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CASE STUDY ON DESERTIFICATION

MONA RECLAMATION EXPERIMENTAL PROJECT

PAKISTAN

This study was undertaken by the Planning and Coordination Cell of the Irrigation Drainage and Flood Control Research Council under a UNDP Project (Project RAS/76/063) for which Unesco was the executing agency. FAO and WMO also collaborated in this study, the purpose of which was to prepare a synthesis of information on waterlogging and salinisation, in a case study of a sample area of a river basin with a major irrigation system. Assistance was also provided by the following organisations:

- Pakistan Water and Power Development Authority
- Irrigation and Power Department, Government of the Punjab
- University of Agriculture, Lyallpur
- Punjab Lands Records Office
- Agriculture Census Organisation
- Population Census Organisation
- Library of the Government College, Lahore

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The following scientists were the members of the panel who participated in the preparation of this report.

Mr. Sayyid Hamid	Chairman of the Panel Ex-Chief Engineer Department of Irrigation Government of the Punjab
Mr. M.A. Qayyum	Director Reclamation and Water Management Master Planning and Review Division Water and Power Development Authority
Mr. Chaudhry Ata-ur-Reham	Project Director Project Planning Organization (Northern Zone) Water and Power Development Authority
Dr. Haider Ali Chaudhry	Professor Faculty of Agricultural Economics and Rural Sociology University of Agriculture
Mr. S.M.H. Zaidi	Superintending Engineer Salinity Control and Reclamation Project-I Department of Irrigation Government of the Punjab
Dr. Ghulam Haider	Superintending Research Officer Mona Reclamation Experimental Project Water and Power Development Authority
Mr. M. Anis Ahmad	Secretary Irrigation, Drainage and Flood Control Research Council

Mr. S.B. Hasan	Director Planning and Coordination Cell Irrigation, Drainage and Flood Control Research Council
Mr. M.A.R. Farooqi	Senior Scientific Officer Planning and Coordination Cell Irrigation, Drainage and Flood Control Research Council

The following staff members of the Irrigation, Drainage and Flood Control Research Council coordinating the work:

Mr. Abdul Majeed	Senior Scientific Officer Planning and Coordination Cell
Mr. K.H. Jafri	Librarian Planning and Coordination Cell

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SUMMARY

(PAKISTAN)

The Mona Reclamation Experimental Project extends over a gross area of some 44,500 ha, about 41,000 ha under irrigation. It is located in the Jhelum River plains 240 km northwest of Lahore. The region is arid to semi-arid with variable rainfall averaging 380 mm, principally in the summer monsoon. Summers are hot and winters mild; annual pan evaporation is 2100 - 3000 mm. Crops grown within the project are cotton, rice, maize and sugarcane in summer and wheat, gram, barley, tobacco and oil-seeds in winter. The crop yields are among the lowest in the world although the climate, soil and water resources offer great potentialities. One of the important constraints in agricultural production is the desertification of good agricultural lands caused by waterlogging and soil salinization as a consequence of unscientific irrigation.

In the pre-irrigation period, no soil survey was carried out in the study area. However, it is reported that the soils were generally productive and there were no visible signs of soil salinity. The groundwater in the area was in the range of 6 - 18 meters below the surface.

Canal irrigation came in the area with the opening of the Lower Jhelum Canal in 1901. There were 11 canal distributaries serving the study area in 1965. The surface drainage system was introduced in the 1930s and by 1965 there was a network of 158 kilometers of drains in the area.

As a result of irrigation activity in the study area, apart from a gradual increase in the cropped area, the cropping pattern shifted more towards cash crops and local variety of cotton changed to improved strains of cotton. The crop yields increased but were still lower than many other countries.

Side by side with prosperity, the irrigation activities brought their ill effects in the area. The percolation of water from the canal system and fields led to the steady rise in the water table and consequent soil salinization resulting in desertification of arable lands. In the early 1960s, 90 per cent of the area was also affected by waterlogging.

For drainage, reclamation and improvement of agriculture in the area and also for investigation and research, the Mona Reclamation Experimental Project comprising 138 tubewells of .05 to .10 m^3/sec capacity each, was implemented in 1965 in the overall context of the SCARP programme (Salinity Control and Reclamation Projects). The results of rehabilitation measures adopted show that the water table has declined by 1 - 2 meters and stabilized over most of the area; the salt free area has also increased by about 4 per cent.

This case study confirms that: salt affected land can be reclaimed through leaching, growing suitable crops and addition of amendments; soil fertility can be improved and maintained by farm-yard manure and fertilizers; imbalance in agricultural inputs is one of the main causes of low yields; marginal quality tubewell waters can be used for successful crop production by addition of suitable amendments.

Applied research on continuous basis is necessary to evaluate the scheduling of irrigation and the control of water applications for both traditional and new crops; there is need to set up pilot projects before embarking on large scale project development in order to pave the way for detailed analysis of future project operations; on-farm water management practices need to be improved.

INTRODUCTION

1. PAKISTAN - GENERAL FEATURES

1.1 Location

Pakistan covers an area of about 797 million ha situated south of the Himalayan mountains. It lies between longitudes 61° and 76°E and latitudes 24° and 37°N and is bordered on the north by China, on the north-west by Afghanistan, on the west by Iran, on the south-east by India and on the south-west by the Arabian Sea.

1.2 Physiography

Physiographically, the country comprises five major regions: the Northern Mountains, the Western Bordering Mountains, the Salt Range and Potwar Plateau, the Indus Plains, and the Baluchistan Plateau. The Indus Plains, which have been formed almost entirely by the deposition of alluvium, constitute the most important physiographic unit, as they comprise the main irrigated areas of the country.

1.3 Administrative units

The provinces of Pakistan - the Punjab, Sind, North Western Frontier Province (NWFP) and Baluchistan - are divided into 16 administrative divisions which comprise 55 districts. These districts are further divided into 231 Tehsils or Talukhas.

1.4 Language

Urdu is the national language whereas Punjabi, Sindhi, Pushto and Baluchi are regional languages. The English language continues to play important part.

1.5 Population

The recorded population of the area falling within the territory of Pakistan was about 16 million in 1901 rising to about 34 million in 1951 and 65 million in 1972. The present estimated population is about 72 million with an average growth rate of 3 per cent.

According to the 1972 Census about 71 per cent of the population live in the rural areas with the remainder in the urban areas. The average population density in the country is 211 persons per square mile ranging from 18 persons per square mile in Baluchistan to 532 in the Punjab. Literacy is around 20 per cent and fewer than 50 per cent of the children are in primary schools.

Karachi is the most populous city with a population of 3.58 million followed by Lahore with 2.16 million. There are 19 cities with a population of over 100,000 persons in the country. The distribution of urban and rural population is given in Table 1.

Table 1: Population of urban and rural areas (1972 Census)

Province	Urban	Rural	Total
Punjab	9,257,312	28,486,292	37,743,604
Sind	5,700,426	8,307,296	14,007,722
North Western Frontier Province	1,202,514	9,620,738	10,823,252
Baluchistan	393,656	2,007,498	2,405,154
	16,557,908	48,557,824	64,479,732

Source: Government of Pakistan, Pakistan Statistical Year Book, 1975, Statistic Division, Ministry of Finance, Planning and Economic Affairs, pp 8-9, 1976.

The demographic analysis carried out in 1965 had revealed a crude birth rate of 50 and a crude death rate of 20 per thousand *per annum*. This indicated an estimated rate of population growth of 3 per cent *per annum*. Such a high birth rate was considered a serious threat to socio-economic development. The Government of Pakistan, therefore, embarked upon a population planning program in the country. The latest (1975) estimates are 44 crude birth rate as against 15 crude deaths rate per thousand *per annum*.

1.6 Climate

The climate of Pakistan is characterised by large seasonal and diurnal fluctuations in temperature and rainfall. Temperature extremes generally range from sub-zero to as much as 46°C and the mean annual precipitation ranges from less than 4 inches in the southern parts to more than 40 inches in the northern areas, making the region a land of great climatic contrast.

In the greater part of the Indus Plains the climate is arid to semi-arid. The summers are very hot with average maximum temperature of 38°C to 40°C. The annual rainfall varies from 10 cm in the south to 76 cm in the north with an average of less than 25 cm. Most of the precipitation occurs in the monsoon period (July to September) when torrential rains sometimes produce one-third of the year's rainfall in a single day. The evaporation rates are very high. The theoretical annual evaporation in the Northern Plains is 150 cm and in the Southern Plains 193 cm. The humidity generally increases, after the relatively dry winter months, through spring to high values during the monsoon period and then drops in the late September or early October.

1.7 Water resources

The water resources of Pakistan include surface waters of the Indus River and its tributaries, local rainfall and usable groundwater from the aquifers underlying the Indus Plains.

The rivers serving the Indus Plains are the Indus and its major tributaries - the Kabul on the right bank, and the Jhelum, Chenab, Ravi, Beas and the Sutlej on the left bank. With the implementation of the Indus Waters Treaty (1960) between Pakistan and India which came into force in April 1970, only rivers Indus, Jhelum and Chenab have fallen to the share of Pakistan. These rivers flow in shallow, meandering channels across the vast alluvial plains which gently slope towards south to southwest along the rivers with extremely flat gradients from about 0.2 metres per km in the Punjab to as low as 0.1 metre per km in Sind. The rivers have individual flow characteristics but they all rise with the snowmelt and monsoon rainfall in the spring and early summer and have a combined peak discharge in July or August. In winter, during the period November to February,

flows are less than one tenth of those in the summer monsoon period. The winter flows consist almost entirely of regeneration or bank storage returning to the river after the summer has ended with the fall in the river stages. The annual average flow in the rivers Indus, Jhelum and Chenab and the river Kabul is about 171.5 billion m^3. The mineral content (total dissolved solids) of the river waters ranges between 100 to 350 ppm from north towards south. The present contribution of the river waters towards agriculture is of the order of 123 billion m^3.

The present contribution of rain to crops in the irrigated areas is estimated at about 7.4 billion m^3 . A rise to about 12.3 billion m^3 as the cropped areas increase is anticipated in the course of development.

The deep alluvial deposits of the Indus Plains form an extensive groundwater aquifer. The physical characteristics of the alluvium are generally favourable to groundwater development. Keeping in view the water quality constraints for irrigation and gradual deterioration of groundwater, it has been estimated that as an interim measure about 54.12 billion m^3 of groundwater can be developed annually. Most of which however, would need mixing with canal water before use. Presently about 24.6 billion m^3 of groundwater is available for agricultural use.

1.8 Agriculture

1.8.1 Soils. There are great variations in the soils of Pakistan. The soil surveys completed over some 233,002 km^2 have established about 250 different soil series. Of these some occupy extensive areas whereas others are of limited extent. The texture of most soils ranges from moderate coarse to moderately fine. Coarse and fine textured soils occur less frequently. The clay minerals are mainly of the illite and chlorite types. The cation exchange capacities of the soils generally range from 20 to 50 per cent. The pH varies between about 8.0 and 8.5, though values up to 10.5 have been recorded in highly sodic soils. The available moisture content between pF 4.2 and 2.0 ranges from 20 to 30 per cent by volume.

The normal soils (not affected by salts) have satisfactory permeability rate. Where fine silts are present, weakly developed soil structure in the top layer due to lack of organic material in the soil results in the formation of a crust which interferes with water infiltration, and therefore, with seedling emergence.

The soils are characteristically deficient in nitrogen, organic matter and available phosphorus. There are some pockets of potash deficiency as well, especially in the rice tract and the sub-montane areas.

1.8.2 Land use and capability. Approximately half of the country consists of mountains and deserts; a quarter is occupied by towns, rivers, canals, roads, etc. Hence less than a quarter remains under cultivation or within the cultivable command area of the irrigation system. The land utilization statistics are shown in Appendix I.

About 13.3 million ha are under irrigated agriculture of which class I (very good), class II (good), class III(moderate) and class IV (poor) lands occupy 38, 51, 6 and 5 per cent area respectively. Class I land has no limitations and has very high potential, while class II land has only minor limitations of various kinds and has high potential for crop production. Classes III and IV have increasingly severe limitations for agricultural use. The land capability classes are shown in Table 2.

Table 2: Extent of different land capability classes in irrigated areas (in million ha.)

	Punjab	Sind	N.W.F.P.	Total
Geographic area	20.64	14.50	10.17	45.31
Total area surveyed	17.49	9.04	3.44	29.97
Land capability of irrigated area:				
Class I	3.61	1.04	0.16	4.81
Class II	3.56	2.50	0.37	6.43
Class III*	1.22	1.29	0.04	2.55
Class IV	0.51	0.10	0.004	0.61
Total	8.90	4.93	0.57	14.40

Source: Government of Pakistan, Agricultural Enquiry Committee Report of the Working Group on Soils and Soil Conservation, Ministry of Food and Agriculture, page 2, April 1975.

*Approximately 30 per cent of this land is at present under irrigation, the rest is uncultivated.

1.8.3 Crops. There are two main cropping seasons; Kharif - the summer season from April to October, and Rabi - the winter season from October to April. Important crops sown in summer are cotton, rice, maize, and sugarcane. Winter crops are wheat, gram, barley, tobacco and oilseeds. Agricultural production is largely subsistance-oriented, with foodgrains occupying major part of the crop area.

The crop yields in Pakistan are among the lowest in the world. The principal reasons for this fact are the shortage of irrigation water (particularly during the critical period of crop growth); the saline-alkali quality of the soils; the lack of effective drainage on irrigated lands; the impurity of the seed used; the low level of fertilizer input; the use of antiquated farm implements; the extremely inadequate use of plant protection measures; the use of unsatisfactory agricultural and irrigation practices.

1.9 Economy

The country being a developing one has a fluctuating economic growth rate. The values of Gross National Product and *per capita* Income at constant factor cost of 1959-60 are given in Table 3.

Table 3: Gross National Product and *per capita* Income at constant factor cost of 1970-1976.

