively high rates of interest still play a significant role in rural credit. The presence of the public agencies has helped to bring down the rates of private loans to about 24 to 36% from the earlier 75% (one anna per rupee per month) or higher.

In Bijnor district credit facilities available are as follows (Table 7.7).

Table 7.7 : Credit Facilities

	Urban	Rural	Total
Branches of Nationalised Bank	51	36	87
Branches of Regional Rural Banks	1	36	37
Branches of non-nationalised banks	35	9	44
Co-operative societies	-	96	96
District Co-operative Bank			

The number of Branches is quite reasonable - There is one branch for about 1500 population. What is needed is thet they fulfil the requirements stated previously and provide the quality of service which is necessary.

7.5 AGRICULTURAL MARKETING

As per proposed crop planning a net income of Rs. 410.7 crores should accrue to the farmers of Bijnor district from their produce. They will retain some part of the produce for their own consumption, but the marketable surplus has to be marketed. Unless efficient and fair marketing system is available, the lion's share of the margin is pocketed by traders and middlemen and the producer gets a raw deal.

The elements of an efficient marketing system are (1) stable and remumerative price level (2) a regulated market system (3) a good storage system, particularly for perishable crops like potatoes, (4) quality conciousness, and quality control including proper processing and packaging and (5) an efficient transportation system.

Government agencies like Food Corporation of India, and state level agencies have done a lot in regulating the market. The mechanism of minimum support price helps to prevent undue fall in prices at harvest time and gives to the farmer a relatively stable price. Nevertheless, there is still a considerable rise in open market price level after one harvest and before the next one. This benefit still goes to the traders and some large farmers who have storage and holding capacity. Nevertheless credit must be given to development of mechanisms for minimum support price, and guaranteed purchase of all that is offered at that price.

The existing system of marketing is generally centred on urban and semi-urban areas. There are eleven development blocks in the District and their locations also serve as mandis. There is a need to develop an heirarchy of marketing centres, which will also be centres of overall growth. Such growth centres have to be developed to have necessary infrastructure, electricity, communications, all weather roads. The transport system is vital not only for marketing but also for distribution of inputs, and dissemination of social services and knowledge. This aspect is so important and besides amenable to rational planning approach that it is discussed in more detail separately, and the methodology illustrated by application to one Tehsil viz Najibabad.

7.6 AGRICULTURAL RESEARCH, EXTENSION AND TRAINING

A strong base of agricultural research is obviously necessary to promote agricultural growth. This was realised in 1960's, and with assistance of PL480 Funds of USA, as well as internal resources, agricultural universities were established in all states or regions. It is their mandate to carry out research directly useful to their area, and to train agricultural graduates and reserach workers. Good work has generally been done by most agricultural Universities. Extension services, which are managed by state governments are not however so efficient. A survey of farmers carried out in irrigated area on Deoband Branch showed that most farmers gained knowledge of new developments like new varietes of seeds, from other farmers, or from radio, very few from official sources (WRDTC Diagnostic

Analysis Report, 1987). More effective and efficient extension services are certainly indicated.

The dissemination of information is far easier with a literate population, with a proportion of better educated individuals among them. The overall literacy rate of 31.8% in Bijnor, in line with the rest of the state is much too low. It is necessary to take urgent and effective steps to bring about rapid spread of literacy, specially among women. This is a basic requirement for reducing fertility and providing better health care to families. Education is also necessary to bring about social change as social backwardness is not only bad in itself, it is also a major obstacle to economic growth.

7.7 THE IMPETUS TO ECONOMIC GROWTH

Direct growth of Agricultural production is not an end in itself; it provides a powerful stimulus to the growth of the entire economy. According to the well known development economist W. Arthur Lewis, `Agricultural stagnation is the main constraint on the rate of growth. It keeps down the living standards of the great majority of the people, and in restricting their purchasing power, restricts also the scope of industrialisation'.

If follows that the planned jump in Agricultural production in Bijnor district must lead to a chain reaction starting with industry directly linked to agriculture.

7.8 FOOD GRAIN BALANCE

The food grain production will be firstly used to meet internal demand, and the surplus will be available for marketing and processing. The 1991 population of the district was 24.55 lakhs. For short term planning, it may be presumed to increase by 25%, or 30.68 lakhs. Assuming non-pulse cereal consumption as 500 gms/capita/day, the annual requirement comes to,

$$\frac{30.68 \times 0.500 \times 365}{1000} = 5.60 \text{ lakh mt.}$$

According to food habits of the people it can be divided as 70% wheat, 20% rice and 10% maize or 3.92 lakh mt of wheat, 1.12 lakh mt of rice and 0.56 lakh mt of maize. Let us further assume 0.3 lakh mt of wheat and 0.2 lakh mt of maize for feeding livestock/poultry. This leaves the following surpluses.

Rice -	2.10 - 1.12	=	0.98 lakh m.t
Wheat-	5.11 - 4.22	=	0.89 lakh m.t
Maize-	1.47 - 0.76	=	0.71 lakh m.t

These quantities are available either for marketing as such or for value added processing.

Pulses - The total production according to proposed crop planning comes to -

Urd	24000 m.t
Gram	3000 m.t
Peas	1500 m.t
Masoor	7200 m.t
Moong	562 m.t
Total	36.262 thousand m.t

This provides a per capita availability of 32.4 gm/capita/day. This is still below requirement though the present production of 6,480 m.t provides a meagre 5.3 gm/capita/day and the balance must be met from outside the district. It should be presumed that for the district as a whole the entire pulse production will be consumed internally.

So far as other crops are concerned the additional production will have to be processed and marketed.

For grain crops and pulses, it may be presumed that milling facilities are available for present production. For additional production including that for internal consumption, additional capacity will be required. The additional production for 12 crops is given in Table 7.8.

In the following paragraphs an attempts is made to assess the number of industrial units needed for processing agricultural produce and the investment and employment generated by them.

7.9 PRIMARY PROCESSING UNITS

a) Dal mills - the total additional production of pulses comes to 36.262 - 6480 = 29,782 m.t. Out of these, some will be consumed whole. From Project Report (SIDC), average processing capacity of one dal mill is 2280 mt/year. Hence 10 such mills will need to be established. These will involve a capital investment of about Rs. one crore and provide employment to 210 persons.

Table 7.8 : Additional Production of Selected Crops

Crops	Present area ha.	Average productivity T/ha	Total production 1000 tonnes	Planned area ha.	Productivity T/ha	Production 1000 tonnes	Additional production 1000 tonnes
Rice	60,704	2.73	165.72	60,000	3.5	210.00	44.28
Maize	579	0.89	0.52	58,797	2.5	147.00	146.48
Urd	3,415	0.54	1.84	30,000	0.8	24.00	22.16
Groundnut	5,103	0.78	3.98	30,000	1.8	54.00	50.02
Fodder	35,699	--	--	--	-	--	--
Wheat	111,952	2.3	257.49	145,949	3.5	511.00	253.33
Potatoes	481	18.8	9.04	50,000	20.0	1000.00	990.96
Mustard Rape seed	2,641	0.73	1.93	1,551	1.0 1.0	1.55	--
Gram	1,773	0.61	1.08	2,000	1.5	3.00	1.92
Peas	686	1.04	0.71	1,000	1.5	1.50	0.79
Masoor	5,328	0.48	2.56	6,000	1.2	7.20	4.64
Berseem	7,937	25.0	198.42	13,000	3.0	390.00	191.57
Moong	642	0.45	0.29	703	0.80	0.56	0.27
Zaid fodder	3,887	--	--	4,000	--	---	--
Sugarcane	172,012	45.0	7740.54	120,000	50.00	6000.00	--
Arhar	865	0.62	0.54	2,000	1.0	2.00	1.95
Total	413,704			561,000			
Total cereals (Rice, maize, wheat)			423.73			867.81	444.08
Total pulses (Urd, gram, peas masoor, moong)			6.48			36.26	29.78
Total oil seeds (Groundnut, mustard, rapeseed)			5.91			55.55	49.64

b) Flour mills - The capacity of a flour mill is taken as 8,100 t/year.

The present production of wheat is estimated as 2.58 lakh m.t and planned production as 5.11 lakh m.t. giving an additional production of 2.53 lakh m.t. The revised internal consumption is 4.22 lakh m.t. Hence additional capacity of flour mills equal to 4.22 - 2.58 = 1.64 lakh m.t. is needed for internal use. Out of the surplus of 0.89 lakh m.t., 0.50 lakh m.t., may be exported as grain and 0.39 lakh m.t. as flour. Hence total milling requirement = 1.64 + 0.39 = 2.03 lakh m.t.

No.of additional flour mills needed are $\frac{2.03 \times 10^5}{8,100}$ = 25 no.

Capital investiment needed = Rs. 25 crores approximately
Employment generated 750 persons.

c) Rice mills - The additional production of rice (paddy) is 44,278 m.t. The entire quanity whether consumed internally or exported has to be milled. If the capacity of one mill is taken as 1200 t/year. number of new rice milling units comes to 44278/1200 = 36.8 or say 37.

These will involve an investment of about Rs. 6 crores and provide employment to 400 persons.

d) Oil expellers for ground nuts - Additional production of ground nuts is 50,020 m.t. About 20% of the produce may be used as roasted nuts. Assume that 40,000 m.t. will be available for oil extraction. The capacity of one unit may be taken as 300 t/year.

Number of units 40,000/300 = 133 units

Capital investment about Rs. 13.30 crores

Employment generated, 1200 persons. There will be further secondary processing to produce refined oil for home use. One or two such large scale units will be viable in the district.

e) Potatoes - For potatoes it is essential to have adequate cold storage capacity. Otherwise distress sales become inevitable. Additional production of potatoes is 9,90,957 m.t. Assuming that 25% can be currently marketed, the number of 500 t cold storage units required will be,

$$\frac{9,90,957 \times 0.75}{500} = 1486 \text{ number}$$

This number seems too large to be accomodated within the district, and some quanity may have to be sent outside for storage. If 1000 units are established within the district, investment needed, Rs. 350 crores approx. Employment generated, 12,000 persons.

f) Processing of maize - As estimated above about 0.71 lakh m.t. of maize will be surplus to the requirements of the district. Maize can be used as raw material for manufacture of starch and also as distillery feed stock for production of alcohol. These are sophisticated high technology industries and possibly two or three plants utilising about 30,000 m.t. can be established within the district, the rest of the quantity may be sold as grain outside the district. Employment potential should be for about 500 persons.

g) Berseem and Zaid Fodder - The substantial additional production of green fodder will give fillip to dairy industry and milk production. There are 4.15 lakh cattle in the district, and it is not the number but the quality and yield which need to be improved. Green fodder is one of the important inputs for increased yield and this is being augmented in the proposed cropping pattern.

7.10 CONTRIBUTION TO OVERALL ECONOMIC GROWTH

As indicated in the previous article, the growth in employment due to direct agricultural processing is not dramatic. However, besides the direct impact, there is also a multiplier effect - with rise of incomes of farmers, farm workers and industrial works, there is demand for consumer goods and services as well social sector services. This leads to increased activity in practically all sectors, both in production and trade.

According John Glasson (1974) (20) the multiplier factor k is defined as -

$$k = \frac{1}{1 - (c-m)(1-t)} \qquad \text{...... (i)}$$

where, c = marginal capacity to consume

or $c = 1 - s$, where s is the marginal capacity to save

m = marginal propensity to import

t = marginal rate of taxation

According to known behaviour pattern of Indian rural population, it will be reasonable to assume that the marginal capacity ot save would be 20%. Bijnor district will be self sufficient, in fact surplus in food, oil seeds etc. but will have to import many items like fertilisers, farm machinery, cloth, electric and electronic goods etc. It will not be unreasonable to assume that 30% of the additional income will go towards purchase of goods from outside, or $m = 0.3$. Agricultural taxation in India is small and may be taken at an average of 5% or $t = 0.05$.

$$\text{Then } k = \frac{1}{1-(0.8-0.3)(1-0.05)} = 2.10$$

Additional agricultural income generated (Tables 6.17, 6.19)

= Rs 410.7 - 228.0 crores

= Rs.182.7 crores

With multiplier effect economic activity generated will be 2.1 x 182.7 = 383.60 crores. For a total population of 30.68 lakhs, it means a per capita addition of Rs. 1250/- to annual income.

7.10.1 Impact on Economic Growth Rate

According to Malassis (1975) (30) if α_a and α_i are the relative size of values added by agriculture and industry (and services) respectively and r_a and r_i the respective growth rates, then,

$$r_Y = \alpha_a r_a + \alpha_i r_i \qquad \ldots\ldots \text{(ii)}$$

where r_Y is the overall economic growth rate. Assigning values of 30% to α_a and 70% to α_i, 2.5 to r_a and 8 to r_i as close to values prevailing in India,

$$r_Y = 0.3 \times 2.5 + 0.7 \times 8 = 6.35$$

or overall growth rate at a moderate 6.35% per annum. As agriculture is a sector which grows relatively slowly, it tends to slow down the overall growth rate. Nevertheless the temptation to give priority to high growth sectors and to reduce the importance of agriculture will be counter productive in the long run. An insufficient growth rate for agriculture can slow down or even obstruct overall development.

But as has been shown by optimisation studies for Bijnor district, the rate of agricultural growth need not always be slow. Without any radical change of technology, simply by optimising the use of available land and water and other inputs an increase of 80% is envisaged in agricultural incomes. Since this does not involve a radical departure in existing practices, there is no reason why it can not be accomplished in 15 years representing a compound growth rate of 4% per annum. In eqn. (ii) if r_a is then changed to 4.

$$r_Y = 0.3 \times 4.0 + 0.7 \times 8.0 = 6.8$$

7.10.2 Effect of Relative Decline of Agariculture

Let Y, Y_a and Y_i be GDPT (total), GDPA (agrl) and GDPI (Indl) respectively, and r_Y, r_a and r_i their respective rates of growth. Then taking incremental values.

$$\Delta Y = \Delta Y_a + \Delta Y_i \qquad \text{... (iii)}$$

Dividing both sides by ΔY, we have

$$\frac{\Delta Ya}{\Delta Y} \quad \frac{\Delta Yi}{\Delta Y} = 1 \qquad \text{...... (iv)}$$

Let $\frac{\Delta Ya}{\Delta Y}$ be called $\alpha a'$

then $$\alpha a' = 1 - \frac{\Delta Yi}{\Delta Y} \qquad \text{........ (v)}$$

But $\Delta Y_i = Y_i \; r_i$ and $\Delta Y = Y r_Y$

then $$\alpha_a' = 1 - \frac{Yi \; ri}{Y r_Y} \qquad \text{..... (vi)}$$

Simplifying we get,

$$\alpha a' = \frac{1}{1 + \frac{Yi \; ri}{Ya \; ra}} \qquad \text{...... (vii)}$$

This formula shows that α', the marginal structural coefficient of agriculture diminishes if the weighted industrial (and services) growth rate is higher than the weighted agricultural growth rate.

According to Malassis, if this process continues, the reduction of marginal coefficent leads to a reduction of the average coefficient in the long run.

7.11 SUMMARY

The following significant quantitative effects are shown to be expected by adoption of proposed crop planning and follow up measures.

1) Increase in agricultural income, Rs. 182.7 crores
   Consequent increase in economic activity, Rs.383.6 crores
2) Increase in cropping intensity
   From 128% to 164%
   (Counting sugar cane once only)
3) Increased employment directly in the farm sector 15.9 million man days or 79,500 workers for 200 days (see Tables 7.5 and 7.6)

   Employment in agricultural processing industries 32,400 persons on a regular basis.
   Increased employment in trade, services etc. will also be substantial and besides the figures given above.

4) Increased Fertiliser Consumption from 54,809 m.t. to 1.29 lakh m.t. or by 74191 m.t

5) Improved nutritional level by providing 500 gms/capita/day of other cereals and 32.4 gms/capita/day of pulses.

7.12 Transport

About 2.2 lakh m.t. of food grains will have to be moved out of the district and additional 74191 m.t of fertilisers brought in. There will also be large scale movement within the district. Other economic goods will also need to be transported into and from the district. Hence the road transport system in the district will need a radical improvement. This aspect is discussed in greater detail later.

CHAPTER - 8

METHODOLOGY FOR PLANNING A RURAL ROAD TRANSPORT NETWORK

8.1 ROLE OF TRANSPORT IN OVERALL DEVELOPMENT

Provision of transport is one of the most important requirements for stimulation of economic activity and growth. Lack of transport condemns an area to backwardness in many ways. In this connection the comment of Robert Chambers (1983) (11) is worth quoting at some length. He states, `Visible development follows main roads. Factories, offices, shops and officials markets all tend to be at the sides of main roads. Even agricultural development has a road side bias. In Tamilnadu agricultural demonstrations of new seeds and fertilizers have often been sited beside main road; and on irrigation system, roads follow canals, so that the farms seen are those of the top enders who receive more water and not those of the tail enders who receive less or none. Services along road sides are also better. An improved tarmac or all weather surface can bring buses, electricity, telephone, piped water supply, and better access to markets, health facilities and schools. Services near main roads are better staffed and equipped. Edward Heneuald found that two schools near a main highway in Sumatra had more than their quota of teachers while a school 1 km off the road had less than its quota'.

Chambers also discusses what he calls the deprivation trap, of which poverty is the main determinant. The other links of the trap are isolation, powerlessness, vulnerability and physical weakness Isolation (lack of education, remoteness, being out of contact) sustains poverty services do not reach those who are remote..... Isolation also accentuates vulnerability -remote marginal areas are more liable to crop failures, and are less well provided with services to handle contingencies like famine or sickness....'

Shenoi (1975)(48) quotes a significant comment from Prof. A.S. Ashby, noted British Agricultural Economist', If I could do only one thing in a region to spur agricultural development, I would build roads. If to this I could add a second, I would build still more roads'.

This particularly holds good for India where majority of villages are not connected to a market by pucca, all weather roads. Consequently, the farmer can not take his produce for sale to remunerative markets. In Punjab, one of the reasons for good progress has been the construction of link roads to practically all villages.

8.1.1 Valuable contributions from different parts of the world have been made through papers contributed to the International Seminar on Rural Transportation (ISRT) held at New Delhi 1989. Chakravorty (1989) (10) outlines the impact of rural roads as follows.

1) Agriculture - Increased production, Changing of Cropping Pattern, advancement in agricultural technology.

2) Transport - Improved vehicle utilisation, reduced operating cost, increased speed, increased mobility.

3) Socio-economic - Increased non -agricultural employment, higher literacy, increased life expectancy, increased utilisation of services, reduced outmigration, and

4) Physical Environment - Changing material use, emergence of urban uses, improved streets, and services. Indeed these cover almost all aspects of a better quality of life for the people. Chakravarty does point out a few ill effects which inevitably follow reduction of isolation e.g. increase in conflicts, law and order problems, speculation in land and depletion of savings.

8.1.2. Sarna (1989) (44) demonstrates that the development of rural roads affects the socio-economic aspects and leads to increased household income, increased employment opportunities, poverty elemination in rural areas of greater contribution of agriculture to the national economy, savings in transport cost and development of other services, amenities and facilities.

Fancisco and Routray (1992) (19) have reported a case study from a typical underdeveloped country, Philippines which has problems similar to those of India. They infer that improved access and expanded transport capacity favour a shift to cultivation of new crops which bring better cash returns. Besides they cite several studies on developing countries where such roads have resulted in increase in rural income (Uganda increased production of cash crops (Uganda and Ivory coast) increased production of rice providing exportable surplus (Madagascar); establishment of more settlements, land extension, change in land use patterns, and crop diversification (Nigeria).

Similar results have also been reported by the authors from Bolivia, Honduras and Brazil. They further report that roads have been responsible for reducing transportation cost by almost 50% in Thailand. An improvement in road accesibility and expansion of transport services lower the transport cost and reduce travel time. The net result is increased mobility of the community for various purposes. The value of land surrounding rural road rises almost in direct proportion to its proximity to the road. Fanciscos and Routray (19) again confirm with many examples the social impacts of rural roads like increased access to health, schools, markets and government services.

8.1.3 Levy et al (1981) (28) bring out another important benefit of improoved transport. The direct access to market enables farmers to bypass middleman and directly transport their produce to the market centres resulting in higher profits. Better information available to the farmers enables them to schedule their sales so as to get higher prices.

While the impact of analysis carried out by Fancisco et al supports positive relationship between transport and development they emphasize the need of integrating transport with other economic factors. Only then the optimal use of transport could be achieved and transport would serve its full function not only as an important facility for mobility but an inducer of change as well.

8.2 BASIS OF DESIGN OF RURAL TRANSPORT NETWORK

Transport is an essential prerequiste to development but it is not sufficient in itself. Transport alone cannot stimulate economic growth unless other elements required for the development process also become available simultaneously. The impact of transport network will be felt fully only if other services, amenities and facilities are also made available at the same time. Among these the important ones are electricity, telephone communications banking service and credit, efficient marketing and distribution centres, effective law enforcement and social services like education, health and welfare for the needy.

The rural road network should be so planned that the facilities of health care, education, agriculture extension services, post offices, and market centres are available to the population within reasonable distances. An economic analysis of road construction and location and scale of facilities has to be made and the rural development to be planned as an integrated system in which roads provide vital linkages.

8.3 ROAD PLANS IN INDIA

Systematic planning for roads started in India with Nagpur plan in 1943. At that time it was realised that for a comprehensive economic development of the country a well planned road system was essential. Two road development plans have subsequently been made, the Bombay Plan of 1961 and the Road Development Plan of 1981. These plans were prepared for a period of 20 years and included guidelines for rural roads.

The aim of these road plans is to provide broad guidelines for the planning construction and improvement of roads. Due to severe constraint of financial resources the road plans incorporate development targets in phases.

8.3.1 The Nagur plan classified roads into different categories according to their importance. The main classifications were National Highways, State Highways, District roads and village roads. The plan fixed the target of twenty six miles of road per hundered sq. miles of area (43.3 km/277.8 sq km of area).

In the metric system this is equivalent to 15.6 km of roads per 100 sq km of area. The route length targets set in the plan were achieved by 1961.

8.3.2 The Bombay Plan 1961

The major objective of the plan was to raise the density of road length from 15.6 to 31 km per 100 sq km of land area. The total targeted road length in the plan was set at 10.57 lakh km against which the length achieved was 11.93 lakh km. The target length of rural roads comprising of secondary district roads and village roads was 651780 km whereas the achieved length was considerably higher at 912684 kms.

Bijnor district has a density of 45 km of road length per 100 sq km of area out of which 33.5 km are PWD roads. Thus the road density is at par with national average but the maintenance is poor and much of this length is hardly motorable. Further even with this density of roads accessibility to villages is still poor and a significant number of villages remain unconnected by all weather roads.

8.3.3 Road Development Plan 1981-2001

This plan (1984) (23) proposed to connect all villages or group of villages which as per 1981 census have a population of 500 or more. These villages are proposed to be connected by an all weather road by the year 2001. For villages of population less than 500 the plan proposes that AWR is available within a distance of 3 km in the plains and 5 km in hilly areas. The fulfilment of this target required a construction of additional 13,21,260 km of rural roads estimated at that time to cost Rs. 24,800.79 crores. The Plan was sought to be completed in three phases and completed by 2001.

8.3.4 Criteria for Rural Road Planning

The Indian Road Congress (IRC) 1984 has suggested the development of certain villages as nodal points at different levels depending upon their potentials. The potentials have been suggested to be measured in terms of the size of the population, area of influence, junction of roads, existence of facilities like government offices, post office, banks, educational institutions, health care facilities, organised markets, bus terminal or railway station, agro service centre and recreational facilities like cinemas.

Srinivasan et al (51) (1987) have suggested a rating method for computation of an index involving the following variables.

1) Demographic - Population, percentage of tribal and schedule cast population, population density.

2) Geographic - Percentage of cultivated to total area, distance to nearest town, hilly area, mining area and costal area.

3) Education - Primary school, high school and intermediate or high level college

4) Health - Government hospitals, dispensaries, primary health centres, private medical practitioners and vetenary hospitals and dispensaries.

5) Commercial and Others - Percentage of electrified habitations, agricultural markets, P & T Offices, banks, drinking water supply, cinema theaters.

8.4 The approach adopted by the author is based on the above philosophy. While road development is highly rewarding in economic terms it is also quite costly. It is therefore, essential to plan the road network so as to get maximum benefits from investment. An approach has been proposed by the author for this purpose and it is demonstrated by application to Najibabad Tehsil of Bijnor district. The area of the Tehsil is 880 sq km and its population 3.28 lakhs. It is divided into two development blocks namely Najibabad and Kiratpur. The approach envisages selection of growth centres in the area which would serve as nucleii of growth in the surrounding villages. The growth centres should be well distributed in the area and should be within a walking distance from the villages it is meant to serve. The growth centres have then to be linked to each other and to the main urban centres in the area. In the present study the area has been divided into hexagons having a side of 4 kms. Thus all villages will be within 4 kms of an all weather road, involving a walk of about one hour. Twenty five such hexagons have been formed, some of them partial. A growth centre has been selected for each hexagon for its growth potential -not necessarily situated in the centre of the hexagon. As an index of growth potential a `centrality score' was calculated for all habitations within the area normally with a population of more than 1000. A few exceptions had to be made to this in sparsely populated zone in the north of the study area. Centrality score is based on weights assigned to the following criteria - Education, health, P & T, market days, communication, power supply.