Year	Gross National Product (G.N.P.) (rupees in million)	Contribution of agriculture sector to G.N.P. (per cent)	Growth of G.N.P. (per cent)	*Per capita* income (rupees)	Growth rate of income (per cent)
1970-71	32,296	37.7	-0.1	525	-3.1
1971-72	32,745	38.5	1.4	517	-1.5
1972-73	35,153	36.5	7.4	539	4.3
1973-74	37,126	36.0	5.6	552	2.4
1974-75 (revised)	38,300	34.2	3.2	553	0.2
1975-76 (provisional)	40,201	33.8	5.0	564	2.0

Source: Government of Pakistan, Pakistan Economic Survey 75-76, Finance Division, Economic Advisor's Wing, Islamabad, pages 8, 9 and 12, 1976.

Although there has been a continuous increase in the Gross National Product, the increase in *per capita* gross income has been insignificant due to the increase in population. The country must take long strides to stabilise the economy and attain self-sufficiency in food. Presently efforts are under way both in the public and private sectors to start another and more lasting 'green revolution'.

1.10 Irrigation and drainage

1.10.1 History of irrigation. Irrigation has been practised in the country from the earliest times. In the recorded history, river flow irrigation as an established practice can be traced as far back as the 8th century A.D., when the Arab conquerors differentiated between the irrigated and non-irrigated lands for the purpose of levying land taxes. The oldest form of river flow irrigation is the 'sailaba' or 'overflow' which is still practised on a substantial scale within the active flood plains along the rivers. This form of irrigation, though most primitive, has made an important contribution to the agricultural economy. Its inherent advantages of maintaining soils relatively salt-free and high in fertility result from the periodic flooding of the riverain areas.

The next stage in the development of irrigation was the use of inundation canals, which drew water during the summer, when the rivers rose above the levels of their inlets and irrigated lands which otherwise would not have received water by natural flooding. The inundation canals are however uncontrolled and cannot exploit low river flows. The irrigation activity was limited to relatively narrow strips of land along the rivers. The supply channels were inefficient, depending on uncertain river flows and tending to silt up rapidly. They were also dangerous because of the disastrous breaches in the flood season. In spite of these shortcomings, the inundation canals did provide a limited source of irrigation. The system was subsequently improved during the Mughal period through semi-controlled structures to extend the period during which water could be diverted from the rivers and further inland by operating small perennial canals for the irrigation of parks and gardens.

The most spectacular achievement in the utilization of river water in the Indus Plains took place from about the middle of the nineteenth century with the development of an intricate system of water control and distribution which has

led to one of the largest irrigation systems in the world. A permanent barrage was constructed in 1859 on the river Ravi, a tributary of the Indus. This made it possible to divert water from the river at all stages of flow and the whole year round. Following this successful attempt, several barrages have been constructed at strategic points across the river Indus and its major tributaries; now with a system of link canals, 70 to 75 per cent of the natural river flows are being utilized.

All the old inundation canal systems which suffered from the fluctuating river levels have since been abandoned or converted to receive controlled supplie

1.10.2 The present irrigation system. The irrigation network comprises some 62,230 km of conveyance channels (canals, branches, distributaries and minors) in 42 principal canal systems which have more than 78,000 water courses (farm channels). In addition, some 600 km of link canals of very large size have also been constructed. There are now seventeen barrages and canal diversion works in the Indus River System. The combined diversion capacity of the main canals system is nearly 250,000 cusecs with individual capacities up to 15,500 cusecs. The diversions are generally limited in the high flow season (summer) by the capacity of the canal system and in the low flow season (winter) by the available water supply.

The gross area commanded by the irrigation system (within the Indus Plains totals about 15.4 million ha of which about 133 million ha are classed as cultivable - some 8.9 million ha of this area receive a perennial supply while the remainder receives non-perennial supplies usually from mid-April to mid-October. Presently about 123 billion m^3 of river flows are diverted, out of which about 71.5 billion m^3 are available at the heads of water courses.

1.10.3 Drainage. Prior to the advent of canal irrigation in the Indus Plains, run-off from monsoon storms found its way to natural channels and eventually entered the rivers. When the canals were constructed they intercepted run-off and increased flood hazards. Surface drainage works, therefore, became necessary to protect the agricultural lands from the effects of excess storm water run-off and flooding. At present, there exists a large network of surface drains in the irrigated areas of the Upper Indus Plains and to a lesser extent in the Lower Indus Plains.

The existing surface drains suffer from several problems, the major one being the inadequate maintenance facilities. During winter, the flow in the drains decrease considerably so that a fungus layer appears on the surface of the water and obstructs its flow. Very often weeds also grow in the bed and along the sides of drains.

Continued seepage from conveyance channels in the absence of an efficient drainage system resulted in a gradual rise of the water table creating waterlogging and soil salinization problems. Large scale efforts to control and eradicate this problem were started by the Government in 1958, under the Salinity Control and Reclamation Projects (SCARPs) Program. This work has been assigned to the Water and Power Development Authority (WAPDA). For sub-surface drainage in the affected areas, vertical drainage has been provided in the plains in those areas where tubewells are feasible. In other areas, horizontal drainage projects have been proposed. So far, about 11,000 tubewells have been installed in the public sector under the above program. In addition, some 146,000 tubewells of relatively smaller capacity in the private sector are also indirectly providing sub-surface drainage.

1.11 Waterlogging and salinity

Prior to the introduction of the present system of canal irrigation in Pakistan, the water table depths over most of the area were from 24.4 to 27.4 m. As the extensive network of canals and water courses was unlined, large quantities of water diverted from the rivers were lost in seepage. Over the years, this continuous seepage raised the water table from varying depths almost to the ground surface causing waterlogging and widespread soil salinization.

The soil salinization was also due to salts in the irrigation water which under existing irrigation practices tends to remain within the soil profile, with a general movement towards the surface.

Thus both waterlogging and salinity have now become widespread throughout the canal-commanded areas. The severity of the problem however varies from place to place and from field to field. (Appendix II gives an idea of the severity and extent of waterlogging and salinity.)

In areas where Salinity Control and Reclamation Projects have been implemented and also where sub-surface drainage is taking place because of the large-

scale groundwater development by means of private tubewells, the water table has declined, but the reclamation of saline soil is slow.

1.12 Project Planning and implementation

The Water and Power Development Authority has formulated two regional plans - one for the northern zone and the other for the southern zone (see Figs. 2 and 3). Detailed planning of seven Salinity Control and Reclamation Projects covering an aggregate gross area of 4.79 million ha in the northern zone has been completed. Of these, four projects involving the installation of 6,844 fresh groundwater tubewells, 560 saline groundwater tubewells, and construction and remodelling of 845 km of surface drains have been approved.

In the southern zone, the planning of eight Salinity Control and Reclamation Projects with an aggregate gross area of 3.6 million ha has been completed. Of these, three projects have so far been approved and taken up for implementation. These projects cover an area of 0.70 million ha, and involve the construction of 1381 fresh groundwater tubewells, 379 saline groundwater tubewells, 1437 km of surface drains and 10 pumping stations.

In North Western Frontier Province besides the completion of 16 dugwells and 1430 m of tile drains in Peshawar City 28 tubewells have been installed and placed in operation.

In Baluchistan construction work has been started on the Hair Din Surface Drainage Scheme which, on completion, would provide drainage facilities to an area of 29,950 ha.

1.13 Impact of Drainage and Reclamation Projects

Thus far, the results of the implementation of the Salinity Control and Reclamation Projects are promising particularly with respect to drainage aspects, in spite of the problems of corrosion and incrustation in tubewells. In Salinity Control and Reclamation Project No 1, which has been in operation for the past 14 years, the water table is now between 3 to 7 m below the ground surface, and the problem of waterlogged has thus been eliminated. Reclamation of about 45 per cent of the saline area has also been achieved. However, the improvement of saline-

sodic or sodic soils has been very slow.

As a result of land drainage, reclamation of considerable salt affected area and availability of increased irrigation supplies through groundwater pumpage by tubewells, the introduction of the use of fertilizers, good quality seeds, better agronomic practices etc., the cropping intensities have gradually increased and the crop yields have improved. Consequently, the gross value of the agricultural produce in the project area (crop and livestock) has increased 2.5 times as compared with the pre-project conditions.

The use of groundwater pumpage however, has created some problems. Monitoring studies have indicated that the deterioration in groundwater quality is, at places, more than what had been anticipated at the time of planning. The deterioration in water quality has been attributed to varying changes in groundwater environment due to extensive groundwater development and its uses.

1.14 Research and Extension

1.14.1 Research. Several institutions in the country are involved in research studies in the fields of irrigation, drainage, reclamation and water management practices. Prominent among these are:

- The Irrigation Research Institute, the Punjab;
- The Directorate of Land Reclamation, the Punjab;
- The Mona Reclamation Experimental Project, Water and Power Development Authority;
- The Irrigation, Drainage and Flood Control Research Council;
- The Agricultural Research Council; and
- The Universities and agricultural research Institutes.

The Irrigation Research Institute has been conducting research since 1924 in hydraulics, irrigation, drainage and reclamation etc. Research on problems relating to reclamation of saline and sodic soils, consumptive use of water, irrigation practices, etc. is being carried out in the Directorate of Land Reclamation, Government of the Punjab. The work at Mona Reclamation Experimental Project (MREP) includes research on the effective use of water and land, the reclamation of saline soils and agricultural development. The Irrigation, Drainage and Flood Control Research (IDFCR) Council organises, promotes, coordinates and conducts research in such fields as irrigation, drainage, hydraulics, tubewells, reclamation and flood

control. Recently the Council has set up a national institute, the Drainage and Reclamation Institute of Pakistan (DRIP), for conducting research in the fields of drainage of agricultural lands; salinity control and land reclamation; water use and management; and economic and technical evaluation of drainage and reclamation methods.

The Agricultural Research Council, the University of Agriculture (Lyallpur), and the provincial Agricultural Research Institutes which concentrate mostly on agricultural subjects are also conducting research on irrigation water requirements of crops, farm water management, etc.

1.14.2 Extension. An agriculture extension service is available in the related organizations. Through the extension workers, efforts are being made to convey the research findings to the cultivators. Modern irrigation practices are being taught by laying out demonstration plots, both on the land of the cultivators and at the experimental farms of various organizations. However, there is a great need to improve the extension service program both qualitatively and quantitatively.

For producing trained extension workers from the public and private sectors, the University of Agriculture, Lyallpur, has started a program called the Farm Guide Movement in which persons from all walks of life interested in social work participate voluntarily. The subjects of training include crop production under irrigated conditions, plant protection, livestock management, community development, adult education, civil defence and first aid. Facilities also exist for training by correspondence in different trades and professions.

2. THE CASE STUDY AREA - GENERAL BACKGROUND

2.1 Brief Description

The case study area, Mona Reclamation Experimental Project (MREP) is located in the north central part of the Chaj Doab*, 48 km north-east of Sargodha, 145 km north of Lyallpur, 241 km north-west of Lahore, lying between longitudes 72°45' and 73°12'N and latitudes 32°15' and 32°30'E. A major portion of the study area is situated in the Bhalwal Tehsil of Sargodha district whereas about one-tenth of it lies in Phalia Tehsil of Gujrat District. It is about 40 km long and 13 km wide and is bounded on the east by Lower Jhelum Canal (LJC) Main Line, and on the north and south by its Shahpur Branch and Northern Branch respectively. No significant boundary line demarcates the case study area on the western side. Most of the area lies in the abandoned flood plain of the Jhelum River; the rest is a part of the ancient alluvial plain. The gross area of the project is about 44,500 ha while the cultivable area is about 41,300 ha. There are 83 villages in the area; of these 45 (54 per cent) lie completely within the boundaries of the area, while the rest are located partly inside and partly outside the boundaries (see Appendix III).

The study area was originally a part of the Shahpur District, consisting chiefly of the Bar or central table-land of the Chaj Doab in the Punjab. This District, with modifications in boundary lines, is now known as Sargodha District. Very little is known about the early history of the study area but the mounds of ruins scattered over its surface suggest that the area might have been cultivated and densely populated at one time. This view is supported by the writings of the Greek historians of Alexander's time describing the region as teeming with population in those days. Historical records and architectural remains of comparatively recent age show that the area was prosperous even during Mughal Emperor Akbar's time. The town of Bhera, which is adjacent to the study area, has an ancient history. The city flourished during the 15th century and brick buildings with beautiful wood carvings still stand denoting the prosperity of that period. The study area is now inhabited mostly by agriculturists. It has also produced excellent soldiers for the armed forces.

2.2 Pre-irrigation conditions

Prior to the development of the canal system, the cultivation in this area depended on rainfall, well irrigation and inundation from the river. Wheat, millet,

* Chaj Doab is the area lying between the rivers Jhelum and Chenab.

cotton, sorghum and gram respectively occupied 46, 21, 8, 6 and 4 per cent of the total cropped area. According to the records available, the depth to water table in the area varied from 6 m to 20 m below the surface increasing with distance from the river.

2.3 Introduction of Canal Irrigation

Inundation canal irrigation was introduced in the case study area in 1860 when the Macnabbwah Canal was excavated. Execution of the Raniwah Canal in Bhera Tehsil followed in 1870. The present form of canal irrigation (weir-controlled irrigation) was first introduced in 1901, with the partial completion and opening of the Lower Jhelum Canal, the construction of which began in 1897. This canal which takes off from Rasul Barrage on river Jhelum has a capacity at its head of 150 m^3/second and commands a gross area of 0,6 million ha. Approximately 31,500 ha of the case study area are commanded by the main line and northern branch of the Lower Jhelum Canal, and receive perennial canal irrigation supplies. The 8,100 ha commanded by the Shapur branch receive non-perennial supplies during summer. A few shallow wells irrigate a small part of the remaining uncommanded area.

The area receiving perennial irrigation supplies is divided into regular squares and killas (1 killa = 0.445 ha) so as to simplify the planning of networks the distribution of water and the management of land. This is not the case with land under command of the Shahpur branch; previously this area was served only by inundation canals from the Jhelum River and was only recently incorporated in the Lower Jhelum Canal system.

Within the canal-commanded area there are patches of 20 to 400 ha, which are 0.33 or 0.66 m higher than the surrounding land and, therefore, cannot presently be irrigated from the canal system; some of these have been dry farmed in the past.

2.4 Impact of Irrigation on Environment

For the purpose of studying environmental changes in the case study area consequent to irrigation activity, three periods have been identified:

- the pre-irrigation period as the time before 1901. In that year the irrigation supplies were made available in the area from the weir-controlled Lower Jhelum Canal and planned settlement started;

- the irrigation period - pre-rehabilitation project: between 1901 and 1965 irrigation activity was in full swing but lack of attention to drainage during this period resulted in waterlogging and salinization of the area, leading to desertification;

- the irrigation period - post-rehabilitation project: after 1965 when large-scale rehabilitation measures including Mona Reclamation Experimental Project, were launched to control waterlogging and salinization.

The introduction of canal irrigation brought about a number of significant changes in the area. Large thorn plains, previously uncultivated and hummocky, were brought under cultivation. Statistics indicate that in the Sargodha district the irrigated area increased from about 22,260 ha in 1900-1901 to 73,250 ha in 1902-1903. Irrigation brought overall prosperity and most of the nomadic people whose livelihood mostly depended on nature started settling. Many new villages were founded by grantees of waste land and colonized largely by immigrants from the neighbouring Khushab area and elsewhere. During this period the settlement work began taking shape. In parts of the case study area, where irrigation through inundation canals was introduced, agricultural prosperity was distinct. This increased agricultural activity, led to a decrease of the fauna and flora.

2.5 Waterlogging and Salinity

Before the introduction of weir-controlled irrigation the water table was 6 to 18 m deep over most of the area and was fairly stable. As soon as canal irrigation was introduced, groundwater levels began to rise. The deep percolation of water from the canal system and irrigated lands formed a new increment of recharge, which was greater than the rate at which water could be discharged from the aquifer. In early 1960s, 90 per cent of the area was affected by the high water table and a little over 19 per cent by salinity to varying degrees; the major portion of saline area was affected by waterlogging also. This situation affected the agricultural productivity of the area which necessitated the adoption of rehabilitation measures and implementation of the project within the overall context of the Salinity Control and Reclamation Programme for controlling and eradicating waterlogging and salinity in the irrigated areas of the Indus Plains. The reclamation project in the case study area comprises 138 deep tubewells of 0.6 to .11 m^3/second capacity, each designed to provide subsurface drainage and supplementary water supplies for irrigation and reclamation activities. This project has been selected as an experimental scheme for the monitoring of all aspects - tubewells, groundwater levels and quality, soils, agriculture, socio-economic conditions - and research on

reclamation of soils and water management. This area was chosen for monitoring and research as it had the advantage of not being in an advanced stage of deterioration so that the results were expected to be available in a shorter period of time.

2.6 Brief Objectives of Mona Reclamation Experimental Project

The main objective of the Mona Reclamation Experimental Project is to gather from operational research information adoptable to the areas being developed under Salinity Control and Reclamation Projects. The studies conducted over the last ten years have shown the relative economic feasibility of various methods of soil reclamation and have helped in setting up water quality criteria for agricultural production on various soils. In addition, valuable data has also been collected on the irrigation practices, water management, precision land levelling and rehabilitation of watercourses.

2.7 Representativity of Case Study Area

The Mona Reclamation Experimental Project has been selected as the Case Study Area as conditions therein are generally representative of the conditions found in the waterlogged and salinized areas of the Northern Indus Plains. The soils are representative of those generally found in the Plains comprising the major soil series identified so far. The area is served by both perennial and non-perennial canals and also includes areas not irrigated by canal works (uncommanded). It is an experimental reclamation scheme from which data is available in a systematic form and on a continuous basis since its inception. Prior to the adoption of improvement measures, the water table was quite high and a considerable area was salt-affected to varying degrees. The groundwater quality in the area also is quite variable, being very good to very poor. The area has a representative cropping pattern and socio-economic conditions are also similar to those of the other irrigated areas where drainage and reclamation projects have been implemented. The availability of bench mark data for future use through a comprehensive socio-economic survey is another consideration for selecting this project as the case study area.

CASE STUDY AREA - PRE-IRRIGATION PERIOD

1. PHYSICAL FEATURES

1.1 Climate

The available recorded information shows that the average annual rainfall in the area was in the order of 38 cm; 28 cm in summer and 10 cm in winter. Rainfall was scanty and varied from year to year and from place to place. For example, at Bhera in 1891-92 total annual rainfall only amounted to 13 cm while the following year it rose to 61 cm. In March 1888 only 1.3 cm of rainfall was recorded in Bhera, while only 16 km away at Miani, rainfall reached nearly 61 cm. In summer, the average maximum temperature was 38°C; the minimum was about 29°C. In winter, the maximum temperature was around 15°C and the minimum was 4°C. The area was less exposed to wind as compared to most parts of the Punjab. However, in dry hot weather dust storms were frequent, generally from the direction of the sandy Thal area.

1.2 Soils and geomorphology

1.2.1 Soils. The soils were inherently fertile, of high potential productivity, and well suited to irrigated farming. The calcium carbonate content of the soils was high, and the sodium content generally low. Although the soils had a relatively low content of organic matter and available nitrogen and phosphate, they were productive when irrigated. The low ratio of sodium to calcium kept the soils sufficiently open to permit a moderately free downward movement of percolating water, and was thus favorable to the reclamation of salinized lands through leaching.

1.2.2 Geomorphology. The study area lies within the alluvial plain formed by sediment deposited mainly by the Jhelum River. The surface relief is generally level with an average slope of 0.02 per cent in a south-western direction. Some depressional areas, it is reported, were quite prominent, and a few patches showed varying degrees of surface relief. The elevation of these areas, situated in the north-eastern and south-western extremities of the area, ranged from about 191 to 198 m above the mean sea level.

The land forms, the meander flood plain and the scalloped interfluve, were recognized in the area (Fig. 1). These constituted 60 and 40 per cent of the area respectively. The plain contained the oldest materials of the Doab, and at its northern boundary showed prominent bluffs.

1.3 Water regime (groundwater)

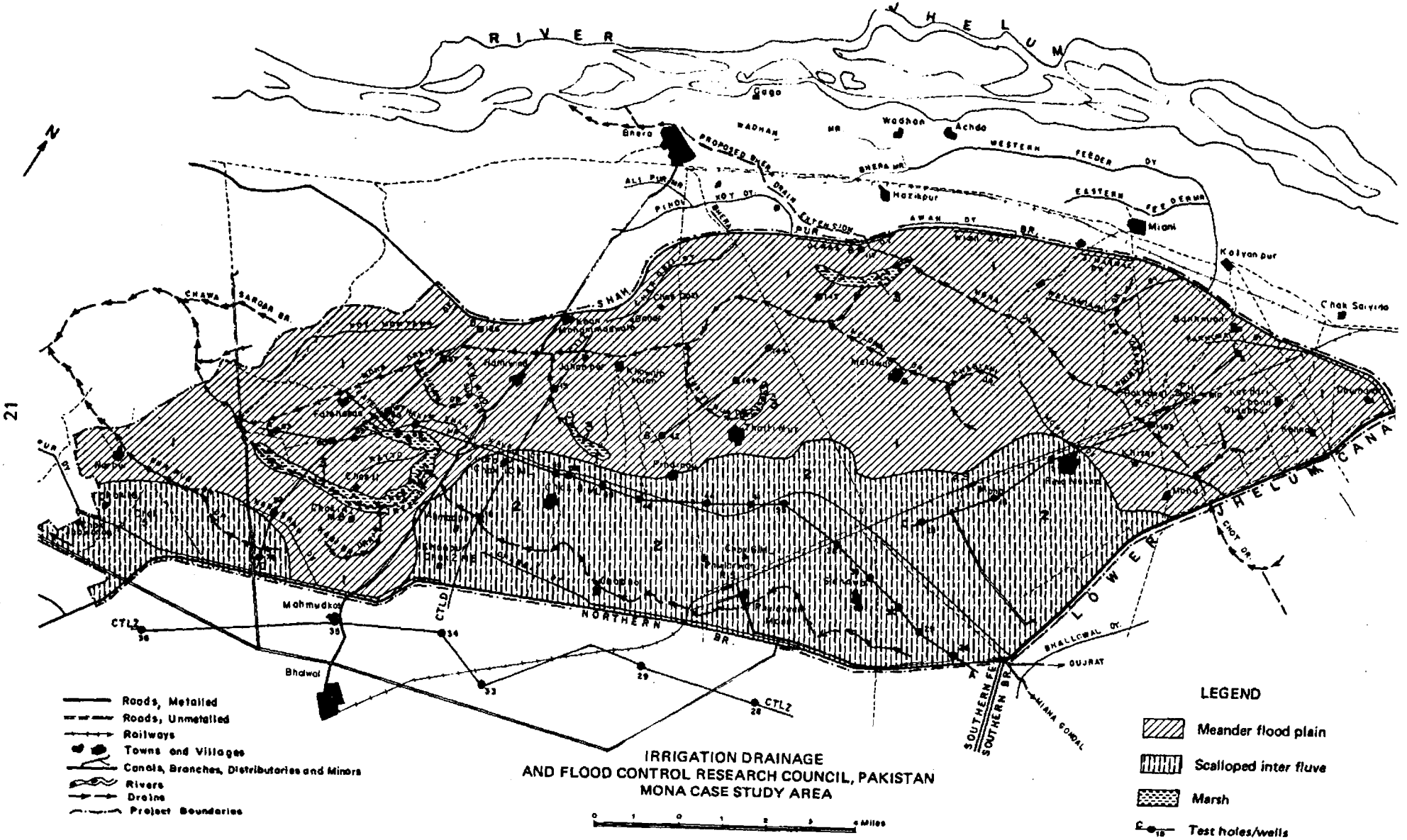
Prior to the irrigation period the water table w s in a dynamic equilibrium and fluctuated with seasonal variations in the recharge; there was no long term trend. The depth of the water table immediately prior to canal irrigation was in the r nge of 6 to 18 m, deepening as distance from the river increased (see fig. 2). The groundwater movement was from north to south away from the river, which was the main source of recharge during the pre-irrigation eriod.

1.4 Flora and fauna

1.4.1 Flora. The characteristic trees and shrubs were van (*Salvadora oleoides*), kari (*Capparis aphylla*), jand (*Prosopis spicigera*), and malla (*Zizyphus nummularia*), kikkar (*Acacia arabica*), tahli (*Dalbergia sissoo*), ukah or koah (*Tamarix articulata*), ber (*Zizyphus jujuba*), lasura (*Cordia myxa*), the tut (mulberry, *Morus alba*), sohanjna (*Pterygo sperma*) and shirih (*Albizzia lebbek*) were largely grown on cultivated lands. Shrubs and plants like lie or pilchi (*Tamarix gallica* or *dioica*), akk (*Calotropis procera*), jawaha (camel-thorn, *Alhagi maurorum*), harmal (*Peganum harmala*) and bhakkhra (*Tribulus alatus*) were also common. The khar or sajji plant (*Salsola griffithsii*) and lana and lani (*Salsolas*) were found in barren saltish soils and nar (reeds) along moist places. The commonest grasses were khabbal (*Cynodon dactylonn*), dub (*Eragrostis cyposuroides*), the chhembar (*Eleusine flagellifera*), sawak (*Panicum colonum*), palwah (*Andropogon annulatum*), dhaman (*Pennisetum cenchroides*), the dabbh (*Poa cynorsuroides*), the kana (*Saccharum munja*), and kah (*S. sponteneum*).

1.4.2 Animals. It is reported that in the pre-irrigation period tigers were present in Sargodha district but none were seen even as far back as 1897. Amongst other wild animals leopards, hyenas were occasionally heard, whereas wolves, foxes, wild cats, mongoose, hedgehogs, rats, mice, badgers (bijju), hare, ravine-deer, pigs and porcupines were frequently seen. The most interesting animals from the sportsman's point of view were mountain-sheep or oorial which was similar to moufflon of Corsica. However, the number of these animals, which were subject to