The weights assigned in computing the centrality score are as follows :

		Weights
I.	Educational Facilities	
1.	Primary or elementary school, kindergarten, pre basic, pre-primary, junior basic	1
2.	Senior basic school, junior high school, middle school	2
3.	Matriculation or secondary	3

4.	Higher Secondary, Intermediate, College, Pre-University	4
5.	College graduate level and above	5
6.	Industrial school and training school	4
7.	Other educational institution	2
II.	**Medical Facilities**	
1.	Hospital	5
2.	Maternity and Child Welfare Centre	4
3.	Maternity Home	3
4.	Child Welfare Centre	2
5.	Primary Health Centre	2
6.	Health Centre	3
7.	Primary Health Sub Centre	1
8.	Dispensary	4
9.	Family Planning Centre	2
10.	Registered private practitioner	1
11.	Subsidised medical practioner	1
III.	**Post & Telegraph**	
1.	Post office	1
2.	Telegraph office	2
3.	Post & Telegraph Office	2
4.	Post office with Telephone connection	3
IV.	**Day or Days of Market**	
1.	Once a week	1
2.	Twice a week	2
3.	Three to four days	3

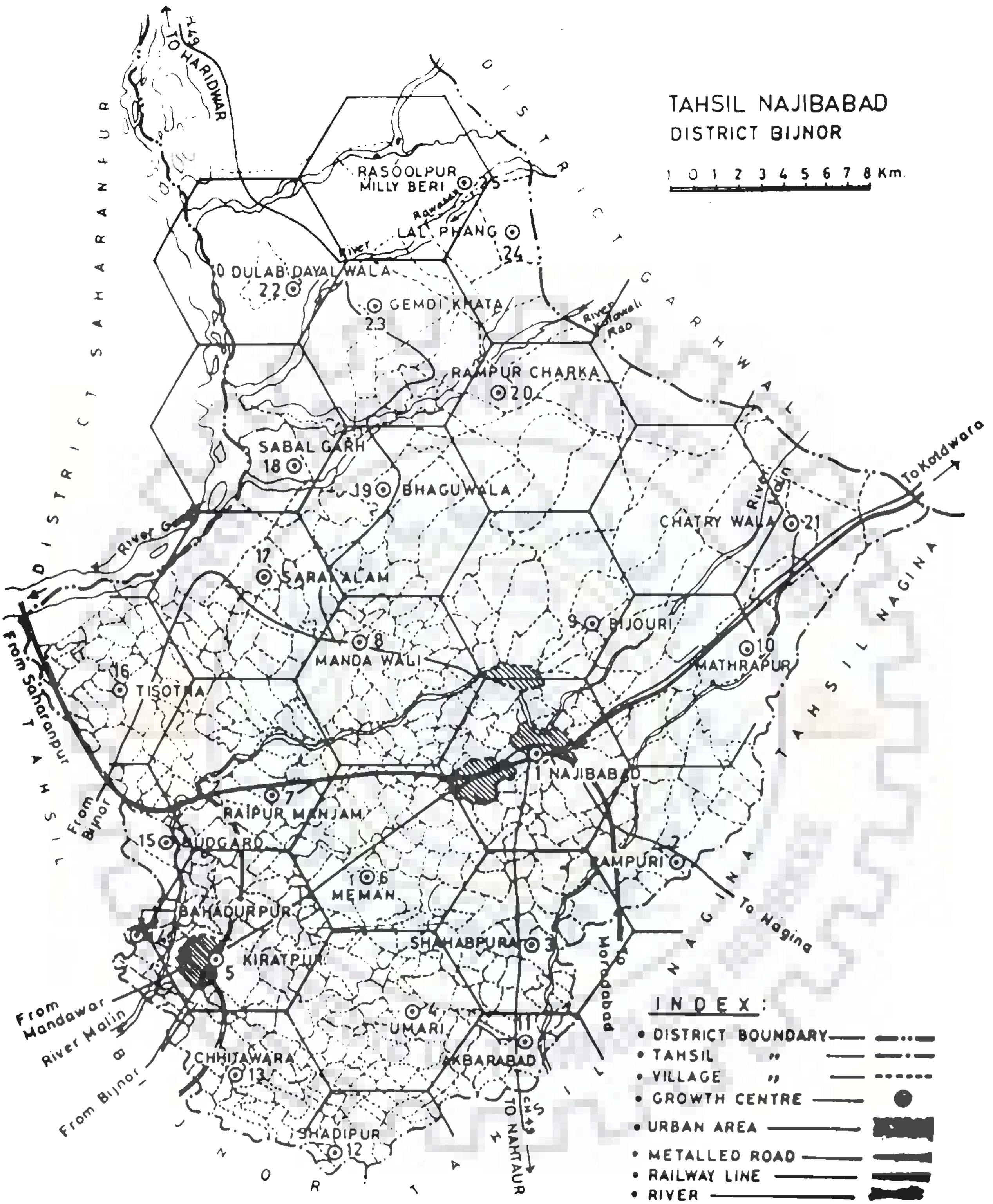
4.	Permanent or daily	4
V.	**Communications**	
1.	Bus stand	1
2.	Railway station	3
VI.	**Nearest Town**	
1.	Nearest town at a distance of more than 10 km	1
2.	Nearest town at a distance of 5 to 10 km	2
3.	Nearest town at a distance of less than 5 km	3
VII)	**Power Supply.**	
1.	Electricity for domestic purpose	1
2.	Electricity for agriculture	1
3.	Electricity for other purposes like industrial, commercial etc.	2
4.	Electricity for all purposes listed above	3

The centrality scores were calculated in all for 93 habitations. Out of these the selected locations were marked on a map of the Tehsil. In each hexagon, a growth centre was then finally selected, taking into account the `centrality score' as well as the location. As far as possible a growth centre located near the centre of the hexagon was selected, but this was not possible in all cases. The growth centres finally selected and their populations and centrality scores are given in Table 8.1 and shown in Map 8.1.

8.4 CONCEPTS FOR PLANNING OF THE NETWORK

For planning a rural road network in an area to be developed the basic approach need not be based on existing trip frequency, as the road network itself is meant to be an instrument for growth. It should be based on functional requirement of potential interaction between the growth centres. The authors have studied several existing approaches by Mahendru et al (29) (1983), Srinivasan et al (51) (1987, 1990) Swaminathan et al (54) (1981) Kumar and Tillotson (27) (1989).

Srinivasan and Mahesh Chand (1987) (51) have suggested a method for rating of villages for road communications as described earlier. The author has also used a similar approach though not exactly the same criteria. However, their method of estimating the road length in each block as applied to Mallapuram district in Kerala was not suited to the present case. In 1990 Srinivasan et al (52) have reported another study illustrating Rural Road Network Planning in Palaghat district. The approach used in this study involves collection of very detailed data of industries, accessibility from existing roads, link lengths and other facilities which can only be collected by a project survey team. Swaminathan et al (54) proposed a system approach which again requires availability of detailed link lengths from all inhabited areas to existing roads. Kumar and Tillotson (27) proposed a methodology of taking several alternative networks and then selecting an optimum network minimising the total cost of initial construction as well as travel. The basic approach suggested by them is similar to that used by the author but the



MAP 8.1 SELECTION OF GROWTH CENTRES

methodology used is different as it enables network optimisation with available data. The approach used by the author modified from that of Mahendru et al (29) is discribed below.

According to Mahendru et al the demographic force of interaction F_{ij} between two centres i and j is given as :

$$F_{ij} = \frac{P_i \times P_j \times [CS_i - CS_j]}{d_{ij}^2} \qquad .... (8.1)$$

F_{ij} = Demographic force of interaction between settlements i and j

Pi & Pj = Populations of settlement i and j respectively

di j = Spatial distance between i and j

CSi & CSj = Centrality scores of settlements i and j respectively based on level and number of socio economic facilities available at the centre

The authors are unable to agree with the use of the parameters of (CSi - CSj), the difference of centrality scores in the formulation of Fij. This would imply zero demographic force between two settlement of equal centrality scores. This is contrary to logic as well as observation. Two centres having similar level of socio-economic facilities have intense interaction with respect to business, trade, industry as well as social services. This view is supported by Srinivasan and Mahesh Chand (1987) who have also taken centrality scores as contributing positively to demographic force. The authors have calculated the demographic force by the following expression.

$$F_{ij} = \frac{P_i \times P_j \times CS_i \times CS_j}{d_{ij}^2} \qquad ..(8.2)$$

The demographic force of interaction calculated as above helps to identify linkage pattern based on function and need.

8.5 OTHER PARAMETERS FOR ROAD NETWORK EVALUATION

Total Link length (LL) - Total link length is the sum of lengths of all the individual links required to provide road connection to all the selected growth centres or nodal points. The total link length determines the investment cost of road construction.

Total Route length (RL) or operational distance - The total Route length is the sum of distances required to be travelled from every node to all other nodes. The travel routes may be through indirect and even long circuitous routes. RL can be calculated by the following expression.

$$RL = 1/2 \sum_{j=1}^{n} \sum_{i=1}^{n} RL_{ij} \qquad .... (8.3)$$

Where

RL = Total route length or total operational distance involved in network for every settlement to interact with every other settlement

RLij = Route length of operational distance involved from settlement i to settlement j

i & j = Growth centres

n = Total number of growth centres of nodes identified in a network to be provided road connection.

8.6 DEMOGRAPHIC FORCE OF INTERACTION

To the extent that the connection between two nodes is indirect or circuitous the interaction will be lower than that ideally possible with direct links. Thus the sum of the actual interaction between all node pairs is an important parameter in the selection of a network. The total demographic force of interaction for a particular network can be expressed as below.

$$F = 1/2 \sum_{j=1}^{n} \sum_{i=1}^{n} F_{ij} \qquad \text{.... (8.4)}$$

Link Efficiency (EL)

Link efficiency is defined as the total amount of interaction measured by equation (8.4) per unit length of link, or

$$E_L = \frac{F}{LL} \qquad \text{.... (8.5)}$$

Route efficiency (ER)

It is defined as the total demographic force of interaction per unit length of total operational distance RL given by equation (8.3) or

$$E_R = \frac{F}{RL} \qquad \text{... (8.6)}$$

8.7 NETWORK EFFICIENCY (En)

Link efficiency reflects economy in intial investment while route efficiency is a measure of required travel distance. The combined effect of both is given by network efficiency En defined as

$$E_n = \frac{F}{LL \times RL} \quad \text{..... (8.7)}$$

8.7.1 EFFICIENCY OF INTERACTION (EL)

A hypothetical maximum level of interaction can be achieved by the theoretical case when every node is connected directly to all other nodes. This would be economically impractical but is useful as a base for comparsion for actual networks. This will be given by :

$$Ei = \frac{F}{F'} \quad \text{..... (8.8)}$$

Where F' is the total demographic force of interaction for the hypothetical case of direct linkage between all nodes.

8.8 ALTERNATIVE ROAD NETWORKS TAKEN UP FOR THE PRESENT STUDY

Besides the hypothetical direct linkage of all nodes (map 8.2) used as a base for comparison two alternatives have been considered as below.

Alternative - I Linkage pattern based on need and minimum link length. This network provides road connections to all growth centres. While the necessity of minimising link length has been kept in view, effort has been made to link all growth centres to the major urban centre of Najibabad as directly as possible. This network is shown in map 8.3.

Alternative - II Modified Road system for improved network efficiency - In the first alternative most of the links passed through Najibabad. This results in higher link length and also the necessity of passing through congested traffic close to Najibabad even for through traffic. To eliminate this in the second alternative a ring road has been provided connecting nodes relatively closer to Najibabad and these are in turn linked to other nodes farther way. This layout is shown in map 8.4.

8.9 COMPUTATIONS AND COMPARISONS

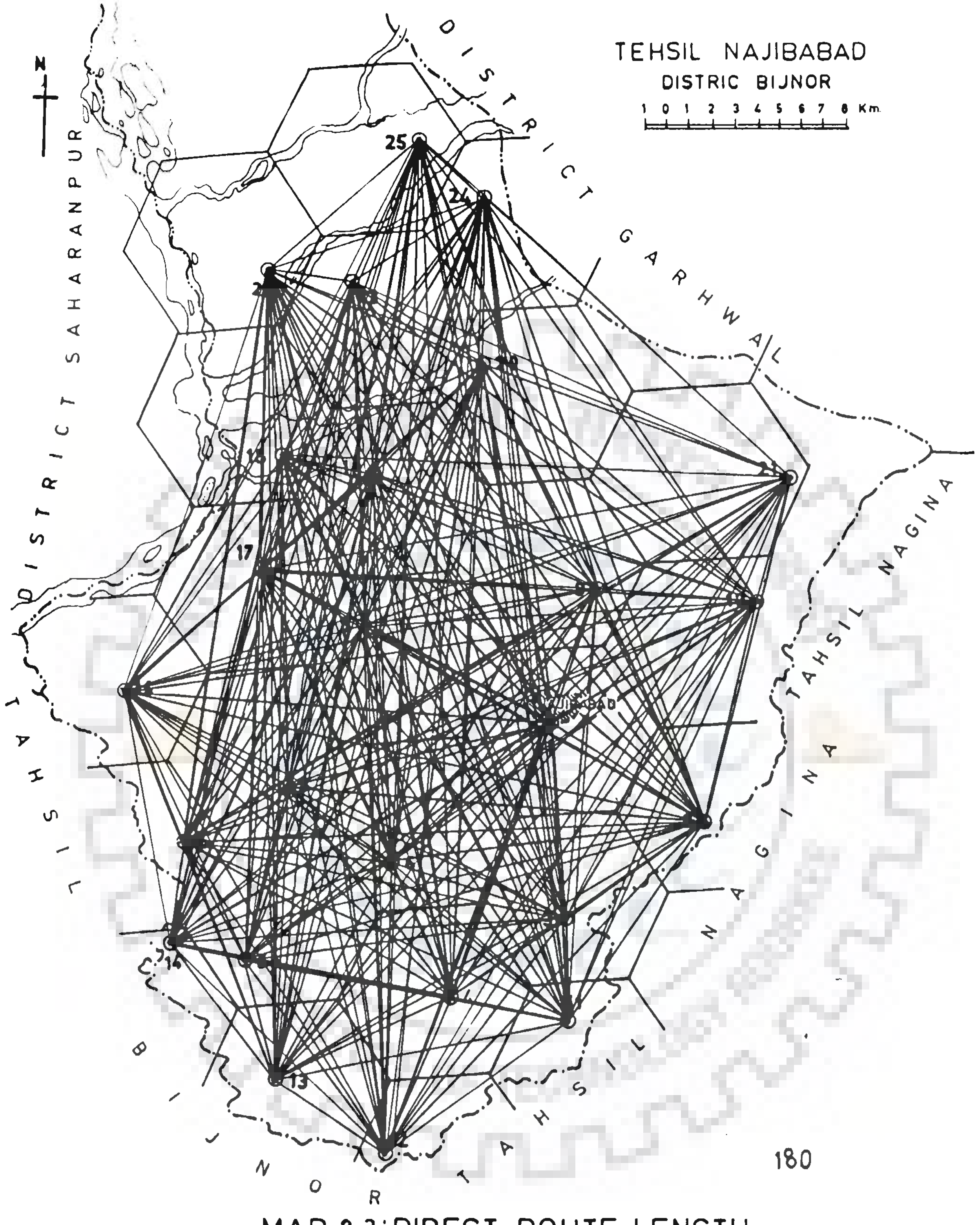
The matrix for direct spatial distance is given in Table 8.2 Matrices for demographic forces of interaction for direct linkages of all nodes are given in Table 8.3. Matrices of Alternative I giving route lengths and demographic forces of interaction for these route lengths are given in Tables 8.4 and 8.5. Similarly for Alternative II route lengths and demographic forces are given in Tables 8.6 and 8.7.