Figure 1 PHYSIOGRAPHY AND LOCATION OF TEST HOLES/WELLS



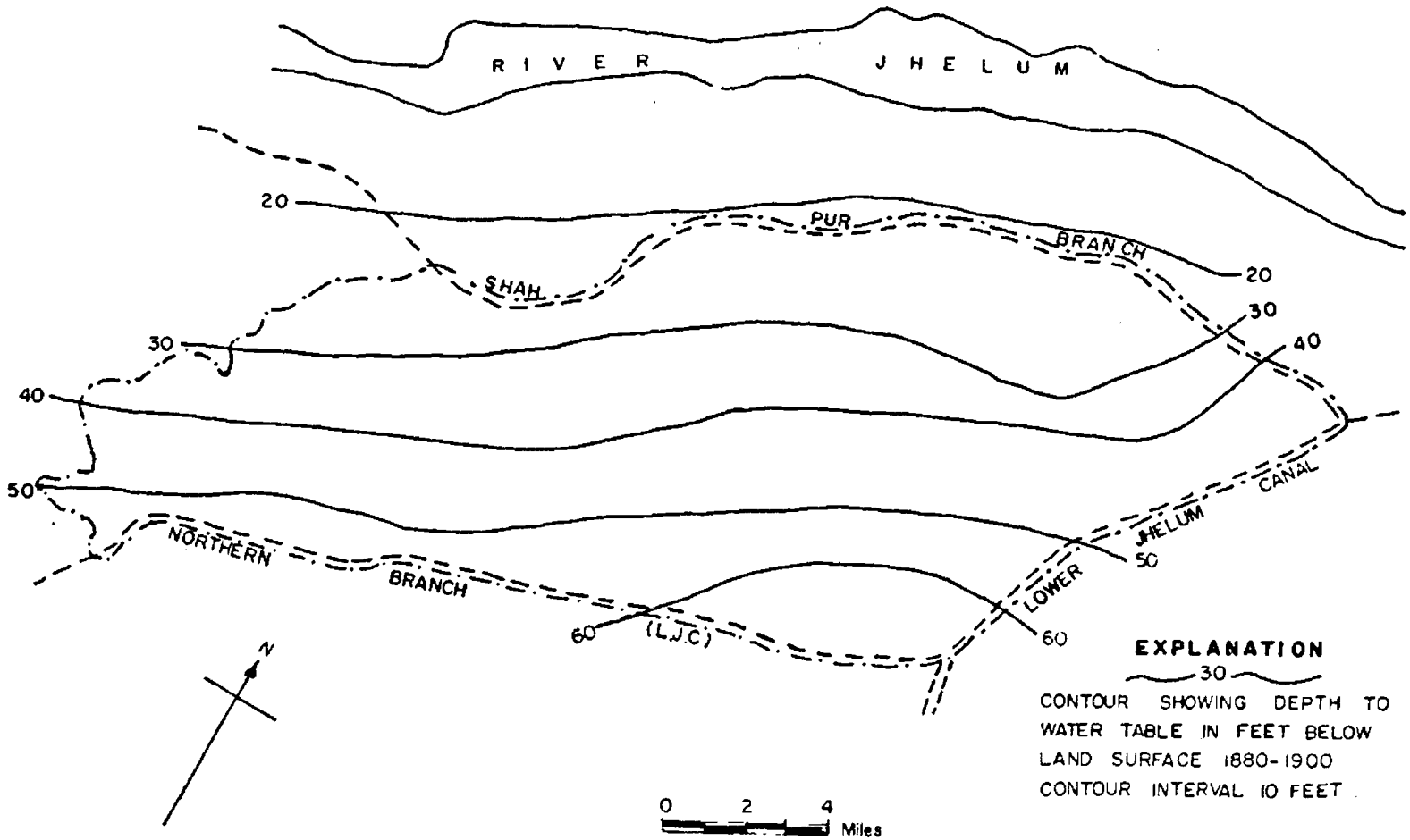


FIGURE 2 MAP SHOWING THE APPROXIMATE DEPTH TO THE WATER TABLE BELOW LAND SURFACE IN THE PRE-IRRIGATION PERIOD (1880-1900)

hunting, rapidly decreased at the end of the nineteenth century. Among the birds, bustard (tog), flocks of imperial painted and pallas sandgrouse, quail (batera) and grey partridges (titar), ducks of many kinds, geese, blue coated demoiselle-crane (kunj) and numerous other aquatic birds, sometimes along with snipe and bittern, were common. Crows and kites were ubiquitous and hawks used to fetch fabulous prices for sporting purposes. In cultivated tracts parrots were noticed filling the atmosphere with their screeching and a golden oriole occasionally seen flashing through the trees. Blue jays and scarlet plumaged woodpeckers added gaiety to the scene. Immense flocks of rosy pastors (tilliar), hereditary enemy of the locust, used to visit the district in hot weather. Among reptiles, snakes of the venomous kinds like cobra (phaniar - *Naja tripudians*), the karait (sangchur - *Bungarus coeruleus*) and *Echis carinata* (phissi or khapra) were common. Locusts, generally coming from south-west, were sometimes seen invading the area in destructive numbers. In 1891 numerous flights of locusts which were recognized as the *Acridium peregrinum*, invaded the area. Another flock of locusts recognized as *Paecilocera picta* visited the area in 1893. A sort of cricket (toka) of genus *Gryllodes* and an acrided of genus *Chrotogonus* often did great damage to the sprouting summer crop.

2. POPULATION

2.1 Density

The exact population of the study area during this period is not known. However, according to the available information in the contiguous area the density of population was 21 persons per km^2 in 1891 which increased to 69 in 1911.

2.2 Occupations

The occupational activities of the population of Sargodha District, according to 1891 census, is given in Table 4.

Table 4: Occupation-wise distribution of population

Occupation	Percentage of total population
Government	1.9
Pasture and agriculture	53.8
Domestic service	5.3
Preparation and supply of material substance	25.3
Commerce and transport	5.1
Professional	2.6
Indefinite and independent	6.0

2.3 Social order and family structure

The men of the pastoral tribes led a comparatively lazy life. The demands on their labour were practically limited to drawing water for cattle and milking the cows. Men of the agricultural population were more or less employed in one or the other operation of husbandry all the year round.

The families in the area have always been patriarchal, patrilocal and patrilineal. Most of the decisions in the family were taken by the elder of the

family. Early marriages and exchange cross-marriages (locally called watta satta) were also practised. In the early periods bride-price was also paid in some cases, and divorces were rare. Nearly 80 per cent of the people between the ages of 30 and 40 were living married lives. The average age at which rural male married was over 21 years. Marriage and other social ceremonies were the main occasions for the villagers to show off. Therefore, huge expenditures were incurred on festivities, even if it meant taking money on loan.

2.4 Education

During the days of the British occupation, the whole educational system was geared to meet the colonial aspirations and law and order requirements. The primary objectives of education were, therefore, to provide men for clerical jobs in different administrative departments and to westernize the people by impressing upon them the superiority of western culture and knowledge.

There were two high schools at Bhera, one maintained by the Municipal Committee and the other an unaided Anglo-Sanskrit School. There was only one girls' school at Bhera. There were two primary schools in the case study area, one at Hazoorpur, and the other a Zimindari School at Chawa. There was no high school in this area prior to 1889. The first one was established in 1890. The literacy in Sargodha District in 1894 was 3.3 per cent among males and less than 0.5 per cent among females.

2.5 Ways of life

The Punjab has always been regarded as the land of villages. In the past every village with a distinct boundary line acted as a separate socio-economic unit. In fact, the inter-village communication was so low that every village was a little estate, self-sufficient within its own environment, resisting all outside influences. Indeed, this was the situation prior to the introduction of the canal irrigation system.

In the villages of the study area, as was the practice all over the country, land ownership, revenue, irrigation and other records were kept on a village basis. The majority of cultivators within the village kept close contact with each other, thus forming a unique communication system through the village dera

(the common sitting place for men) and the tanoor (village bakery) where women gathered for routine gossip and news. The village thus formed a cohesive social unit.

Every village had a settlement pattern with a headman, a watchman, a number of landowners, artisans who served the agriculturists, in addition to certain priestly castes.

2.6 Social customs

The joint family system was the common living pattern but it appears that many of the people thought that living in nuclear families was less problematic. Generally, the people were socially conservative and their patterns of social mobility were restrictive.

Women were generally regarded as inferior in status. However, a woman as a mother, wife, or sister, had a significant influence on the day-to-day running of household affairs. High value was placed on sons as they ensured the continuity of the family, economically and socially. A woman who gave birth to many sons enjoyed high social prestige. The tragedy of the woman was not biological, it was rather sociological and ideological. There were a number of customs, taboos, beliefs, prejudices, superstitions, myths, rituals and institutions which made women socially inferior to men. Studies have shown that in farm operations, women assisted their menfolk. Usually they looked after the domestic animals and also worked in the fields during harvesting, threshing, winnowing and picking, in addition to engaging in household chores. Public opinion was generally against providing education to women.

2.7 Nutritional habits

The food of the common people was simple, consisting generally of cereals, vegetables, milk and its by-products. During the hot weather, it consisted of bread made from wheat flour with buttermilk, pickles or gur (locally-made sugar) while in cold weather, millet or maize bread were taken with the same accompaniments. The people had their regular meals twice a day at about 10 a.m. and then after sunset. In the hot weather, in addition to the regular meals, the remains of the previous day's food were used with buttermilk, which was taken to the men working in the fields, about an hour after sunrise; parched grain was taken in the afternoon.

3. ECONOMY

3.1 Type of crops

Before the introduction of the Lower Jhelum Canal, the cultivation in Sargodha District was mostly barani (rainfed), dug wells and in some parts sailaba (river overflow) or innundation canals. The main food crops were wheat, bajra, jowar and grams, while the cash crop was mostly cotton. Crops like sugarcane, maize, tobacco or poppy were the minor ones, and an insignificant proportion of the land was allotted to them. Fruit and vegetables were also grown generally with well irrigation.

3.2 Crop yields

The average yields of crops in Bhera Tehsil are given in Table 5.

Table 5: Average yield of crops in Bhera Tehsil (kg/ha)

Crop	Barani area	Area under wells	Area under sailaba and inundation
wheat	550	1100	735
barley	550	1100	735
grams	735	735	735
bajra (millets)	365	920	645
jowar (sorgham)	365	550	460
cotton	365	550	365
maize	-	1100	735
rice	-	1100	1100
sugarcane	-	1840	-

3.3 Cropping pattern, cropping intensity and crop acreage

Table 6 gives an indication of the cropping pattern prevalent during the pre-irrigation period in Sargodha District. The total cropped area was approximately 205,600 ha.

Table 6: Cropping pattern during pre-irrigation period in Sargodha District

Crop	Area under the crop (percentage of the total)
wheat	42
cotton	6
oil-seeds	4
grams	5
bajra (millets)	18
jowar (sorgham)	7
pulses	3
barley	3
other cereals	2
miscellaneous	10

As can be seen from this table, wheat and bajra (millet) were the important crops in those days.

Normally, 15 to 20 per cent of the cultivated area was left fallow throughout the year and about 60 per cent was put under Rabi (winter) crops and 20 to 25 per cent under Kharif (summer) crops. This meant that a large area was put under wheat year after year with an occasional change to oilseeds followed by cotton or fodder, succeeded after a fallow by cotton.

3.4 Livestock

In the pre-irrigation period, cows, buffaloes, camels, sheep, goats and horses were the most important livestock in the area. The district of Sargodha used to be one of the best areas in the country for breeding horses and ponies. The milch animals of that period were low yielders. On the average, a cow gave 2.5 to 3.5 kg of milk per day. The livestock position in the Sargodha district in 1893 is given in Table 7.

Table 7: Livestock statistics of Sargodha District in 1893

Animals	number in thousands
bulls and bullocks	111
cows	124
male buffaloes	15
cow buffaloes	35
calves and young buffaloes	72
sheep	193
goats	115
horses and ponies	8
mules and donkeys	21
camels	13

Large numbers of cattle were annually destroyed by diseases. No preventive measures were adopted by the people to save their livestock from contagious diseases. Outbreaks of rinderpest and foot-and-mouth disease were of almost annual recurrence.

3.5 Marketing of agricultural products

In the pre-irrigation period, the farmers did not have much marketable surplus to sell and therefore market structure had not developed.

CASE STUDY AREA - IRRIGATION PERIOD

1. PRE-REHABILITATION PROJECT

1.1 The canal irrigation system

The case study area is served by a part of the Lower Jhelum Canal (LJC) system which takes off from the left bank of the Jhelum River at Rasul; the Rasul barrage was constructed in 1901. The construction of the LJC was begun in 1897; the canal was opened in 1903. It was originally planned to irrigate some 242,816 ha of land, and this objective was attained by 1908-09. The LJC now has a capacity of 149.5 m^3/sec at its head and commands a total gross area of 647,511 ha and a culturable commanded area of 607,042 ha. The canal commands a greater part of Sargodha and Jhang Districts lying between the Jhelum and Chenab rivers. The irrigated tract extends to the confluence of the two rivers, the Chenab and the Jhelum. The development of the whole system as it now exists took place between 1897 and about 1919.

In the case study area, approximately 31,566 ha are commanded by the main line and northern branch of the Lower Jhelum Canal, and receive perennial canal irrigation supplies. The 8094 ha commanded by the Shahpur Branch Canal receive Kharif (summer) supplies only. The remaining 5665 ha are not commanded by gravity irrigation systems and are at present largely irrigated by tubewells and open-wells etc. The various irrigation commands are given in Fig. 3.

1.1.1 Irrigation network. The case study area is served by a network of seven distributaries off-taking from the Lower Jhelum Canal-Main Line, and its Northern Branch and Shahpur Branch. The authorised full supply (AFS) of these distributaries and other relevant information is given in Appendix III. Except for a small amount of discharge through the Fatehpur Distributary, all canal inflow in the distributaries is consumed within the area. The annual average perennial diversion during the period 1960-65 from the Main Line and Nor hern Branch of the Lower Jhelum Canal was (169 x 10^6 m^3) commanding a culturable area of 25,110 ha and the non-perennial supply from the Shahpur Branch for the same period was of the order of 34 x 10^6 m^3 commanding a cultivable area of 6,680 ha. This data is based on the canal statistics collected by the Provincial Irrigation and Power Department.

1.1.2 Design and execution. The water from the outlets is conveyed in ditches called 'water courses'. Generally the supply from the outlets in a water course is of the order of 0.03 to 0.08 m^3 per second depending upon the size of the area to be irrigated from the particular outlet. The water courses branch off into field channels as they run through the farm land to deliver water to the farmers' individual holdings. Usually these water courses consist of earthen channels.

Each outlet of the canal system that delivers water to a water course serves a land area known locally as 'chak' which varies in size from 120 to 160 ha to 400 to 600 ha, the average being a little more than 2.56 km^2, or about 280 ha. There are about 233 outlets under the canal and tubewell systems in the case study area. The outlet, chakbandi* registers, and chakbandi maps are maintained by the Irrigation Department. They provide data for full outlets serving water courses, including the authorized discharge of each outlet, the gross area, the cultivable commanded area, the 'ghair mumkin' area (area occupied by villages, roads, etc.), net irrigable area, and the point where each water course leaves the distributary. The chakbandi maps are drawn to a large scale of 6.3 or 9.5 cm/km. Individual maps show details of part or all of the lands served by a distributary of the canal system covering about 3 to 15 outlets. The features of most maps include land surface contours at one foot intervals for all squares**, positions of water courses and uncommanded areas such as roads and villages.