CONCLUSIONS

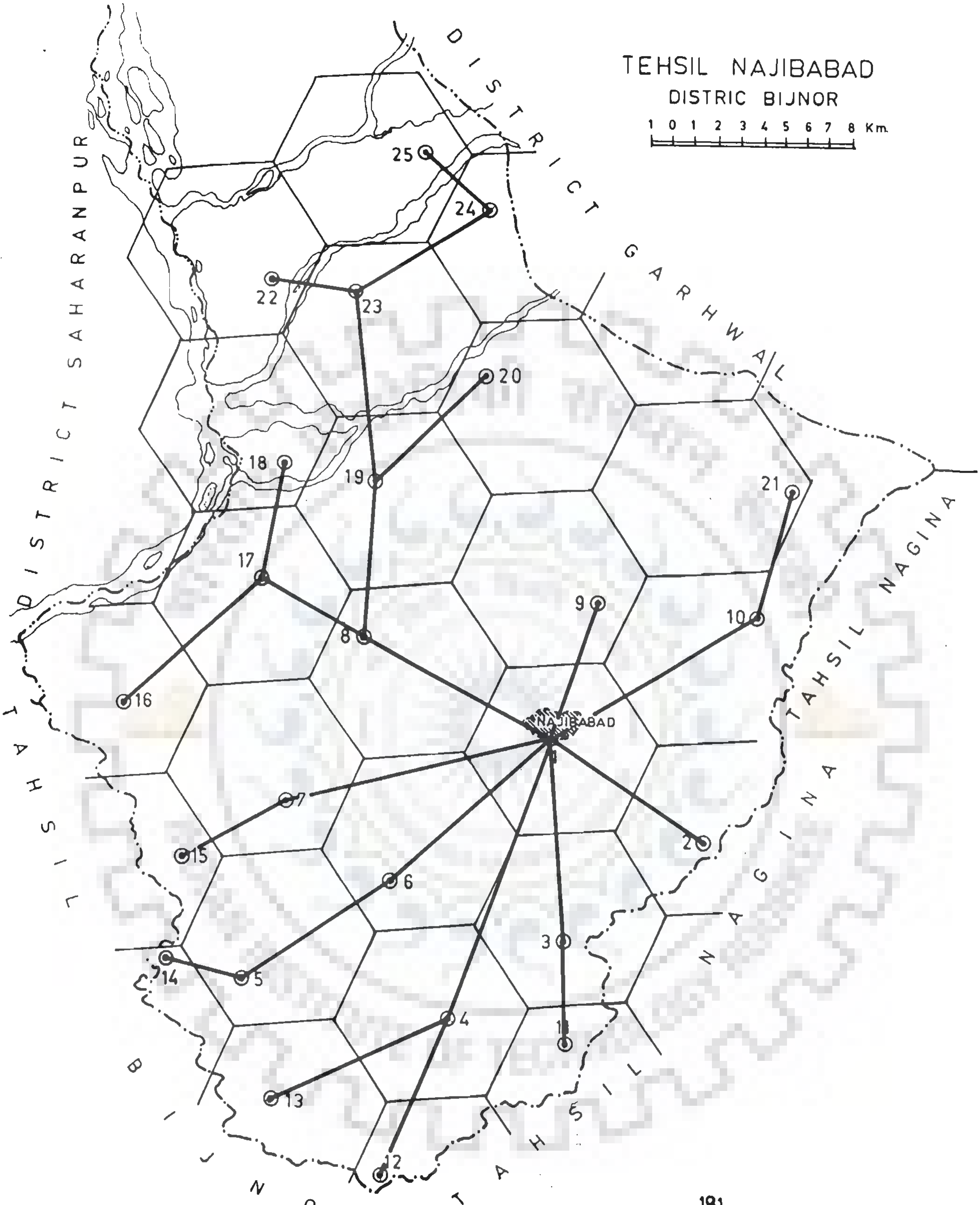
The comparison of the two proposed alternative networks with respect to the efficiency defined earlier is given in Table 8.8. As can be seen the Link length required for alternative - I is 78.6 kms which is only 2.9% of the hypotehtical fully developed network. For alternative - II it is 95.9 kms or 3.5% of the base. The Route length however is larger at 4016.3 km for alternative I in comparison to 3534.3 kms. of alternative - II. The network efficiency En is 0.56×10^6 for alternative - I and 0.59×10^6 for alternative - II. The network efficiencies E are 89.8% and 92.2% respectively.

The author considers Alternative II to be more advantageous. While involving a small additional initial investment it will give economy in operational costs and even more in travel time and convenience to the road users.

It is considered that this approach is applicable to all similar situations. It is simple to use and data required would be conveniently available. More sophisticated optimisation procedures may be theoretically more sound, but their final reliability will depend entirely on the reliability of data used. The data for influence areas for road stretches or of number of trips is very unlikely to be accurate unless very costly and time consuming surveys are carried out.



MAP-8.2: DIRECT ROUTE LENGTH



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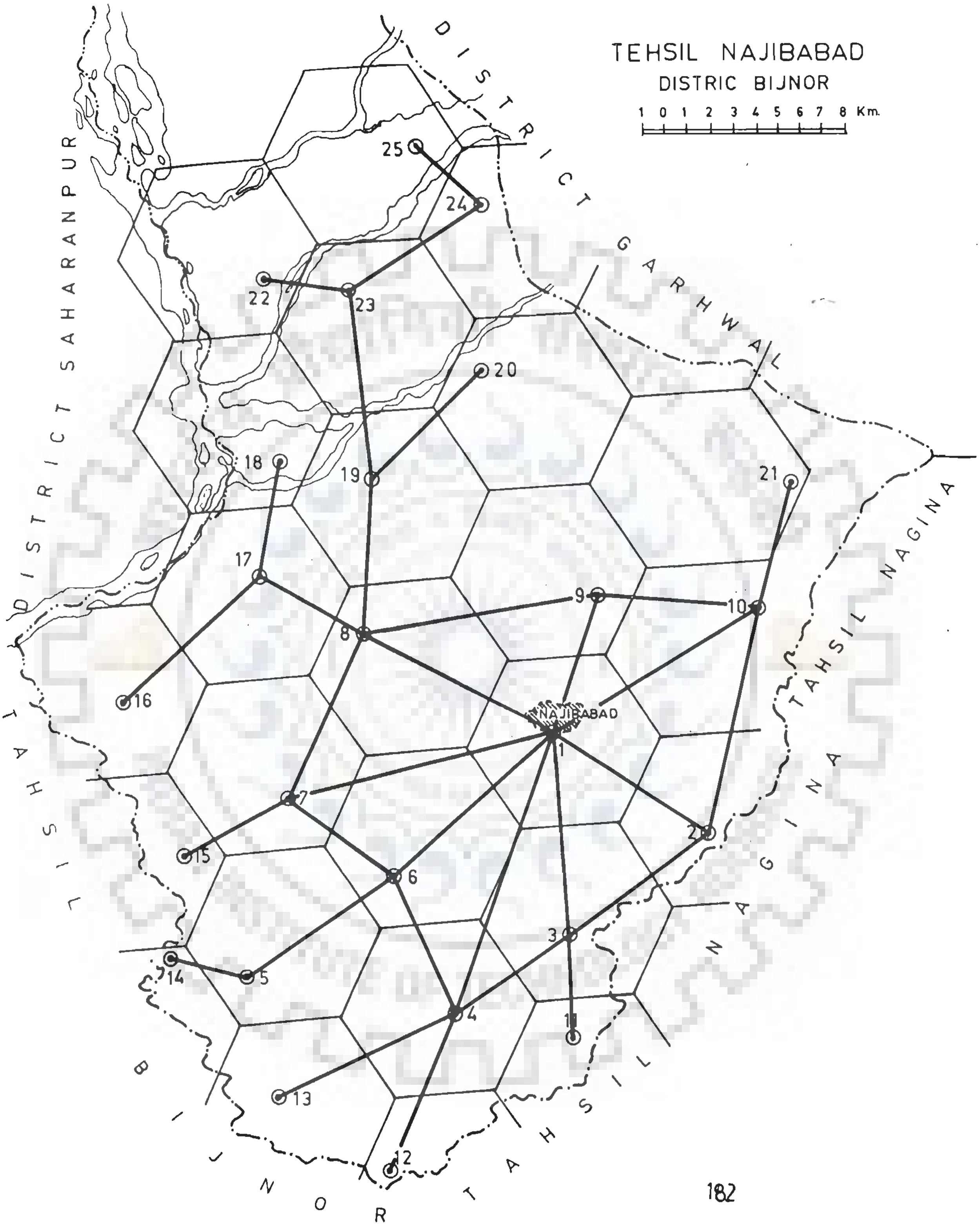
MAP-8.3-ALTERNATIVE I



MAP-8·4:ALTERNATIVE II

Table 8.1 LIST OF GROWTH CENTRES

Settlement No.	Name of settlement	Population	Centrality score
1.	Najibabad	55,109	100
2.	Rampur	1,010	10
3.	Shahabpura	1,102	3
4.	Umari	1,129	6
5.	Kiratpur	32,079	49
6.	Meman	2,901	3
7.	Raipur Manzam	1,019	12
8.	Manda Wali	2,324	13
9.	Bijouri	725	4
10.	Mathrapur	1,360	7
11.	Akbarabad	3,094	6
12.	Shadipur	2,681	7
13.	Chhitawara	1,397	8
14.	Bahadurpur	1,231	10
15.	Budgara	2,121	6
16.	Tisotra	2,343	9
17.	Sarai Alam	2,554	6
18.	Sabal Garh	792	4
19.	Bhaguwala	4,700	19
20.	Rampur Charka	327	2
21.	Chatry Wala	202	1
22.	Dulab Dayal Wala	683	4
23.	Gemdi Khata	552	3
24.	Lal Dhang	3,777	12
25.	Rasoolpur Milly Beri	2,932	3

Table 8.2 : Matrix for Spatial Distances (Direct route length)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1.	0	3.5	4.1	6.1	8.4	4.3	5.4	4.4	3.0	4.9	6.1	9.7	9.3	9.0	7.8	8.4	6.5	7.6	6.3	7.5	7.8	10.9	10.1	11.1	12.7
2.	3.5	0.0	3.5	6.2	7.7	6.3	8.4	7.8	5.3	4.8	5.8	9.5	12.1	11.1	12.4	11.6	10.3	11.2	9.8	18.5	7.6	14.2	13.2	13.7	15.3
3.	4.1	3.5	0.0	3.2	4.7	3.6	6.2	7.3	7.0	7.6	2.2	6.1	6.7	8.1	7.8	9.8	9.5	11.3	10.3	11.7	10.2	14.8	13.9	15.3	16.7
4.	6.1	6.2	3.2	0.0	3.2	3.2	5.5	7.9	9.2	10.4	2.4	3.5	3.8	5.9	6.2	9.1	9.7	11.8	11.1	13.4	13.0	15.7	15.1	16.8	18.0
5.	8.4	7.7	4.7	3.2	0.0	3.9	2.7	5.9	8.5	10.6	5.3	5.4	3.8	1.6	3.1	6.0	7.2	9.5	9.0	11.7	12.7	13.2	1.3	15.1	16.2
6.	4.3	6.3	3.6	3.2	3.9	0.0	2.6	4.9	6.8	9.1	4.9	6.3	5.1	4.2	4.1	6.3	6.7	8.8	8.1	10.4	11.4	12.6	12.1	14.0	15.3
7.	5.4	8.4	6.2	5.5	2.7	2.6	0.0	3.8	7.4	10.1	7.4	8.0	6.3	4.4	2.4	3.8	4.6	6.9	6.8	9.7	11.8	10.8	12.7	12.8	13.8
8.	4.4	7.8	7.3	7.9	5.9	4.9	3.8	0.0	4.7	7.8	9.3	9.7	9.7	7.8	5.9	5.2	2.3	3.8	3.1	6.1	8.9	7.6	7.2	9.2	10.3
9.	3.0	5.3	7.0	9.2	8.5	6.8	7.5	4.7	0.0	3.2	9.0	12.7	12.3	11.5	9.8	9.7	6.5	6.7	4.9	5.2	4.5	9.2	8.1	8.4	9.9
10.	4.9	4.8	7.6	10.4	10.6	9.1	10.1	7.8	3.2	0.0	9.6	13.7	13.6	13.9	12.4	12.6	9.6	9.8	7.8	7.3	2.8	11.5	10.3	10.0	11.7
11.	6.1	5.0	2.2	2.4	5.3	4.9	7.4	9.3	9.0	9.6	0.0	4.6	5.8	8.2	8.4	11.0	11.1	13.1	12.2	13.8	12.2	16.6	15.9	17.3	18.6
12.	9.7	9.5	6.1	3.5	5.4	6.3	8.0	9.7	12.7	13.7	4.6	0.0	2.6	6.5	7.6	11.0	12.6	14.9	14.6	16.7	16.5	18.8	18.4	20.1	21.5
13.	9.3	10.1	6.7	3.8	3.8	5.1	6.3	9.7	12.3	13.6	5.8	2.6	0.0	3.8	5.3	8.6	10.8	13.1	13.0	15.7	16.2	16.9	16.8	18.9	19.9
14.	9.0	11.1	8.1	5.9	1.6	4.2	4.4	7.8	11.5	13.9	8.2	6.5	3.8	0.0	2.2	5.3	7.9	10.5	12.8	13.8	15.9	14.2	14.3	16.9	17.7
15.	7.8	10.4	7.8	6.2	3.1	4.1	2.4	5.9	9.8	12.4	8.4	7.6	5.3	2.2	0.0	3.4	5.9	8.4	8.6	11.7	14.3	12.2	12.2	14.8	15.5
16.	8.4	11.6	9.8	9.1	6.0	6.3	3.8	5.2	9.7	12.6	11.0	11.0	8.6	5.3	3.4	0.0	3.7	5.9	6.8	9.9	13.8	9.3	9.7	12.4	12.9
17.	6.5	10.3	9.5	9.7	7.2	6.7	4.6	2.3	6.5	9.6	11.1	10.6	12.8	7.9	5.9	3.7	0.0	2.5	3.0	6.2	10.5	6.1	6.3	8.9	9.5
18.	7.6	11.2	11.3	11.8	9.5	8.8	6.9	3.8	6.7	9.8	13.1	14.9	13.1	10.5	8.4	5.9	2.5	0.0	2.0	4.3	10.1	3.9	4.0	6.8	7.2
19.	6.3	9.8	10.3	11.1	9.0	8.1	6.8	3.1	4.9	7.8	12.2	14.6	13.0	10.8	8.6	6.8	3.0	2.0	0.0	3.2	8.2	4.9	4.1	6.3	7.1
20.	7.8	10.5	11.7	13.4	11.7	10.6	9.7	6.1	5.2	7.3	13.8	16.7	15.7	13.8	11.7	9.9	6.2	4.3	3.2	0.0	6.6.	4.7	3.1	3.5	4.9
21	7.3	7.6	10.2	13.0	12.7	11.4	11.8	8.9	4.5	2.8	12.2	16.5	16.2	15.9	14.3	13.8	10.5	10.1	8.2	6.6	0.0	11.1	9.5	8.2	10.1
22.	10.9	14.2	14.8	15.7	13.2	12.6	10.8	7.6	9.2	11.5	16.6	18.8	16.9	14.2	12.2	9.3	6.1	3.9	4.9	4.7	11.1	0.0	1.7	4.7	4.1
23.	10.1	13.2	13.9	15.1	1.3	12.1	10.7	7.6	8.1	10.3	15.9	18.4	16.8	14.3	12.2	9.7	6.3	4.0	4.1	3.1	9.5	1.7	0.0	3.2	3.2
24.	11.1	13.7	15.3	16.8	15.1	14.0	12.8	9.2	8.4	10.0	17.3	20.1	18.9	16.9	14.8	12.4	8.9	6.8	6.3	3.5	8.2	4.7	3.2	0.0	1.8
25.	12.7	15.3	16.7	18.0	16.2	15.3	13.8	10.3	9.9	11.7	18.6	21.5	19.9	17.7	15.5	12.9	9.5	7.2	7.1	4.9	10.1	4.1	3.2	1.8	0.0

Table 8.3 : Matrix for Demographic Force of Intraction, Direct route

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	0	4543.69	1083.82	1003.25	122766.77	2593.91	2310.95	8599.96	1775.73	2185.08	2749.38	109.92	712.10	837.52	1152.72	1646.94
2.	4543.68	0	2.73	1.78	267.77	2.21	1.75	5.02	1.04	4.17	7.5	2.10	1.11	1.10	1.19	1.58
3.	1083.82	2.73	0	2.19	235.25	2.22	0.11	1.87	0.20	0.54	12.68	1.68	0.82	0.62	0.69	0.73
4.	1003.25	1.78	2.19	0	1039.83	5.76	0.28	3.28	0.23	0.60	21.83	1.04	5.24	2.40	2.24	1.72
5.	122766.77	267.77	235.25	1039.83	0	899.40	2636.60	137.59	63.09	133.18	1038.81	1011.64	1216.57	7558.48	208.18	920.72
6.	2593.91	2.21	2.22	5.76	899.40	0	15.74	10.95	0.55	1.00	6.73	4.12	3.74	4.65	6.59	4.62
7.	2310.95	1.75	0.11	0.28	2636.60	15.74	0	25.58	0.65	1.14	4.15	3.59	3.44	7.78	27.02	17.86
8.	8599.96	5.02	1.87	3.28	137.59	10.95	25.58	0	3966.27	4.73	6.48	6.03	3.59	6.11	2.37	23.56
9.	1775.73	1.04	0.20	0.23	63.09	0.55	0.65	3966.27	0	2.70	0.66	0.34	0.21	0.28	0.08	0.65
10.	2185.08	4.17	0.54	0.60	133.18	1.00	1.14	4.73	2.70	0	1.92	0.95	0.58	0.61	0.17	1.26
11.	2749.38	7.5	12.68	21.83	1038.81	6.73	4.15	6.48	0.66	1.92	0	16.46	6.17	3.40	0.72	3.24
12.	109.92	2.10	1.68	1.04	1011.64	4.12	3.59	6.03	0.34	0.95	16.46	0	31.03	5.47	0.89	3.27
13.	712.10	1.11	0.82	5.24	1216.57	3.74	3.44	3.59	0.21	0.58	6.17	31.03	0	9.53	1.08	3.19
14.	837.52	1.10	0.62	2.40	7558.48	4.65	7.78	6.11	0.28	0.61	3.40	5.47	9.53	0	6.93	9.24
15.	1152.72	1.19	0.69	2.24	208.18	6.59	27.02	2.37	0.08	0.17	0.72	0.89	1.08	6.93	0	23.21
16.	1646.94	1.58	1.73	1.72	920.72	4.62	17.86	23.56	0.65	1.26	3.24	3.27	3.19	9.24	23.21	0
17.	1998.79	1.46	0.56	1.10	46.46	2.97	8.86	30.41	0.37	0.55	0.08	0.63	0.51	1.05	1.95	8.20
18.	302.26	0.26	0.08	0.15	5.52	0.36	0.81	6.63	0.20	0.31	0.34	0.27	0.21	0.35	0.57	1.92
19.	12399.18	9.39	2.78	5.56	1732.93	11.85	23.62	280.74	10.79	13.97	11.14	7.86	5.91	9.42	15.37	40.72
20.	59.24	0.06	0.02	0.02	7.51	0.05	0.09	0.53	0.07	0.12	0.04	0.04	0.03	0.04	0.06	0.14
21.	20.89	0.004	0.006	0.008	0.20	0.01	0.02	0.08	0.03	0.24	0.03	0.01	0.008	0.009	0.01	0.02
22.	126.72	0.14	0.04	0.08	24.65	0.15	0.29	1.43	0.09	0.20	0.18	0.15	0.11	0.17	0.23	0.67
23.	89.46	0.10	0.03	0.05	481.08	0.10	0.18	0.97	0.07	0.15	0.12	0.09	0.07	0.10	0.14	0.37
24.	202.71	0.24	0.86	1.039	3.12	0.20	0.34	1.62	0.19	0.43	0.28	0.21	0.14	0.20	0.25	0.62
25.	300.54	0.38	0.10	0.18	5.27	0.33	0.56	2.50	0.26	0.61	0.47	0.36	0.25	0.35	0.47	1.11

Table 8.3 contd..

17	18	19	20	21	22	23	24	25
1998.79	302.26	12399.18	59.24	20.89	126.72	89.46	202.71	300.54
1.46	0.26	9.39	0.06	0.04	0.14	0.10	0.24	0.38
0.56	0.08	2.78	0.02	0.006	0.04	0.03	0.06	0.10
1.10	0.15	5.56	0.02	0.008	0.08	0.05	1.009	0.18
46.46	5.52	1732.94	7.51	0.20	24.65	1481.08	3.12	5.27
2.97	0.36	11.85	0.05	0.01	0.15	0.10	0.20	0.33
8.86	0.81	23.62	0.09	0.02	0.29	0.18	0.34	0.56
30.41	6.63	280.74	0.53	0.08	1.43	0.97	1.62	2.50
0.37	0.20	10.79	0.07	0.03	0.09	0.07	0.19	0.26
0.55	0.31	13.97	0.12	0.24	0.20	0.15	0.43	0.61
0.08	0.34	11.14	0.04	0.03	0.18	0.12	0.28	0.47
0.63	0.27	7.86	0.04	0.01	0.15	0.09	0.21	0.36
0.51	0.21	5.91	0.03	0.008	0.11	0.07	0.14	0.25
1.05	0.35	9.42	0.04	0.009	0.17	0.10	0.20	0.35
1.95	0.57	15.37	0.06	0.01	0.23	0.14	0.25	0.47
8.20	1.92	40.72	0.14	0.02	0.67	0.37	0.62	1.11
0	7.77	152.05	0.26	0.03	1.13	0.64	0.88	1.49
7.77	0	70.73	0.11	0.006	0.57	0.33	0.31	0.54
152.05	70.73	0	5.70	0.27	10.16	8.80	10.20	15.58
0.26	0.11	5.70	0	0.002	0.08	0.11	0.24	0.24
0.03	0.006	0.27	0.002	0	0.004	0.003	0.01	0.02
1.13	0.57	10.16	0.08	0.004	0	1.61	0.56	1.43
0.64	0.33	8.80	0.11	0.003	1.61	0	3.83	7.44
0.88	0.31	10.20	0.24	0.01	0.56	3.83	0	123.05
0.49	0.54	15.58	0.24	0.02	1.43	7.44	123.0	0

$$F = 1/2 \sum_{j=1}^{25} \sum_{i=1}^{25} F_{ij} = 196285.44$$

$$F_{ij} = \frac{P_l * P_a \, XCS_i * CS_j}{d^2_{ij}}$$

Table 8.4 Alternative - I (Minimal spanning tree - Matrix for route length)

0	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	0.0	3.5	4.0	7.2	8.4	4.3	5.4	4.4	3.0	4.9	6.1	10.7	11.1
2.	3.5	0	7.6	10.7	11.9	7.8	8.9	7.9	6.5	8.4	9.6	14.2	14.5
3.	4.0	7.6	0	3.2	12.5	8.4	9.5	8.4	7.1	8.9	6.2	10.7	11.0
4.	7.2	10.7	3.2	0	15.6	11.5	12.6	11.6	10.3	12.2	5.4	3.5	3.8
5.	8.4	11.9	12.5	15.6	0	3.9	13.8	12.8	11.5	13.4	14.5	19.2	19.4
6.	4.3	7,8	8.4	11.5	3.9	0	9.7	8.7	7.4	9.2	10.4	15.1	15.3
7.	5.4	8.9	9.5	12.6	13.8	9.7	0	9.8	8.4	10.3	11.5	16.1	16.4
8.	4.4	7.9	8.4	11.6	12.8	8.7	9.8	0	7.4	9.3	10.4	15.1	15.4
9	3.0	6.5	7.1	10.3	11.5	7.4	8.4	7.4	0	7.9	9.1	13.7	14.0
10.	4.9	8.4	8.9	12.2	13.4	9.2	10.3	9.3	7.9	0	11.0	15.6	15.7
11.	6.1	9.6	6.2	5.4	14.5	10.4	11.5	10.4	9.1	11.0	0	8.9	9.4
12.	10.7	14.2	10.7	3.5	19.2	15.1	16.1	15.1	13.7	15.6	8.9	0	7.3
13.	11.0	14.5	11.0	3.8	19.4	15.3	16.4	15.4	14.0	15.7	9.4	7.3	0
14.	10.1	12.6	13.3	16.5	1.6	12.5	14.6	13.6	12.3	14.2	15.3	19.9	20.2
15.	7.8	11.3	11.8	14.9	16.2	12.1	9.5	12.2	10.8	12.7	13.8	18.5	18.8
16.	9.6	13.1	13.6	16.8	18.0	13.9	13.6	5.2	12.6	14.5	15.7	20.3	20.6
17.	6.7	10.2	10.7	13.9	15.1	11.0	12.1	2.3	9.7	11.6	12.7	17.4	17.7
18.	9.2	12.7	13.2	16.4	17.6	13.5	14.6	4.8	12.2	14.1	15.3	19.9	20.2
19.	7.5	11.0	11.5	14.7	15.9	11.8	12.9	3.1	10.5	12.4	13.6	18.2	18.5
20.	10.7	14.2	14.8	17.9	19.2	15.1	16.1	6.3	13.7	15.7	16.8	21.5	21.7
21.	7.8	11.3	11.8	14.9	16.2	12.1	13.2	12.2	10.8	2.8	13.8	8.5	18.8
22.	13.3	16.8	17.3	20.5	21.7	17.6	18.7	8.9	16.3	18.2	19.4	24.0	24.3
23.	1.5	15.1	15.6	18.8	19.9	15.9	16.9	7.2	14.6	16.5	17.6	22.3	22.5
24.	14.4	17.9	18.5	21.7	22.9	18.8	19.8	10.4	17.5	19.4	20.5	25.2	25.4
25.	16.5	20.0	20.5	23.7	24.9	20.8	21.9	12.2	19.5	21.4	22.5	27.2	27.4

Table 8.4 Contd...