Water distribution to the farmers on each outlet is made through a system called 'Warabandi'. Each farmer gets his share of water for fixed period in each week or ten days period as may be the prevalent practice. His time in a week or ten days is in direct proportion to his farm area. The farmer diverts water to his field by making a cut in the water course at the beginning of his land holdings. When his stipulated time is over, he closes the earthen cut and allows the water to flow downstream to the area of next farmer. This practice suffers from the inherent defect that a farmer is obliged to turn water on his field whether he needs it or not and at critical times of his crop requirements, he may have to wait for his turn. However, this in una oidable because the river flows are variable from time to time and have to be used as the supply becomes available. After the construction of the Mangla Dam on the river Jhelum, partial regulation of river water has been achieved and variations are now less.

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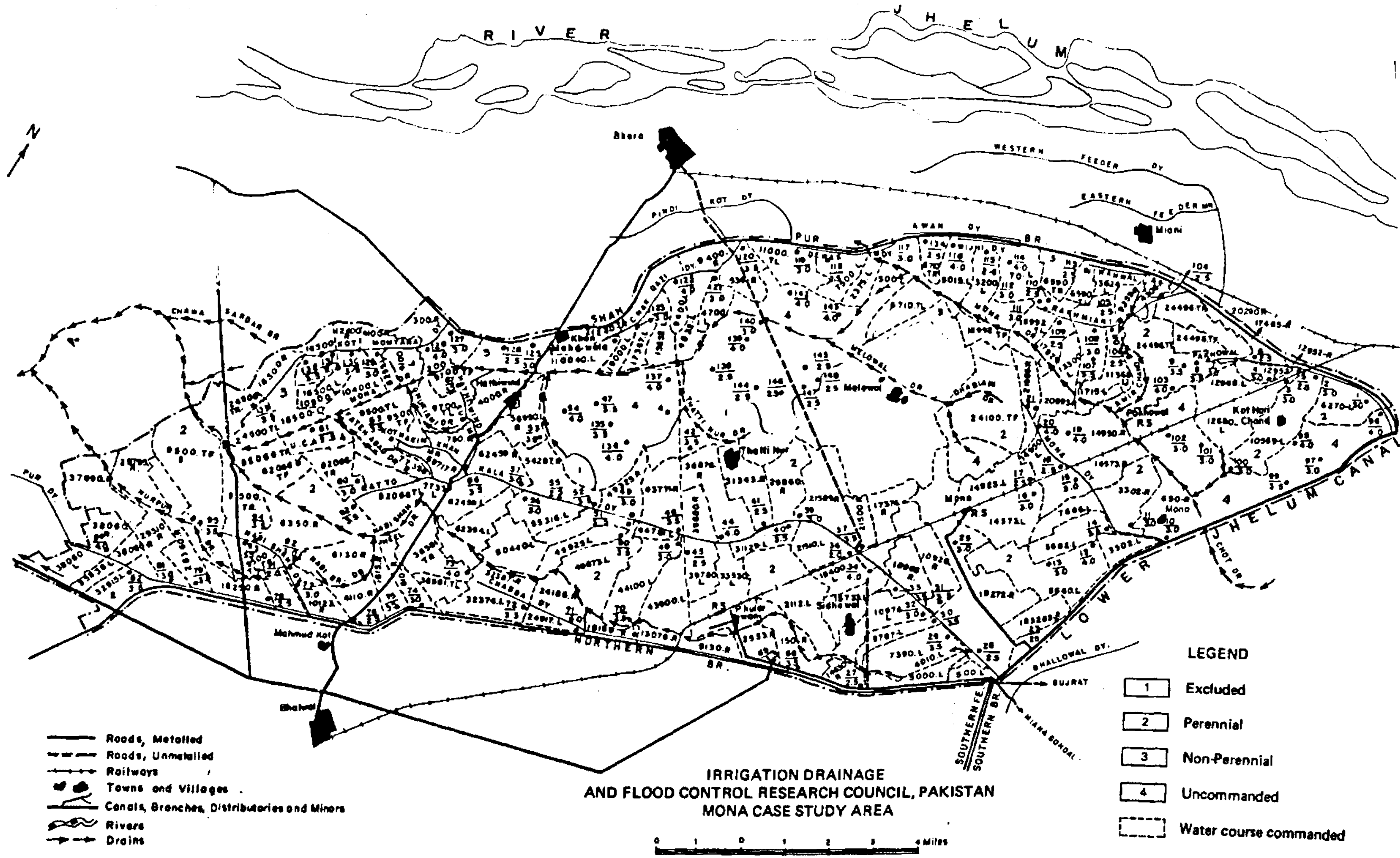
* The water distribution scheme of a chak.

** The area receiving perennial irrigation is divided into regular squares and killas with the result that distribution of water and management of land is easy. This is not the case with land under command of Shahpur Branch. Previously this area was served only by inundation canals from the Jhelum River. The Shahpur Branch was only recently incorporated in the Lower Jhelum Canal.

Figure 3 IRRIGATION COMMANDS



1.1.3 Flow pattern. The flow in the irrigation channel is dependent upon the variable flows available from the rivers. There are times when acute shortage occurs due to deficient supply in the rivers. When this occurs all irrigation canals cannot be supplied with water according to their designed full capacity. In such circumstances canals are run with partial supplies and in rotation. The distribution system of outlets is designated so that each outlet draws its proportional share and water is carried to the tail end of the channel. Shortages are thus proportionally distributed throughout the system. The outlets designed with the above objective in view are called adjustable proportionate modules. These have been developed to provide an equitable distribution of the prevailing supplies.

1.1.4 Maintenance of irrigation network. As elseshere the irrigation canals in the area have been constructed with raised earthen banks to maintain water surface levels higher than the surrounding lands - a necessity for gravity flow. The raised banks are subject to weathering by rains, windstorms, etc. During heavy rains, the banks are eroded, necessitating annual maintenance. Turfing on bank slopes is designed to minimize rain cuts and dirt tracks are maintained along all the channels to facilitate insp ction. Trees are usually planted along the canal banks for aesthetic purposes as well as for timber.

Besides the embankments of the extensive canal system, the flow section, which in earthen channels is subject to erosion and scour from silty water with varying quantities of silt charge must also be maintained. Periodical desilting of the irrigation channel is provided through manual labour. When hydraulic regime is sufficiently disturbed owing to appreciable silt deposits, to avoid heavy expenditure on silt clearance, the outlets are redesigned to conform to the raised water levels in the channel caused by raised bed levels. The method ensures equitable distribution of canal supplies up to the tail end of the channel.

1.2 The drainage system

1.2.1 Drainage network. The case suudy area is provided with a network of surface drains for handling storm run-off. However, there is little data available to trace the development of the drainage network. In the entire project area of approximately 492 km^2 there is a total of 129 km of main and branch drains and 29 km of tributary drains. This means there is about 0.32 linear km of drains per km^2 of catchment area. This compares favourably with the figure of not less

than 0.25 km per km^2 recommended for the Chaj Doab. The Mona Drain is the main drain, running from east to west, bisecting the area and forming the irrigation boundary between the Shahpur and the Northern Branches. It has a capacity of 1.0 m^3/sec and originates at the eastern end of the study area where it intersects the Chot Drain. The Mona Drain leaves the scheme area at R.D. 170,000 where its capacity is 21.7 m^3/sec.

1.2.2 Drains discharge. Except for the past few years, no data on the discharge of the drains are available. In 1956 the Irrigation Department installed a gauging station on the Mona Drain at the point of outflow from the area (R.D. 135,000) and in 1960 another gauging station was installed near the point where the drain enters the area (R.D. 14,000). The station at R.D. 14,000 measures practically all the surface run-off water inflow to the project area from adjacent areas up-doab; the station at R.D. 135,000 records most of the surface run-off water outflow. Drain discharge data on these stations are given in Table 8.

Table 8: Measured annual inflow and outflow from the Mona Drain (in million m^3)

Year	Discharge measuring sites	
	Inflow at station R.D. 14,000	Outflow at station R.D. 135,000
1960-61	18.01	31.70
1961-62	7.03	31.08
1962-63	7.03	34.66
1963-64	6.54	27.75
1964-65	4.69	35.03
1965-66	7.40	28.37

1.3 Layout of village

After the introduction of the Lower Jhelum Canal, the face of the countryside completely changed. The number of villages of each size increased considerably, showing that population increase has been evenly distributed over all sizes

of villages. The number of inhabited villages and towns in district Sarghoda increased from 706 in the pre-irrigation period to 1,066 in 1911. It may be noted that many of the villages were very large estates or townships and that their population was not often collected in one village, much of it being in hamlets situated at some distance from the parent village. There was nothing very distinctive about the arrangement of the houses in most of the old towns and villages. The dwellings were clustered together in a haphazard manner and the only principles of town-planning were those which relegated the lowest grades of menials to the outskirts of the towns and grouped the other non-owners around the homestead of the particular owners under whose patronage they carried on their trades or labour. In villages, the courtyards were generally kept spacious, in comparison with smallness of the buildings and the narrowness of the streets.

The development of the villages continued over a period of time. In the case study area prior to the rehabilitation measures there were 83 villages. Of these, 45 villages lie completely within the boundaries of the study area, while the remainder are partially inside. Each village in the case study area has a unique socio-economic characteristic and is the smallest unit in the prevalent administrative set-up (Appendix IV).

1.4 Land tenure and size of holdings

In 1917, for district Sargodha as a whole 39 per cent of the cultivation was done by owners or grantees themselves, 2.3 per cent by occupancy tenants and 58 per cent by tenants at-will; the remaining less than one per cent were the squatters. The land tenure system highly biased in favour of landlords persisted for many generations. The development of agriculture was directly linked with the facilities available for irrigation.

In 1965-66, in the case study area, there existed three tenurial systems; owner-operators, owner-cum-tenants and tenants. Under the system of owner-operators, or peasant-proprietorship, farm land was cultivated by the owner himself. The owner-operators were natives, settlers, as well as refugees. The natives were the original inhabitants of the area, and held right of ownership to the land since times unknown. Their forefathers held large pieces of land, which had been sub-divided continuously amongst the heirs generation after generation. The settlers were given title to the land at the advent of canal irrigation in

the area, and a 2-square (20 ha) holding was granted to each of them, with the condition that a mare would be maintained on it for the supply of horses to the cavalry. The settler holdings had also been reduced in size due to sub-division, sale or purchase of land; the holdings of the settlers were no longer uniform in size. The owner-operators were an important class of cultivators of the area, as they constituted 42 per cent of the total cultivators and operated 43 per cent of the farm area. Nearly 56 per cent of them were concentrated in the perennial, 12 per cent in the non perennial areas, and the remainder within the uncommanded areas. On the whole, more than half of these cultivators had land holdings below the subsistance level.

Studies have revealed that very few cultivators liked to be tenants when they had land of their own. Though as many as 50 per cent of the owner-cultivators held operational units below the subsistance level, they did not like to have additional land on rent. Again only about one-fifth of the cultivators were owner-cum-tenants, operating about 17 per cent of the total farm area. As many as 37 per cent of the cultivators in the case study area were tenants, a landless class depending directly on leased land for their livelihood. They operated 40 per cent of the total farm area.

1.5 Colonists

A number of colonists were occupancy tenants and others had expectation of obtaining that status. The colonists were considered as a distinct body of men formed of various classes. The area held by each class, as per conditions in 1917, in district Sargodha are given in Table 9.

The most important were the horse breeders who were bound to keep up in good conditions a braded mare for every unit of grant and to give the Army Remount Department the first refusal of the progeny. The difference between the peasants and the nazrana-payers was that the former could keep up only one mare with a 2-squares (20 ha) unit of grant on which they were required to reside, while the latter could keep two or more mares with 1.5 square unit and reside elsewhere. In all horse-breeding grants succession was according to the rule of primogeniture. The aboriculture colonists used to hold their lands on 20 years lease subject to a resumption in the event of previous death or breach of conditions. Nurserymen ordinarily received 10 killas (more than 4 1/2 ha), 3 of which were required to be set aside and maintained as nursery for saplings. A

tree planter ordinarily received one square and was bound to plant not less than two miles of the road side avenue with shisham (*Dalbergia sissoo*) or kikar (*Acacia arabica*) trees. He was also bound to maintain the avenue in proper condition.

Table 9: Areas held by different colonists

Class of colonist	Area allotted (ha)
I. Horse breeders	
a. peasants	
cavalry	11,709
others	67,085
b. Nazrana-paying*	
stud-farms	2,733
cavalry	2,802
others	6,214
II. Aboriculturists	
a. nurserymen	883
b. planters	507
III. Other colonists	
a. peasants	28,286
b. Nazrana-paying	17,182

The other colonists had no special conditions or service except in case of recipients of grants of 4 squares or more in which case if a peasant died before acquiring occupancy right, all his rights were extinguished. Another difference between peasants and nazrana-payers was that the unit of grant for the former was one square and for the latter two or more squares and whereas the former obtained occupancy rights or entry, the latter became only entitled if still surviving after five years from the commencement of the tenancy. These two

* A class supposed to pay gifts at ceremonial occasions.

classes of grantees were cross divided as shown below:

Class of grantee	Area allotted (in ha)
Infantry grantees	12,112
Civil grantees	9,409
Janglis (locals)	24,207

The infantry grantees were prisoners while the civil grantees were a miscellaneous collection, largely non-agriculturists and non-residential. The Janglis were the old denizens of the Bar; they were no farmers. In addition to the occupancy tenants and Lower Jhelum Colonists there were a certain number of other persons holding land under Government. These were:

(i) Holders of land on long leases under the rules of 1897;
(ii) Holders of land on annual leases; and
(iii) A leasee who accepted a grant in exchange for land.

1.6 Climate

There are no climatic data recording stations in the case study area whose long term systematic data is available. The nearest stations with available data, Sargodha, Miani and Bhalwal, are all outside the project boundary. A weather station at Phularwan within the study area was established in 1969/70. For this report, the data from Sargodha has been utilized to determine the rainfall pattern (Appendix V). The mean annual rainfall there is 37.8 cm and varies from less than 0.5 cm in November to 11.4 cm in July and is concentrated mostly in the monsoon months (see Fig. 4); the maximum rainfall intensity and its recurrence is given in Fig. 5. According to the published data of the Meteorological Department for the years 1931-60, the mean monthly maximum temperatures at Sargodha varied from 66°F (19°C) in January to 107°F (42°C) in June and the minimum from 40°F (5°C) to 82°F (28°C) (see Fig. 6 and Appendix VI). The annual extremes range from 26°F (-3°C) to 119°F (48°C) on the basis of unpublished data for the period 1957-74 (Appendix VII). The average normal relative humidity varies from 34 per cent in June to 73 per cent in January (see Fig. 7 and Appendix VIII). The sunshine intensity in langleys per day is not available; however, mean monthly solar radiation varies from 0.4 cm per day in December to 0.89 cm per day in May (Appendix IX). The wind velocity recorded at the Sargodha station by an

anemometer at 16.7 m above ground level, varies from a minimum of 0.3 knots per hour in July (see Fig. 8 and Appendix X). The average annual evaporation at Sargodha is 236 cm (Appendix XI).

1.7 Soils

The major differentiating factor of the soils in the area is textural variation, both vertical and horizontal. The soils have been classified according to the texture of the subsoil to a depth of 1.83 m. Five soil series are, therefore, recognized: Jhang (coarse), Farida (moderately coarse), Buchiana (medium), Chuharkana (moderately fine), and Nokhar (fine textured). These are further divided into categories on the basis of surface soil and substrata textures. The surface layer texture is important to crop production as this zone is the seed bed, the layer actually cultivated by the farmer. It contains most of the plant roots and controls the infiltration of water. The substrata categories are helpful in assessing the drainage problems. Greyish brown and light brown coloured soils are most common while rusty and reddish brown mottlings have been observed in some profiles at variable depths. The soil material is usually calcareous except for coarse textured soil material which may be non-calcareous to slightly calcareous. Lime nodules occur in some profiles at variable depths.

The soil series groups mapped in the area are shown on the accompanying soil map (see Fig. 9) and the details of their distribution in different landforms is given in Table 10.

Table 10: The proportionate extent of various soil groups in different physiographic plains

Group no	Soil series	Per cent area meander flood plain	scalloped interfluve	project
1	Jhang soils (sand and loamy sand sub-soil)	17.3	3.5	11.7
2	Farida soils (sandy loam and fine sandy loam sub-soil)	42.7	30.6	37.7
3	Buchiana soils (loam, silt loam and silt sub-soil)	11.5	23.6	16.3
4	Chuharkana soils (sandy clay, loam, clay loam textured sub-soil)	24.7	41.1	31.2
5	Nokhar soils (sandy clay and silty clay sub-soil)	0.7	0.3	0.5
-	Miscellaneous land type (settlements, roads, streams and grave-yards etc.)	3.1	0.9	2.5
	TOTAL	100.0	100.0	100.0

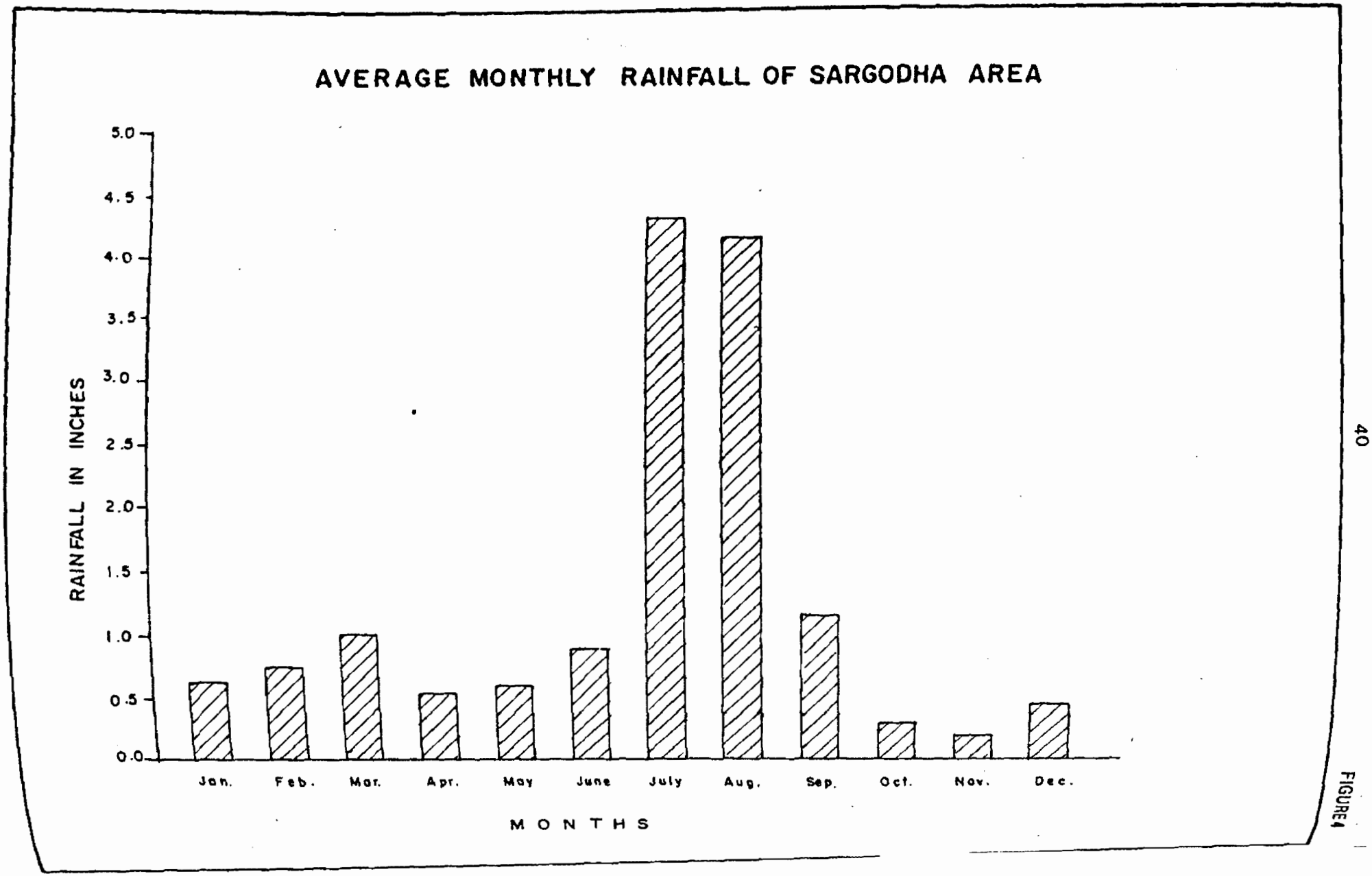

AVERAGE MONTHLY RAINFALL OF SARGODHA AREA
RAINFALL IN INCHES
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
MONTHS

FIGURE 4

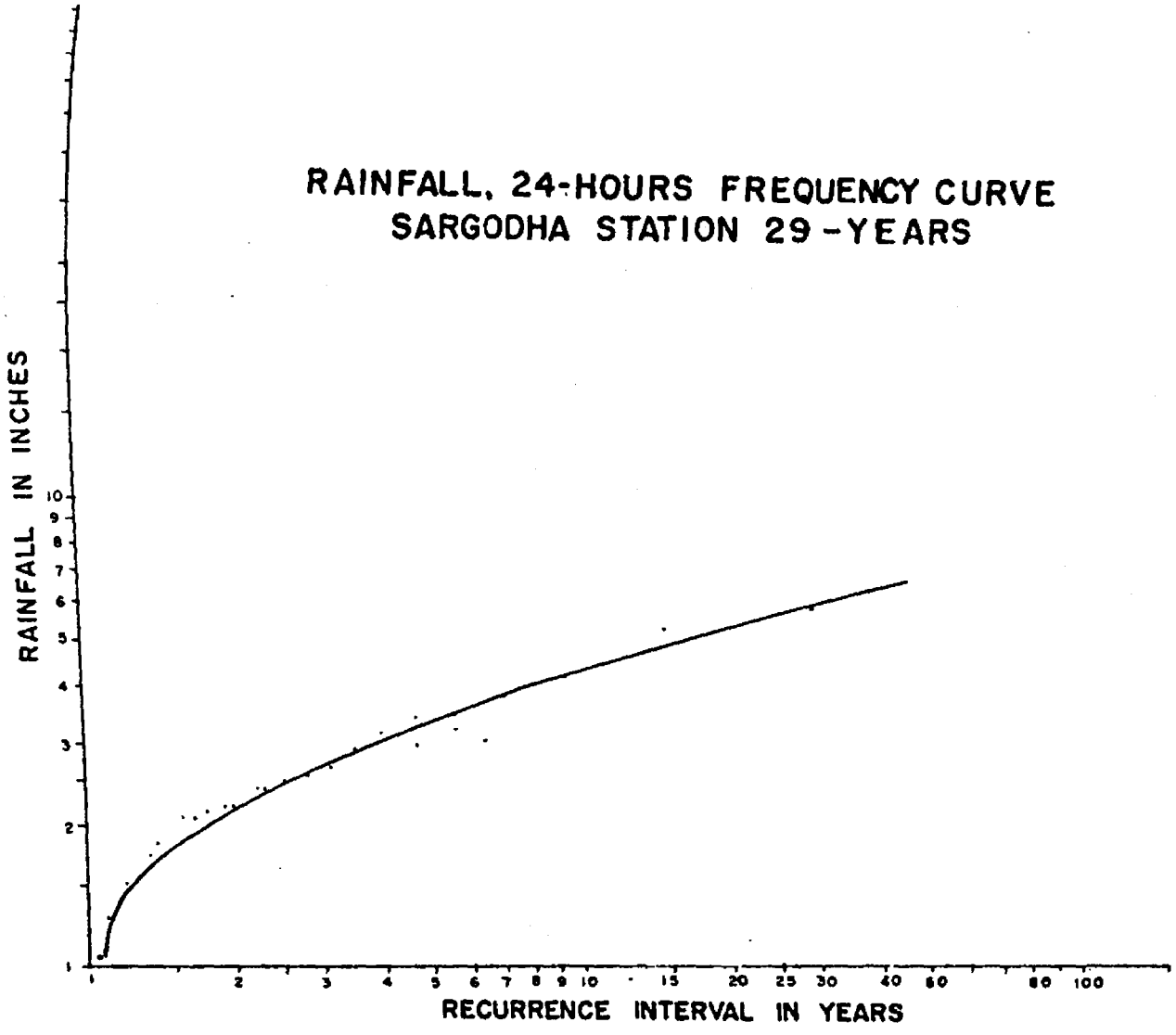

RAINFALL, 24-HOURS FREQUENCY CURVE
SARGODHA STATION 29-YEARS
RAINFALL IN INCHES
1
2
3
4
5
6
7
8
9
10
RECURRENCE INTERVAL IN YEARS
1
2
3
4
5
6
7
8
9
10
15
20
25
30
40
60
80
100

FIGURE 5

FIGURE 6

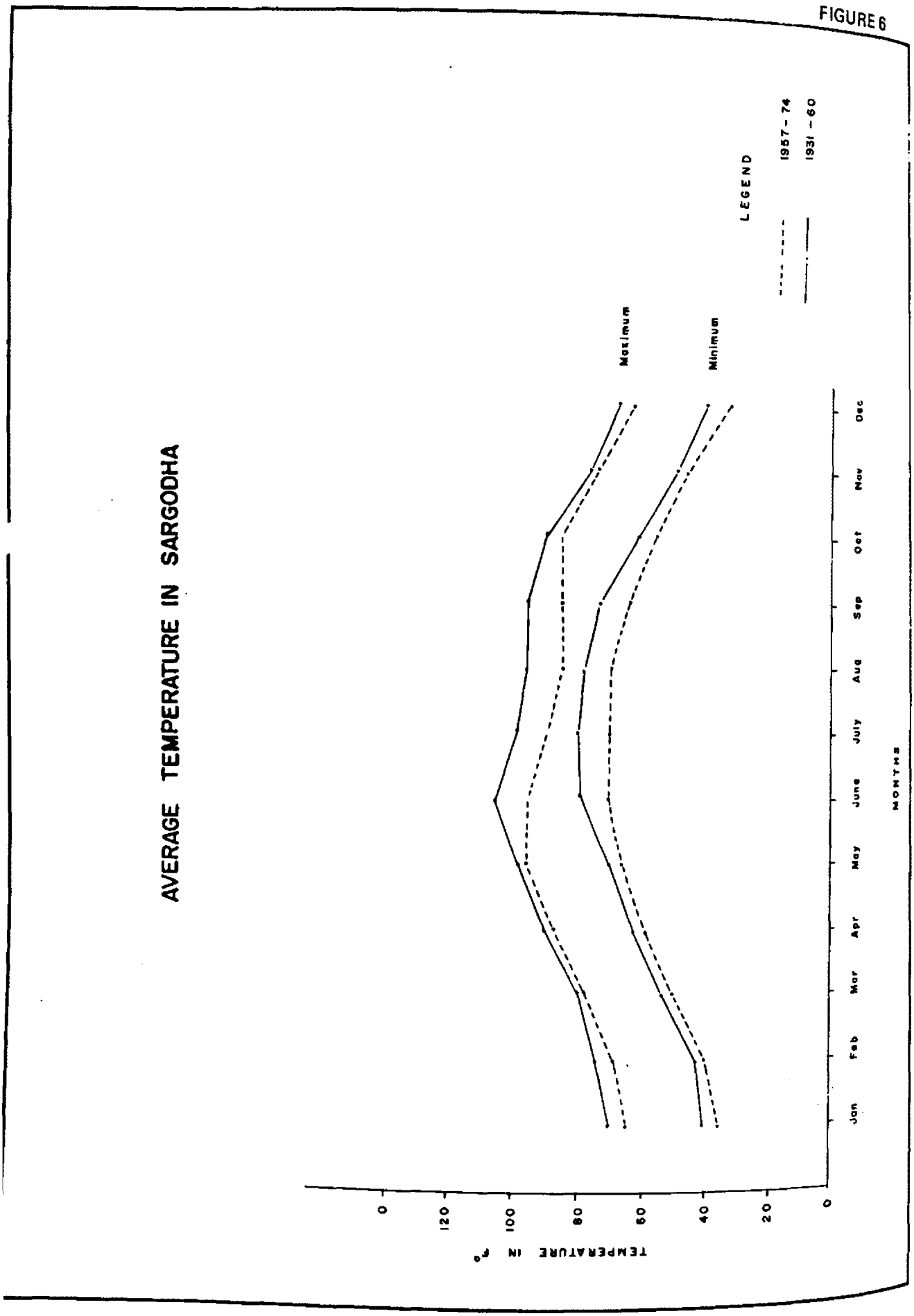

AVERAGE TEMPERATURE IN SARGODHA
LEGEND
1957 - 74
1931 - 60
Maximum
Minimum
TEMPERATURE IN F°
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
MONTHS