14	15	16	17	18	19	20	21	22	23	24	25
10.1	7.8	9.6	6.7	9.2	7.5	10.7	7.8	13.3	11.5	14.4	16.5
12.6	11.3	13.1	10.2	12.7	11.0	14.2	11.3	16.8	15.1	17.9	20.0
13.3	11.8	13.6	10.7	13.2	11.5	14.8	11.8	17.3	15.6	18.5	20.5
16.5	14.9	16.8	13.9	16.4	14.7	17.9	14.9	20.5	18.8	21.7	23.7
1.6	16.2	18.0	15.1	17.6	15.9	19.2	16.2	21.7	19.9	22.9	24.9
12.5	12.1	13.9	11.0	13.5	11.8	15.1	12.1	17.6	15.9	18.8	20.8
14.6	9.5	13.6	12.1	14.6	12.9	16.1	13.2	18.7	16.9	19.8	21.9
13.6	12.2	5.2	2.3	4.8	3.1	6.3	12.2	8.9	7.2	10.4	12.2
12.3	10.8	12.6	9.7	12.2	10.5	13.7	10.8	16.3	14.6	17.5	19.5
14.2	12.7	14.5	11.6	14.1	12.4	15.7	2.8	18.2	16.5	19.4	21.4
15.3	13.8	15.7	12.7	15.3	13.6	16.8	13.8	19.4	17.6	20.5	22.5
19.9	18.5	20.3	17.4	19.9	18.2	21.5	18.5	24.00	22.3	25.2	27.2
20.2	18.8	20.6	17.7	20.2	18.5	21.7	18.8	24.3	22.5	25.4	27.4
0	17.8	19.6	16.7	19.2	17.5	20.8	17.8	23.3	21.6	24.5	26.5
17.8	0	17.3	14.4	16.9	15.3	18.5	15.5	21.1	19.3	22.2	24.2
19.6	17.3	0	3.7	6.2	8.3	11.5	17.3	14.1	12.4	15.6	17.3
16.7	14.4	3.7	0	2.5	5.4	8.6	14.4	11.2	9.5	12.7	14.4
19.2	16.9	6.2	2.5	0	7.9	11.1	16.9	13.7	12.0	15.2	16.9
17.5	15.3	8.3	5.4	7.9	0	3.2	15.2	5.8	4.1	7.3	9.0
20.8	18.5	11.5	8.6	11.1	3.2	0	3.2	9.0	7.3	10.5	12.3
17.8	15.5	17.3	14.4	16.9	15.2	3.2	0	13.3	11.6	14.8	16.5
23.3	21.1	14.1	11.2	13.7	5.8	9.0	13.3	0	1.7	4.9	6.5
21.6	19.3	12.4	9.5	12.0	4.1	7.3	11.6	1.7	0	3.2	4.9
24.5	22.2	15.6	12.7	15.2	7.3	10.5	14.8	4.9	3.2	0	1.7
26.5	24.2	17.3	14.4	16.9	9.0	12.3	16.5	6.5	4.9	1.7	0

$$RL = 1/2 \sum_{j=1}^{n} \sum_{i=1}^{n} RL_{ij} = 4016.3$$

Table 8.5 : Alternative - I Minimal Spanning Tree Matrix of Demographic Force

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	0	4543.68	1138.69	720.12	122766.77	2593.90	2310.95	8599.96	1775.73	2185.08	2749.38	90.33	509.01	665.02	1152.72
2.	4543.68	0	0.44	0.60	112.11	1.44	1.58	4.89	0.69	1.36	2.03	0.94	0.54	0.78	1.01
3.	1138.69	0.44	0	2.19	33.26	0.40	0.04	1.42	0.19	0.40	1.60	0.54	0.31	0.23	0.30
4.	720.12	0.60	2.19	0	43.75	0.45	0.05	1.52	0.19	0.43	4.31	0.11	5.24	0.31	0.39
5.	122766.77	112.11	33.26	43.75	0	899.41	100.90	289.85	34.47	83.34	138.79	80.02	46.68	7558.48	76.22
6.	2593.90	1.44	0.40	0.45	899.41	0	1.13	3.47	0.46	0.98	1.49	0.72	0.42	0.69	0.76
7.	2130.95	1.58	0.04	0.05	100.90	1.13	0	3.85	0.50	1.10	1.72	0.89	0.51	0.71	1.72
8	8599.96	4.89	1.42	1.52	289.85	3.47	3.85	0	1599.98	3.33	5.19	2.49	1.42	2.01	0.55
9.	1775.73	0.69	0.19	0.19	34.47	0.46	0.50	1599.48	0	0.44	0.65	0.29	0.17	0.24	0.07
10.	2185.08	1.36	0.40	0.43	83.34	0.98	1.10	3.33	0.44	0	1.46	0.73	0.43	0.58	0.16
11.	2749.38	2.03	1.60	4.31	138.79	1.49	1.72	5.19	0.65	1.46	0	4.40	2.35	0.98	0.27
12.	90.33	0.94	0.54	0.11	80.02	0.72	0.89	2.49	0.29	0.73	4.40	0	3.94	0.58	0.15
13.	509.01	0.54	0.31	5.24	46.68	0.42	0.51	1.42	0.17	0.43	2.35	3.94	0	0.34	0.09
14.	665.02	0.78	0.23	0.31	7558.48	0.69	0.71	2.01	0.24	0.58	0.98	0.58	0.34	0	0.11
15.	1152.72	1.01	0.30	0.39	76.22	0.76	1.72	0.55	0.07	0.16	0.27	0.15	0.09	0.11	0
16.	1260.94	1.24	0.38	0.51	102.30	0.95	1.39	23.53	0.39	0.95	1.59	0.96	0.56	0.68	0.90
17.	1181.24	1.49	0.44	0.54	10.56	1.10	1.28	30.41	0.16	0.38	0.06	0.33	0.19	0.24	0.33
18.	206.27	0.20	0.06	0.08	1.61	0.15	0.18	4.15	0.06	0.15	0.25	0.15	0.09	0.11	0.14
19.	5748.86	7.45	2.23	3.17	555.23	5.58	6.56	280.74	2.35	5.53	8.96	5.06	2.92	3.59	4.85
20.	31.48	0.03	0.01	0.01	2.79	0.02	0.03	0.50	0.01	0.03	0.04	0.03	0.02	0.02	0.02
21.	18.30	0.02	0.01	0.01	0.12	0.01	0.01	0.04	0.01	0.24	0.02	0.01	0.01	0.01	0.01
22.	85.11	0.10	0.03	0.04	9.12	0.08	0.01	1.04	0.03	0.08	0.13	0.09	0.05	0.06	0.08
23.	69.01	0.07	0.02	0.03	6.32	0.06	0.07	0.97	0.02	0.06	0.10	0.06	0.04	0.04	0.06
24.	120.44	0.14	0.04	0.65	1.36	0.11	0.14	1.27	0.04	0.11	0.20	0.13	0.08	0.09	0.11
25.	178.04	0.22	0.07	0.11	2.23	0.18	0.22	1.79	0.07	0.18	0.32	0.22	0.13	0.15	0.19

Table 8.5 contd...

	16	17	18	19	20	21	22	23	24	25
1	1260.94	1881.24	206.27	8748.86	31.48	18.30	85.11	69.01	120.44	178.05
2	1.24	1.49	0.20	7.45	0.03	0.02	0.10	0.07	0.14	0.22
3	0.38	0.44	0.06	2.23	0.01	0.01	0.03	0.02	0.04	0.07
4	0.51	0.54	0.08	3.17	0.01	0.01	0.04	0.03	0.65	0.11
5.	102.30	10.56	1.61	555.23	2.79	0.12	9.12	6.32	1.36	2.23
6	0.95	1.10	0.15	5.58	0.02	0.01	0.08	0.06	0.11	0.18
7	1.39	1.28	0.18	6.56	0.03	0.01	0.10	0.07	0.14	0.22
8	23.53	30.41	4.15	280.74	0.50	0.04	1.04	0.97	1.27	1.79
9	0.39	0.16	0.06	2.35	0.01	0.01	0.03	0.02	0.04	0.07
10	0.95	0.38	0.15	5.53	0.03	0.24	0.08	0.06	0.11	0.18
11	1.59	0.06	0.25	8.96	0.04	0.02	0.13	0.10	0.20	0.32
12	0.96	0.33	0.15	5.06	0.03	0.01	0.09	0.06	013	0.22
13	0.56	0.19	0.09	2.92	0.02	0.01	0.05	0.04	0.08	0.13
14	0.68	0.24	0.11	3.59	0.02	0.01	0.06	0.04	0.09	0.15
15	0.90	0.33	0.14	4.85	0.10	0.01	0.08	0.06	0.11	0.19
16	0	8.20	1.74	27.33	0.10	0.01	0.29	0.23	0.39	0.62
17	8.20	0	7.77	46.93	0.14	0.08	0.33	0.28	0.43	0.65
18	1.74	7.77	0	4.53	0.02	0.02	0.05	0.04	0.06	0.10
19	27.33	46.93	4.53	0	5.70	0.08	7.25	8.90	7.59	9.70
20	0.10	0.14	0.02	5.70	0	0.01	0.02	0.02	0.03	0.04
21	0.01	0.01	0.002	0.08	0.01	0	0.003	0.002	0.004	0.006
22	0.29	0.33	0.05	7.25	0.02	0.003	0	1.56	0.52	0.57
23	0.23	0.28	0.04	8.90	0.02	0.002	1.56	0	3.83	3.17
24	0.39	0.43	0.06	7.59	0.03	0.004	0.52	3.83	0	137.95
25	0.62	0.65	0.10	9.70	0.04	0.096	0.57	3.17	137.95	0

$$F = 1/2 \sum_{j=1}^{n} \sum_{i=1}^{n} F_{ij} = 1,76,314.41 * 106$$

Table 8.6 Alternative II - Matrix for Route Length (Km)

0	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	0.0	3.5	4.1	7.3	8.4	4.3	5.4	4.4	3.0	4.9	6.7	10.8	11.1
2.	3.5.	0.0	3.5	6.2	11.9	7.8	8.9	7.9	6.5	4.8	5.7	10.2	10.5
3.	4.1	3.5	0.0	3.2	10.3	6.4	9.0	8.7	7.1	9.0	6.3	6.7	7.0
4.	7.3	6.2	3.2	0.0	7.1	3.2	5.8	9.6	10.3	12.2	5.4	3.5	3.8
5.	8.4	11.9	10.3	7.1	0.0	3.9	6.5	10.3	11.2	13.1	12.5	10.6	10.9
6.	4.3	7.8	6.4	3.2	3.9	0	2.6	6.4	7.3	9.2	8.6	6.7	7.0
7.	5.4	8.9	9.0	5.8	6.5	2.6	0	3.8	8.4	10.3	11.5	9.3	9.6
8.	4.4	7.9	8.7	9.6	10.3	6.4	3.8	0	4.7	7.9	10.5	13.1	13.4
9.	3.0	6.5	7.1	10.3	11.2	7.3	8.4	4.7	0	3.2	9.1	13.8	14.1
10.	4.9	4.8	9.0	12.2	13.1	9.2	10.3	7.9	3.2	0	10.5	14.4	15.0
11.	6.7	5.7	6.3	5.4	12.5	8.6	11.5	10.5	9.1	10.5	0	8.9	9.2
12.	10.8	10.2	6.7	3.5	10.6	6.7	9.3	13.8	13.6	14.4	8.9	0	7.3
13.	11.1	10.5	7.0	3.6	10.9	7.0	9.6	13.4	14.1	15.0	9.9	7.3	0
14.	10.0	13.5	11.9	8.7	1.6	5.5	8.1	11.9	13.0	14.9	14.1	12.2	12.5
15.	7.8	11.3	11.4	8.2	8.9	5.0	2.4	6.2	10.9	12.7	13.6	11.7	12.0
16.	8.4	11.9	18.0	14.8	15.5	11.6	9.0	5.2	9.9	13.1	15.7	18.3	18.6
17.	6.5	10.0	10.8	11.9	12.6	8.7	6.1	2.3	7.0	10.2	12.8	15.4	15.7
18.	9.0	12.5	13.3	14.4	15.1	11.2	8.6	4.8	9.5	12.7	15.3	17.9	18.2
19.	7.5	11.0	11.6	12.7	13.4	9.5	6.9	3.1	7.8	10.9	13.6	16.2	16.5
20.	10.7	14.2	14.8	15.9	16.6	12.7	10.1	6.3	11.0	14.1	16.8	19.4	19.7
21.	7.7	7.6	11.8	15.0	15.9	12.0	13.1	10.7	6.0	2.8	13.3	19.3	19.6
22.	12.4	15.9	16.5	17.6	19.2	15.3	12.7	8.9	13.6	16.7	19.4	22.0	22.3
23.	11.6	15.1	15.7	16.8	17.5	13.6	11.0	7.2	11.9	15.0	17.7	20.3	20.6
24.	14.8	18.3	18.9	20.0	20.7	16.8	14.2	10.4	15.1	18.2	20.9	23.5	23.8
25.	16.6	20.1	20.7	21.8	22.5	18.6	16.0	12.2	16.9	20.0	22.7	25.3	25.6

Table 8.6 Contd..