FIGURE 7

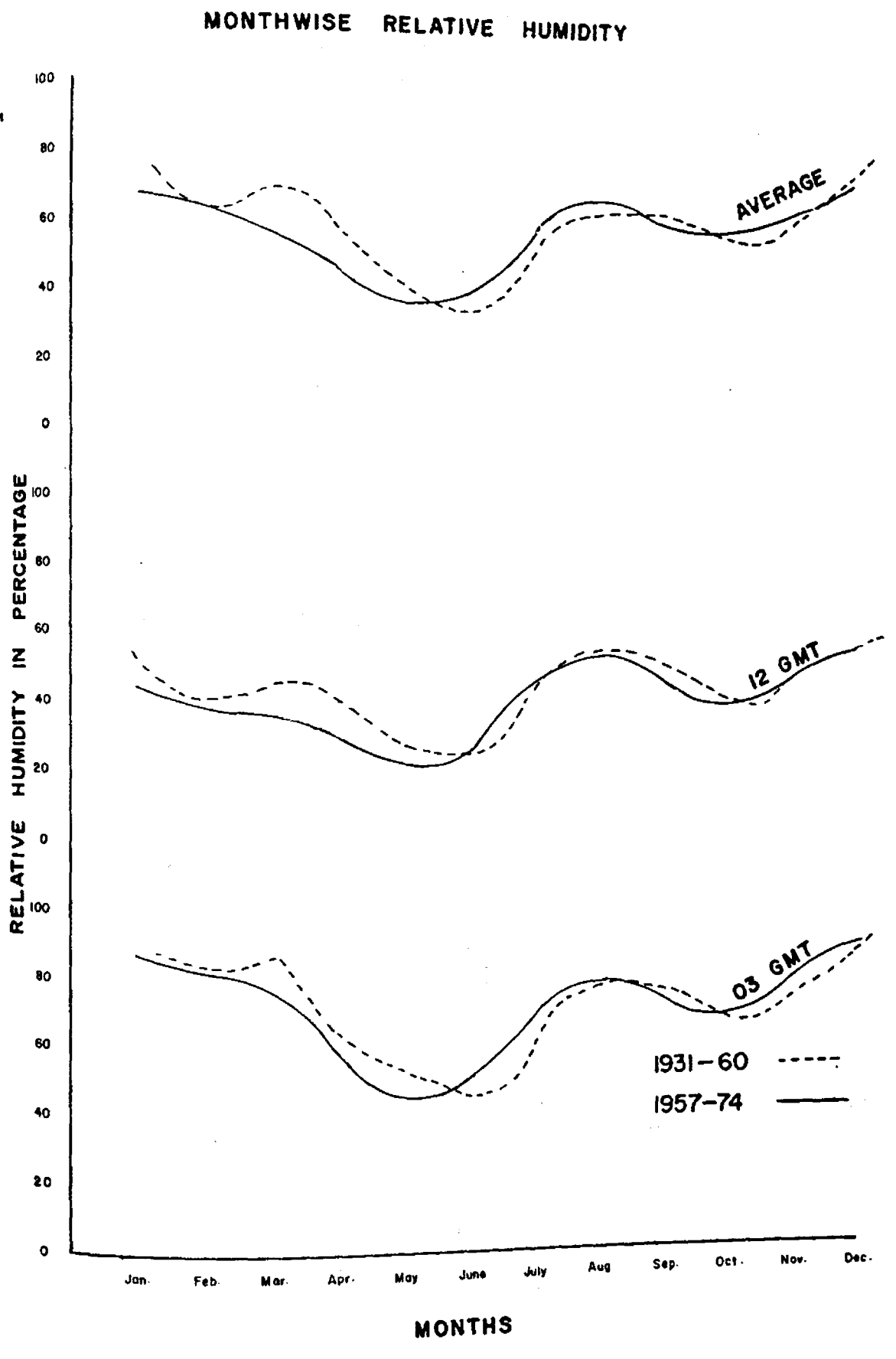

MONTHWISE RELATIVE HUMIDITY
RELATIVE HUMIDITY IN PERCENTAGE
100
80
60
40
20
0
AVERAGE
12 GMT
03 GMT
1931–60
1957–74
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug
Sep.
Oct.
Nov.
Dec.
MONTHS

FIGURE 8

MONTHWISE NORMAL WIND DIRECTION AND SPEED
(BASED ON DATA FROM 1931-60)

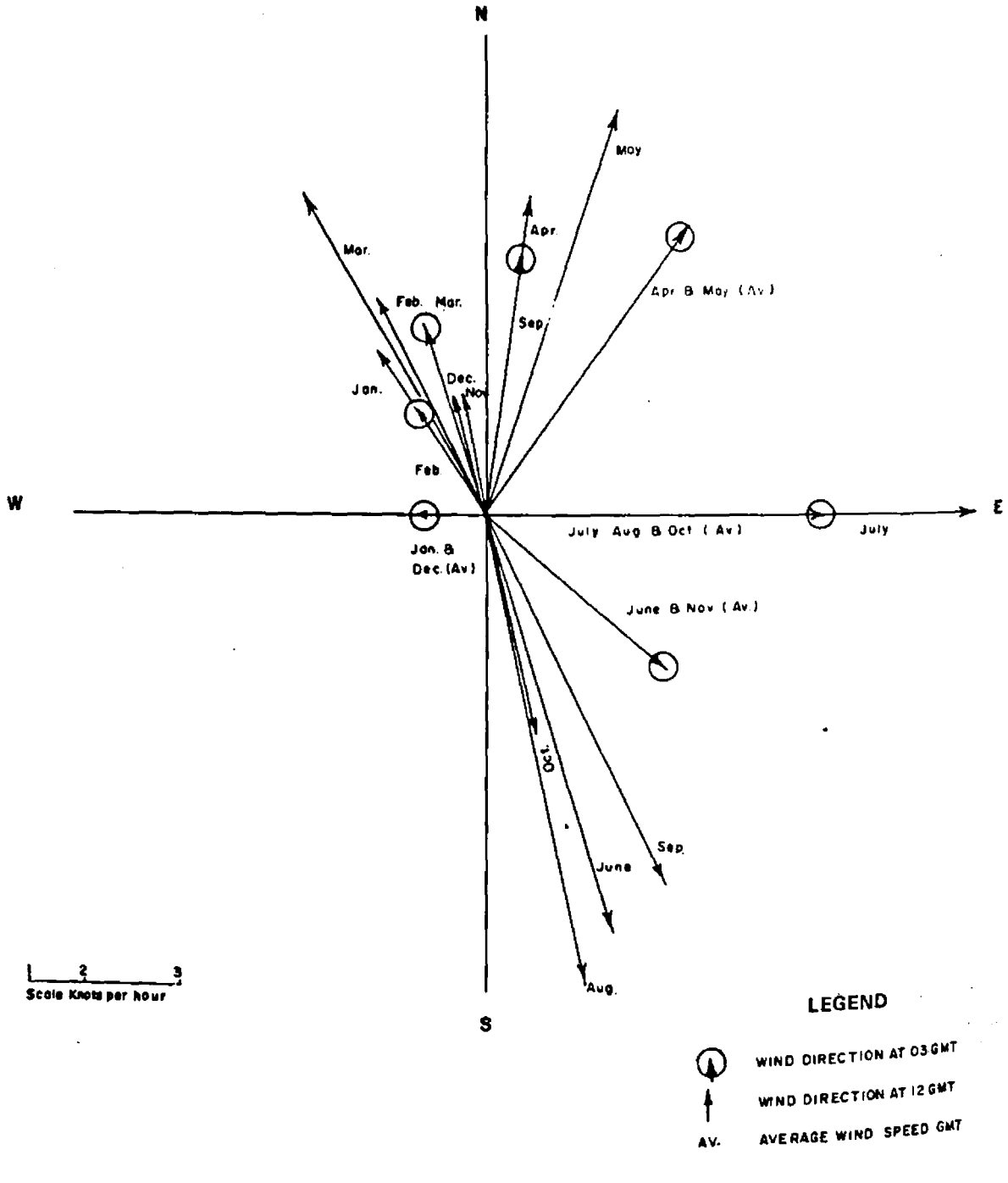
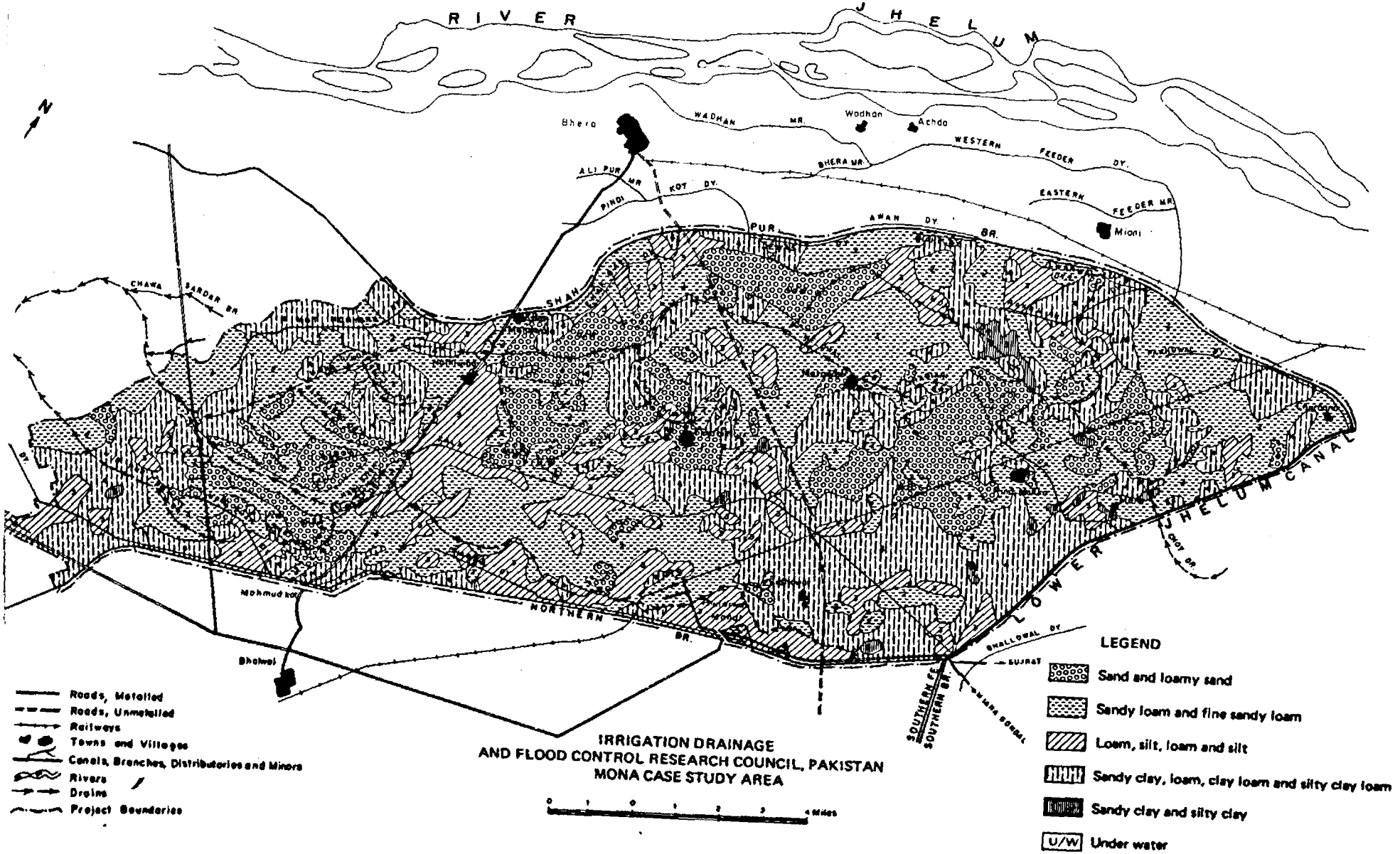


Figure 5 SOIL CLASSIFICATION



The distribution of major soil associations in the area as mapped on the basis of a reconnaissance soil survey by the Soil Survey Project of Pakistan, is given in Table 11.

Table 11: Proportionate extent of major soil associations in the Mona project-area

Soil association	Percent of the total area
Hafizabad	43.5
Bhalwal	29.7
Rasulpur	8.8
Shahpur	8.6

Note: The remaining 9.4 per cent of the total area is occupied collectively by Gandhara, Miani, Missan, Gujranwala and Feroz associations. Their individual percentages are insignificant.