14	15	16	17	18	19	20	21	22	23	24	25
10.0	7.8	8.4	6.5	9.0	7.5	10.7	7.7	12.4	11.6	14.8	16.6
13.5	11.3	11.9	10.0	12.5	11.0	14.2	7.6	15.9	15.1	18.3	20.1
11.9	11.4	1.8	10.8	13.3	11.6	14.8	11.8	16.5	15.7	18.9	20.7
8.7	8.2	14.8	11.9	14,4	12.7	15,9	15.0	17.6	16,8	20.0	21.8
1.6	8.9	15.5	12.6	15.1	13.4	16.6	15.9	19.2	17.5	20.7	22.5
5.5	5.0	11.6	8.7	11.2	9.5	12.7	12.0	15.3	13.6	16.8	18.6
8.1	2.4	9.0	6.1	8.6	6.9	10.1	13.1	12.7	11.0	14.2	16.0
11.9	6.2	5.2	2.3	4.8	3.1	6.3	10.7	8.9	7.2	10.4	12.2
13.0	10.9	9.9	7.0	9.5	7.8	11.0	6.0	13.6	11.9	15.1	16.9
14.9	12.7	13.1	10.2	12.7	10.9	14.1	2.8	16.7	15.0	18.2	20.0
14.1	13.6	15.7	12.8	15.3	13.6	16.8	13.3	19.4	17.7	20.9	22.7
12.2	11.7	18.3	15.4	17.9	16.2	19.4	19.3	22.0	20.3	23.5	25.3
12.5	12.0	18.6	15.7	18.2	16.5	19.7	19.6	22.3	20.6	23.8	25.6
0	10.5	17.1	14.2	16.7	15.0	18.2	17.5	20.8	19.1	22.3	23.1
10.5	0	11.4	8.5	11.0	9.3	12.5	15.5	15.1	13.4	16.6	18.4
17.1	11.4	0	3.7	6.2	8.3	11.5	15.9	14.1	12.4	15.6	17.4
14.2	8.5	3.7	0	2.5	5.4	8.6	13.0	11.2	9.5	12.7	14.5
16.7	11.0	6.2	2.5	0	7.9	11.1	15.5	13.7	12.0	15.2	17.0
15.0	9.3	8.3	5.4	7.9	0	3.2	13.8	5.8	4.1	7.3	9.1
18.2	12.5	11.5	8.6	11.1	3.2	0	17.0	9.0	7.3	10.9	12.3
17.5	15.5	15.9	13.0	15.5	13.8	17.0	0	19.6	17.9	21.1	22.9
20.8	15.1	14.1	11.2	13.7	5.8	9.0	19.6	0	1.7	4.9	6.7
19.1	13.4	12.4	9.5	12.0	4.1	7.3	17.9	1.7	0	3.2	5
22.3	16.6	15.6	12.7	5.2	7.3	10.9	21.1	4.9	3.2	0	1.8
23.1	18.4	17.4	14.5	17.0	9.1	12.3	22.9	6.7	5.0	1.8	0

$$RL = 1/2 \sum_{j=1}^{n} \sum_{i=1}^{n} RL_{ij} = 3534.3$$

Table 8.7 : Alternative II - Matrix for Demographic Force of Interaction

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	4543.68	1083.82	700.52	122766.77	2593.91	2310.95	8599.96	1775.73	2185.08	2279.00	88.67	499.88	678.39	1152.72	1646.94
2.	4543.68	0.00	2.73	1.78	112.11	1.44	1.56	4.88	0.69	4.17	5.77	1.82	1.02	0.68	1.006	1.50
3.	1083.82	2.73	0	2.19	48.98	0.70	0.05	1.32	0.19	0.39	1.55	1.38	0.75	0.29	0.32	0.22
4.	700.52	1.78	2.19	0	211.22	5.76	0.25	2.23	0.19	0.43	4.31	1.04	5.24	1.10	1.28	0.65
5.	122766.77	112.11	48.98	211.22	0	899.41	454.93	447.63	36.34	87.20	186.75	262.54	147.86	7558.48	252.54	137.96
6.	2593.91	1.44	0.70	5.76	899.41	0	15.74	6.42	0.47	0.98	2.18	3.64	1.98	3.54	4.43	1.36
7.	2310.95	1.56	0.05	0.25	454.93	15.74	0	25.58	0.50	1.10	1.72	2.65	1.48	2.29	27.02	3.18
8.	8599.96	4.88	1.32	2.22	447.63	6.42	25.58	0	3966.27	4.61	5.09	3.30	1.88	2.63	2.14	23.56
9.	1775.73	0.69	0.19	0.19	36.34	0.47	0.50	3966.27	0	2.70	0.65	0.29	0.16	0.21	0.07	0.62
10.	2185.08	0.17	0.39	0.43	87.20	0.98	1.10	4.61	2.70	0	1.60	0.86	0.47	0.53	0.16	1.17
11.	2279.00	5.77	1.55	4.31	186.75	2.18	1.72	5.09	0.65	1.60	0	4.40	2.45	1.15	0.27	1.59
12.	88.67	1.82	1.38	1.04	262.54	3.64	2.65	3.30	0.29	0.86	4.40	0	3.94	1.55	0.37	1.18
13.	499.86	1.02	0.75	5.24	147.86	1.98	1.48	1.88	0.16	0.47	2.45	3.94	0	0.88	0.21	0.68
14.	678.39	0.68	0.29	1.10	7758.48	3.54	2.29	2.63	0.21	0.53	1.15	1.55	0.88	0	0.30	0.89
15.	1152.72	1.006	0.32	1.28	252.54	4.43	27.02	2.14	0.07	0.16	0.27	0.37	0.21	0.30	0	2.06
16.	1646.94	1.50	0.22	0.65	137.96	1.36	3.18	23.56	0.62	1.17	1.59	1.18	0.68	0.89	2.06	0
17.	1998.79	1.55	0.43	0.73	15.17	1.76	5.04	30.41	0.32	0.49	0.06	0.42	0.24	0.33	0.94	8.20
18.	215.54	0.20	0.06	10.35	2.18	0.22	0.52	4.15	0.10	0.19	0.25	0.19	0.11	0.14	0.33	1.74
19.	8748.86	7.45	2.19	4.25	795.08	8.61	22.94	280.74	4.26	7.15	8.96	6.39	3.67	4.89	13.14	27.33
20.	31.48	0.03	0.0098	0.02	3.73	0.04	0.08	0.497	0.015	0.03	0.04	0.03	0.02	0.02	0.05	0.10
21.	18.78	0.04	0.005	0.006	0.13	0.01	0.01	0.05	0.016	0.24	0.02	0.01	0.0058	0.008	0.01	0.017
22.	97.92	0.11	0.03	0.06	11.65	0.10	0.21	1.04	0.04	0.09	0.13	0.11	0.06	0.08	0.15	0.29
23.	67.82	0.07	0.02	0.04	8.17	0.08	0.17	0.97	0.03	0.07	0.08	0.08	0.04	0.06	0.12	0.23
24.	114.02	0.14	0.04	0.77	1.66	0.14	0.27	1.27	0.06	0.13	0.19	0.15	0.09	0.11	0.20	0.39
25.	175.91	0.22	0.07	0.13	2.73	0.22	0.42	1.79	0.09	0.21	0.32	0.26	0.15	0.20	0.33	0.61

Table 8.7 contd..

	17	18	19	20	21	22	23	24	25
1.	1998.79	215.54	8748.86	31.48	18.78	97.92	67.82	114.02	175.91
2.	1.55	0.20	7.45	0.03	0.04	0.11	0.07	0.14	0.22
3.	0.43	0.06	2.19	0.098	0.005	0.03	0.02	0.04	0.07
4.	0.73	10.35	4.25	0.02	0.006	0.06	0.04	0.77	0.13
5.	15.17	2.18	795.02	3.73	0.13	11.65	8.17	1.66	2.73
6.	1.76	0.22	8.61	0.04	0.01	0.10	0.08	0.14	0.22
7.	5.04	0.52	22.94	0.08	0.01	0.21	0.17	0.27	0.42
8.	30.41	4.15	280.74	0.497	0.05	1.04	0.97	1.27	1.79
9.	0.32	0.10	4.26	0.015	0.016	0.04	0.03	0.06	0.09
10.	0.49	0.19	7.15	0.03	0.24	0.09	0.07	0.13	0.21
11.	0.06	0.25	8.96	0.04	0.02	0.13	0.098	0.19	0.32
12.	0.42	0.19	6.39	0.03	0.01	0.11	0.08	0.15	0.26
13.	0.24	0.11	3.67	0.02	0.0058	0.06	0.04	0.09	0.15
14.	0.33	0.14	4.89	0.02	0.008	0.08	0.06	0.11	0.20
15	0.94	0.33	13.14	0.05	0.01	0.15	0.12	0.20	0.33
16.	8.20	1.74	27.33	0.10	0.017	0.29	0.23	0.39	0.61
17.	0.0	7.77	46.93	0.14	0.018	0.33	0.28	0.43	0.64
18.	7.77	0.0	4.53	0.02	0.0026	0.05	0.04	0.06	0.096
19.	46.93	4.53	0.0	5.70	0.09	7.25	8.80	7.59	9.49
20.	0.14	0.02	5.70	0.0	0.0004	0.02	0.02	0.02	0.04
21	0.018	0.0026	0.09	0.0004	0.0	0.002	0.001	0.002	0.003
22.	0.33	0.05	7.25	0.02	0.002	0.0	1.56	0.52	0.54
23.	0.28	0.04	8.80	0.02	0.001	1.56	0.0	3.83	32.05
24.	0.43	0.06	7.59	0.02	0.002	0.52	3.83	0.0	123.05
25.	0.64	0.096	9.49	0.04	0.003	0.54	3.05	123.05	0.0

$$F_{ij} = \frac{P_i * P_j \times CS_i * CS_j}{d_{ij}^2} \times 10^6$$

$$F = 1/2 \sum_{j=1}^{25} \sum_{l=1}^{25} F_{ij} = 180986.88$$

Table 8.8 Comparison of Alternative Network Options

Sl. No.	Network	E.L	L.L	F	E_L	E_g	EN	E_I
1.	Fully developed	2680.3	2680.3	196,285.44x10^6	73.23x10^6	73.23x10^6	.0273x10^6	100%
2.	Alternative - I	78.6	4016.3	176,314.14x10^6	2243.18x10^6	43.9x10^6	.56x10^6	89.825%
3.	Alternative - II	95.9	3534.3	180,936.88x10^6	1887.24x10^6	51.21x10^6	.59x10^6	92.2%

CHAPTER - 9

CONCLUSIONS

The objective of the present study was to demonstrate a planning strategy through which the country can be freed from the trap of degrading poverty and consequent poor quality of life available to the people. A measure of this is the Human Development Index of latest UNDP report according to which India ranks 138th among 176 countries. As bulk of India's population is engaged in agriculture and there are serious difficulties in diverting a significant proportion of the work force to other sectors of the economy, the only remedy is to make agriculture more rewarding, profitable and labour intensive.

Accordingly a study of Bijnor District has been made with a view to optimise agricultural incomes with available land and water resources and other necessary inputs. Bijnor district is situated on the left bank of River Ganga in Moradabad Division of U.P. It is predominantly agricultural with limited industrial development with a total area of 4,84,800 ha and 1991 population of 24.55 lakhs. It represents a typical district in Northern Indian plains and the planning methodology evolved for it will have wide applicability.

Optimisation of Agricultural Income

Bijnor District is presently mostly dependent on ground water for irrigation. The network of Eastern Ganga canal channels which will run during Kharif only is still under construction. An estimate is made of the water resources ground and surface, which will be available on completion of this work. Present Ground water availability will be augmented by increased seepage from additional irrigated area and from Eastern Ganga Canal. It is shown that 1,66,500 ham of ground water will be available against 115,673 ha m at present. Canal water available during kharif only has a potential of 1,16,170 ham. (Chapter-4).

After studying the existing cropping pattern, seventeen crops have then been selected taking into account the soil, climate and farmers preferences of the district (other considerations were self sufficiency in food and fodder and problems of storage and marketability) . The optimal water requirements of these crops have been worked out on basis of their evapotranspiration requirement based on pan evaporation data (Tables 5.2, 5.19).

Next the input and labour cost and benefits that can be obtained from each of these crops have been worked out (Tables 6.1 to 6.15). These are necessarily based on averages as there are considerable fluctuations in both. Reliable data has been used as far as possible on basis of both published information and enquiry. After that a linear programming model has been used to find the optimum cropping pattern.

The objective function used maximises the combined net monetary benefits from all crops, subject to obligatory constraints of land and water availability and non-negativity of crop areas and water requirements. However, without other crop area constraints an impractical result involving only three crops viz. Groundnut, wheat and potatoes is obtained (Table 6.18). This is not acceptable as it greatly distorts land and water use, provides no fodder for the large animal population and poses impossible problems of storage, transport and marketability. Hence, it was necessary to progressively arrive at optimal, but at the same time practical, cropping pattern by imposing crop area constraints. Finally two studies G and E (Table 6.19) were arrived at which give practically the same net benefits. While both indicate the need to reduce area under the presently dominant sugarcane, study G does so to a lesser extent and is considered more practical.

It is shown that the net benefit from the revised cropping pattern comes to Rs. 4107 million which is 80% more than Rs.2280 million available with existing cropping pattern, irrigation resources and inputs.

The Impetus to Economic Growth

The increased agricultural incomes will give a strong impetus to overall economic growth in the district. It is shown that an increase in agricultural income of Rs. 182.7 crores will multiply into an increase in economic activity of 383.6 crores (Chapter 7). This will result in direct employment opportunity of 15.9 million mandays or, 79,500 workers for 200 days in the farm sector (Tables 7.5, 7.6).

It is proposed to establish small scale agricultural processing industries which will provide regular employment to

33,400 persons. Increased employment in trade, services etc. will be in addition to the figures given above and will also be substantial (Chapter 7).

There will be substantial improvement in the nutritional level and health of the people due to availability of more food and income.

The fertiliser consumption will increase from 54,809 m tonnes to 129,000 m tonnes an addition of 74,191 mt. It has been shown that about 2.2 lakh mt of food grains will move out of the district. There will also be a large increase in movement of goods within the district. Development of a road network is thus not only essential but highly rewarding in economic terms for the development of the district.

An approach to planning of rural road network

Provision of transport is one of the most important requirements for stimulation of economic activity and growth. Many eminent economists and social scientists have stressed the extreme importance of a transport net work. Bijnor district, like other similar districts in India, does not have a well developed network of all weather roads linking its villages. Since road construction is quite costly it is necessary to make it as cost effective as possisble. One tehsil of Bijnor distt. viz. Najibabad has been selected to demonstrate the planning methodology for road network suggested by the author (Chapter 8).

The Tehsil area was divided into 25 hexagons, a few of them partial, with a side of 4 km. A `growth centre' based on population and other attributes, quantified by a `centrality score' was identified inside each hexagon. A road network has been planned (Map 8.4) based on demographic force of interaction between growth centres, centrality scores, and aimed at maximising network efficiency. With this net work no village will be more than one hour's walk a way from an all weather road, and most will be much nearer. All growth centres will be linked to each other and to the major urban centre of Najibabad. The net work efficiency comes to 92.2% against a theoretical maximum of 100% achievable by direct linkage of every node to every other node at enormous cost.

Inference

It can be conclusively inferred that poverty is not preordained or determined by forces beyond human control. It is a symptom of under-development and nonutilisation of natural and human resources. By united effort and hardwork towards scientific, prudent and sustainable development of our natural resources there is no reason why India should be among the poorer countries of the world. Infact, there are enough resources and manpower to bring it to a leading position. That this can be achieved without radical changes in policy or technology is shown by the present case study of a typical district in plains of Northern India, with a predominantly agricultural economy.

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* * * * *

APPENDICES

LP OPTIMUM FOUND AT STEP 29

OBJECTIVE FUNCTION VALUE

1) 0.4126599E+10

VARIABLE	VALUE	REDUCED COST
X1	60000.000000	0.000000
X2	61948.027344	0.000000
X3	30000.000000	0.000000
X4	30000.000000	0.000000
X5	36000.000000	0.000000
X6	146724.015625	0.000000
X7	50000.000000	0.000000
X8	0.000000	1010.489258
X9	1551.972290	0.000000
X10	2000.000000	0.000000
X11	1000.000000	0.000000
X12	6000.000000	0.000000
X13	13000.000000	0.000000
X14	702.946045	0.000000
X15	4000.000000	0.000000
X16	120000.000000	0.000000
X17	2000.000000	0.000000
G1	5519.505371	0.000000
G2	8067.564453	0.000000
G3	29049.314453	0.000000
G4	17387.800781	0.000000
G5	25873.777344	0.000000
G6	6738.805176	0.000000
G7	0.000000	6481.288086
G9	0.000000	6481.288086
G10	42012.898438	0.000000
G11	23751.865234	0.000000
G12	8098.471680	0.000000
G8	0.000000	6481.288086

NOTE : In optimisation constraint for area, when a crop is in the field for part of a month the area is multiplied by that fraction. Actually, although for a fraction of the month, the crop is occupying full land area. Hence manual adjustment has been made to meet the land area constraint correctly.

```
!       file name is bs3.dat
BAT
      max  4800 x1+4075 x2+6340 x3+9160 x4+4000 x5+6790 x6+8050 x7
           + 4900 x8+4150 x9+4180 x10+3510 x11+4970 x12+6370 x13+
           3050 x14+2800 x15+11850 x16+6060 x17
          SUBJECT TO          /
  2)    x1+.33 x2+.5 x4+.5 x5+x7+x10+.5x13+x16+x17 <=341500
 3).5 x1+.5 x6+x7+.5 x8+x9+x10+x12+x13+x16+x17 <=341500
 4) x6+x7+x8+.5 x9+x10+x11+x12+x13+x16+x17 <= 341500
 5) .5 x2+x4+x14+x15+x16 <= 341500
 6) x1+x2+x3+x4+x5+.33 x14+.33 x15+x16+x17 <= 341500
 7) x1+x2+x3+x4+x5+x9+x16+x17<= 341500
 8) .0123 x6+.027 x7+.0115 x8+.027 x10+.0298 x11+.0377 x12+.0122 x13
    +.0155 x16+.0181 x17 -g1 <=0
 9) .0360 x6+.0216 x7+.0369 x10+.0369 x11+.0398 x12+.0113 x16 -g2 <=0
 10) .0764 x6+.0422 x10+.0472 x11+.0258 x12+.0764 x13+.138 x16-g3<=0
 11) .0526 x13+.1392 x16-g4 <=0
 12) .075 x4+.2364 x14+.2364 x15+.1876 x16-g5 <=0
 13) .050 x2+.0828 x14+.0828 x15+.0726 x16-g6 <=5460
 14) .461 x1-g7<=36800
 15) .2078 x1+.050 x9-g9 <=31170
 16) .3765 x1+.0149 x2+.0366 x4+.1273 x7+.0822 x9+.0693 x10+.0209 x13
     +.1346 x16+.1435 x17 -g10 <=5940
 17) .028 x1+.075 x6+.0551 x7+.050 x8+.032 x9+.0132 x10+.0649 x12
     +.0363 x13+.0603 x16+.0696 x17 -g11<=0
 18) .0117 x6+.0422 x7+.0142 x8+.0029 x9+.0207 x10+.0861 x11+.0469 x12
     +.0315 x16+.0392 x17 -g12 <=0
 19) g1+g2+g3+g4+g5+g6+g7+g8+g9+g10+g11+g12 <=166500
 20) g1<=45000
 21) g2<=45000
 22) g3<=45000
 23) g4<=45000
 24) g5<=45000
 25) g6<=45000
 26) g7<=45000
 27) g8<=45000
 28) g9<=45000
 29) g10<=45000
 30) g11<=45000
 31) g12<=45000
 32) x1>=60000
 33) x6>=110000
 34) x5 =36000
 35) x13 >=13000
 36) x16 >= 120000
 37) x4 <= 30000
 38) x7 <= 50000
 39) x2 >= 5000
 40) x3 <= 30000
 41) x10 >=2000
 42) x11 >= 1000
 43) x12 >= 6000
 44) x15 >= 4000
 45) x17 >= 2000
 46) x8 <=10000
 47) x9 <=20000
 49) x14 <=30000
END


BAT
leave
```

LP OPTIMUM FOUND AT STEP 30

OBJECTIVE FUNCTION VALUE

1) 0.4205008E+10

VARIABLE	VALUE	REDUCED COST
X1	50000.000000	0.000000
X2	1000.000000	0.000000
X3	30000.000000	0.000000
X4	30000.000000	0.000000
X5	106936.710938	0.000000
X6	156718.359375	0.000000
X7	50000.000000	0.000000
X8	0.000000	1163.457397
X9	21563.287109	0.000000
X10	2000.000000	0.000000
X11	1000.000000	0.000000
X12	6000.000000	0.000000
X13	13000.000000	0.000000
X14	30000.000000	0.000000
X15	35343.292969	0.000000
X16	100000.000000	0.000000
X17	2000.000000	0.000000
G1	5332.435547	0.000000
G2	8201.360352	0.000000
G3	27052.880859	0.000000
G4	14603.799805	0.000000
G5	36457.152344	0.000000
G6	7260.424805	0.000000
G7	0.000000	5354.035645
G9	0.000000	5354.035645
G10	36292.703125	0.000000
G11	23655.802734	0.000000
G12	7643.438477	0.000000
G8	0.000000	5354.035645

```
!        file name is bs4.dat
BAT
       max   4800 x1+4075 x2+6340 x3+9160 x4+4000 x5+6790 x6+8050 x7
             + 4900 x8+4150 x9+4180 x10+3510 x11+4970 x12+6370 x13+
             3050 x14+2800 x15+11850 x16+6060 x17
            SUBJECT TO
  2)   x1+.33 x2+.5 x4+.5 x5+x7+x10+.5x13+x16+x17 <=341500
 3).5 x1+.5 x6+x7+.5 x8+x9+x10+x12+x13+x16+x17 <=341500
 4) x6+x7+x8+.5 x9+x10+x11+x12+x13+x16+x17 <= 341500
 5) .5 x2+x4+x14+x15+x16 <= 341500
 6) x1+x2+x3+x4+x5+.33 x14+.33 x15+x16+x17 <= 341500
 7) x1+x2+x3+x4+x5+x9+x16+x17<= 341500
 8) .0123 x6+.027 x7+.0115 x8+.027 x10+.0298 x11+.0377 x12+.0122 x13
    +.0155 x16+.0181 x17 -g1 <=0
 9) .0360 x6+.0216 x7+.0369 x10+.0369 x11+.0398 x12+.0113 x16 -g2 <=0
 10) .0764 x6+.0422 x10+.0472 x11+.0258 x12+.0764 x13+.138 x16-g3<=0
 11) .0526 x13+.1392 x16-g4 <=0
 12) .075 x4+.2364 x14+.2364 x15+.1876 x16-g5 <=0
 13) .050 x2+.0828 x14+.0828 x15+.0726 x16-g6 <=5460
 14) .461 x1-g7<=36800
 15) .2078 x1+.050 x9-g9 <=31170
 16) .3765 x1+.0149 x2+.0366 x4+.1273 x7+.0822 x9+.0693 x10+.0209 x13
     +.1346 x16+.1435 x17 -g10 <=5940
 17) .028 x1+.075 x6+.0551 x7+.050 x8+.032 x9+.0132 x10+.0649 x12
     +.0363 x13+.0603 x16+.0696 x17 -g11<=0
 18) .0117 x6+.0422 x7+.0142 x8+.0029 x9+.0207 x10+.0861 x11+.0469 x12
     +.0315 x16+.0392 x17 -g12 <=0
 19) g1+g2+g3+g4+g5+g6+g7+g8+g9+g10+g11+g12 <=166500
 20) g1<=45000
 21) g2<=45000
 22) g3<=45000
 23) g4<=45000
 24) g5<=45000
 25) g6<=45000
 26) g7<=45000
 27) g8<=45000
 28) g9<=45000
 29) g10<=45000
 30) g11<=45000
 31) g12<=45000
 32) x1>=50000
 33) x2>=1000
 34) x3 <=30000
 35) x4 <=30000
 36) x5 >= 36000
 37) x6 >= 110000
 38) x7 <= 50000
 39) x10 >= 2000
 40) x11 >= 1000
 41) x12 >= 6000
 42) x13 >= 13000
 43) x14 <= 30000
 44) x15 >= 4000
 45) x16 >= 100000
 46) x17 >= 2000
END


BAT
leave
```