Hafizabad association comprises non-saline, non-alkali, well drained soils consisting of brown to dark brown, very friable, massive calcareous loam with weak sub-soil structures and a distinct zone of lime accumulation containing common lime nodules (kankar) in the lower sub-soil. Bhalwal association soils are deep non-saline, non-alkali, well drained, calcareous and moderately fine textured, with a distinct kankar zone in the lower sub-soil. Shahpur association soils are deep moderately well drained, calcareous and fine-textured, with weak sub-soil structure and weak zone of lime accumulation in the lower sub-soil.

1.8 Impact of irrigation on environment

1.8.1 Climate. The impact of irrigation activity in the case study area on the various parameters of climate is not known as no micro-climatic studies have been carried out.

1.8.2 Soils. With the introduction of canal irrigation and consequent rise in the water table of the study area there has been continuous accumulation of salts

in the soil profile and considerable land went out of cultivation between the period of introduction of canal irrigation and the installation of tubewells for salinity control and reclamation. The proportionate extent of different categories of surface salinity as well as profile salinity determined as a result of surveys by Water and Power Development Authority in the study area are given in Table 12.

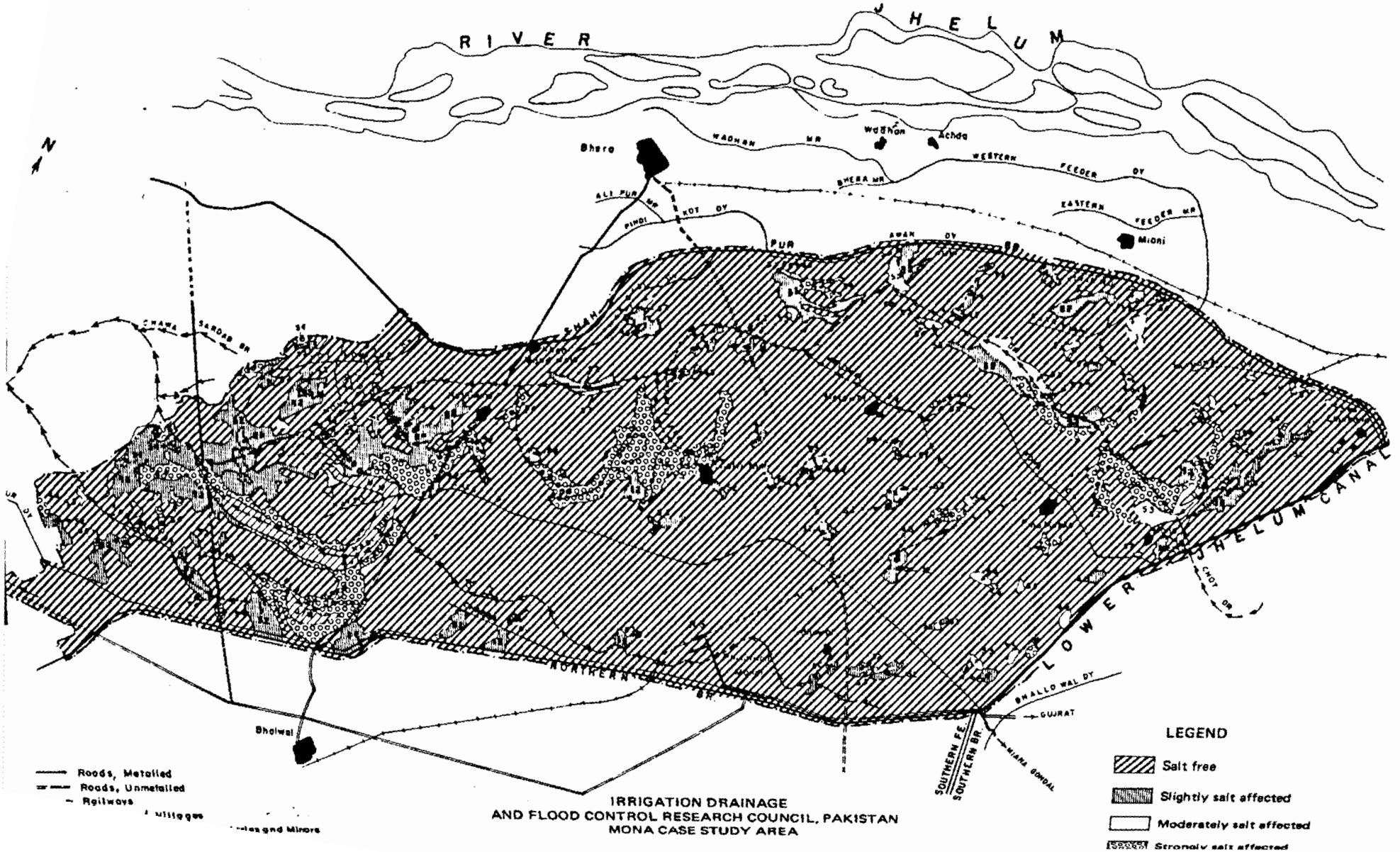
Table 12: Proportionate extent of different categories of surface salinity

Surface salinity class	Percent
salt free area	78.6
slightly saline area (S_2)	9.1
moderately saline area (S_3)	6.7
strongly saline area (S_4)	0.8
miscellaneous land type	4.8
TOTAL	100.0

In areas where salinity developed as a result of prolonged evaporation of irrigation water in the root zone, the soils have not been affected physically. But where saline-alkali conditions existed due to alternating salinization and exchange of calcium with sodium, the soil structure was destroyed whenever there was leaching, and the soils became impervious to air and water. These soils have been classified as non-saline alkali (about one-sixth of the total area) and saline alkali (about 28 per cent of the area) respectively. The saline alkali soils in the Mona project almost invariably have gypsum in the profile and are therefore amenable to reclamation by simple leaching.

The visual appraisal of surface salinity of Mona project area, was based on aerial photographs, the condition of crops, the kind of natural vegetation and the visible concentration of salts on the soil surface (see Fig. 10). Four classes of salinity were established which are described in Appendix XII .

Figure 10 SOIL SALINITY PRE-REHABILITATION STATUS



IRRIGATION DRAINAGE
AND FLOOD CONTROL RESEARCH COUNCIL, PAKISTAN
MONA CASE STUDY AREA

1.8.3 Cropping pattern. As a result of irrigation activity in the study area, apart from a gradual increase in the cropped area, the cropping pattern shifted more towards cash crops and the local variety of cotton changed to improved strains of cotton (see Table 13). The crop yields increased but were still lower than many other countries.

1.8.4 Water regime. After the introduction of the canal system the dynamic equilibrium of the groundwater reservoir was disturbed due to the addition of new source of recharge i.e., seepage from the canal system, irrigation applications to crops and greater infiltration of the rain water due to impeded run-off. Under the changed hydrologic environments, the water table gradually started rising as indicated in the selected well hydrographs given in Fig. 11 to 14. These hydrographs show that the rate of rise was fast in the beginning for the areas where the depth to water table was great. As the water table rose towards the land surface, evaporation losses from groundwater reservoir were introduced and a new equilibrium was attained which is indicated by the gradual levelling of the hydrographs. The change in the depth to water table between the pre-irrigation period (1900) and 1965, is given in Fig. 15. The average hydrograph for the project area indicating the historic rise is given in Fig. 16. The depth to water table in July 1965 prior to the introduction of tubewell project (shown in Fig. 17) indicates that the water table prior to the reclamation measures had come very close to the land surface, resulting in waterlogging.

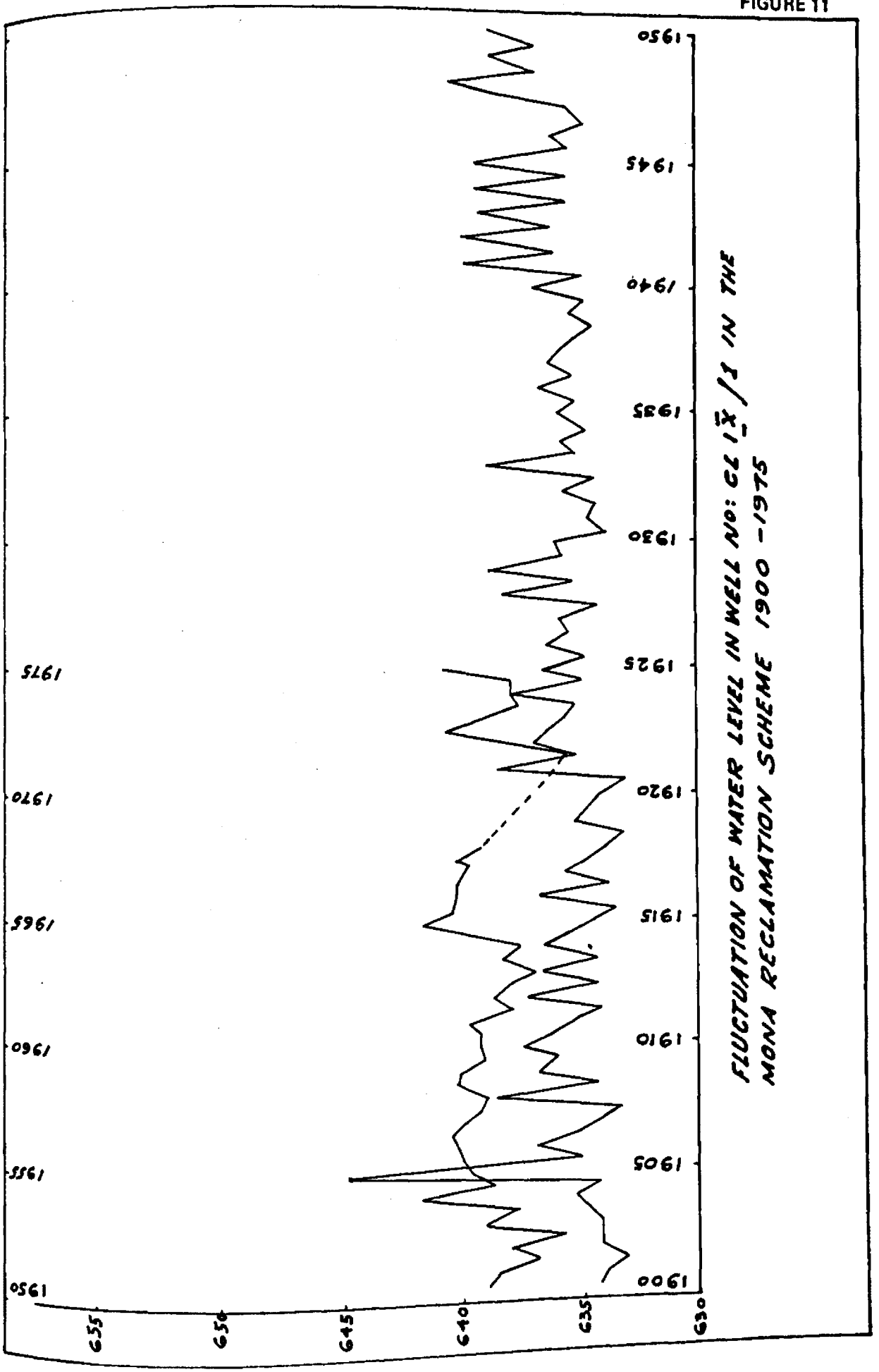
1.8.5 Flora. In the irrigation period the existing flora prospered. As more land was brought under cultivation, the planting of kikar (*Acacia arabica*) and tahli (shisham, *Dalbergia sissoo*) was continued as per standing settlement rules. This resulted in the specialization of the arboriculture for production of kikar and tahli. Under canal colonization, lands were given to tree planters who were bound to plant kikar or tahli. In this way the kikar and tahli were largely grown on cultivated land. Among the trees which had been introduced in the irrigation period with success, were the mulberry (*Tutmorus alba*), the dhrek, tand or bakain (*Melia azadarach*), the poplar (shuraida, *Populus alba*), and willow (haint, *Salix*). In depressions and in areas close to the canals, grass like *Eragrostis cynosuroides* (dab), *Sachharum munja* (kana), *S. spontaneum* (kahi), *Eleusine flagellifera*, *E. aegyptica*, *Peristorum archnoides* (bui), *Blumea spp.*, *Chenopidium alba* (bathu), and Bhung (marijuana) plants were seen growing wildly in the area.

Table 13: Cropping pattern of Sargodha District (ha)

Year	Total cropped area	Crop											
		Rice		Wheat		Maize		Sugarcane		Cotton		Oilseed	
		Area	%age	Area	%age	Area	%age	Area	%age	Area	%age	Area	%age
1890-91	226,443	888	0.4	101,458	44.8	-	-	479	0.2	16,295	7.2	13,085	5.8
1903-04	313,359	2,160	0.7	154,522	49.3	-	-	497	0.1	12,327	3.9	6,417	2.0
1910-11	476,518	3,074	0.6	208,488	43.8	7,901	1.6	3,314	0.7	38,369	8.9	-	-
1920-21	444,991	1,761	0.4	156,990	35.3	6,144	1.4	2,927	0.7	49,598	11.0	32,133	7.2
1930-31	523,755	1,480	0.3	178,057	34.0	8,386	1.6	3,585	0.7	56,172	10.7	27,934	6.1
1940-41	650,670	2,063	0.3	208,975	32.1	9,238	1.4	4,887	0.7	89,836	13,8	16,985	2.6
1955-56	752,187	7,603	1.0	226,869	30.2	17,333	2.3	11,125	1.5	86,024	11.4	14,791	2.0
1970-71	899,615	22,229	2.4	283,814	30.2	25,363	2.8	46,231	5.1	100,902	11.3	6,357	0.7
1972-73	967,489	25,040	2.6	289,119	29.9	25,227	2.6	35,000	3.6	89,210	9.2	13,403	1.4
1973-74	990,890	24,297	2.5	291,551	29.4	23,757	2.4	40,384	4.4	92,999	9.4	14,271	1.4

Source: Directorate of Land Records, Punjab, Lahore.

FIGURE 11



FLUCTUATION OF WATER LEVEL IN WELL NO: GL 1 $\bar{X}$ /1 IN THE MONA RECLAMATION SCHEME 1900 - 1975

FIGURE 12

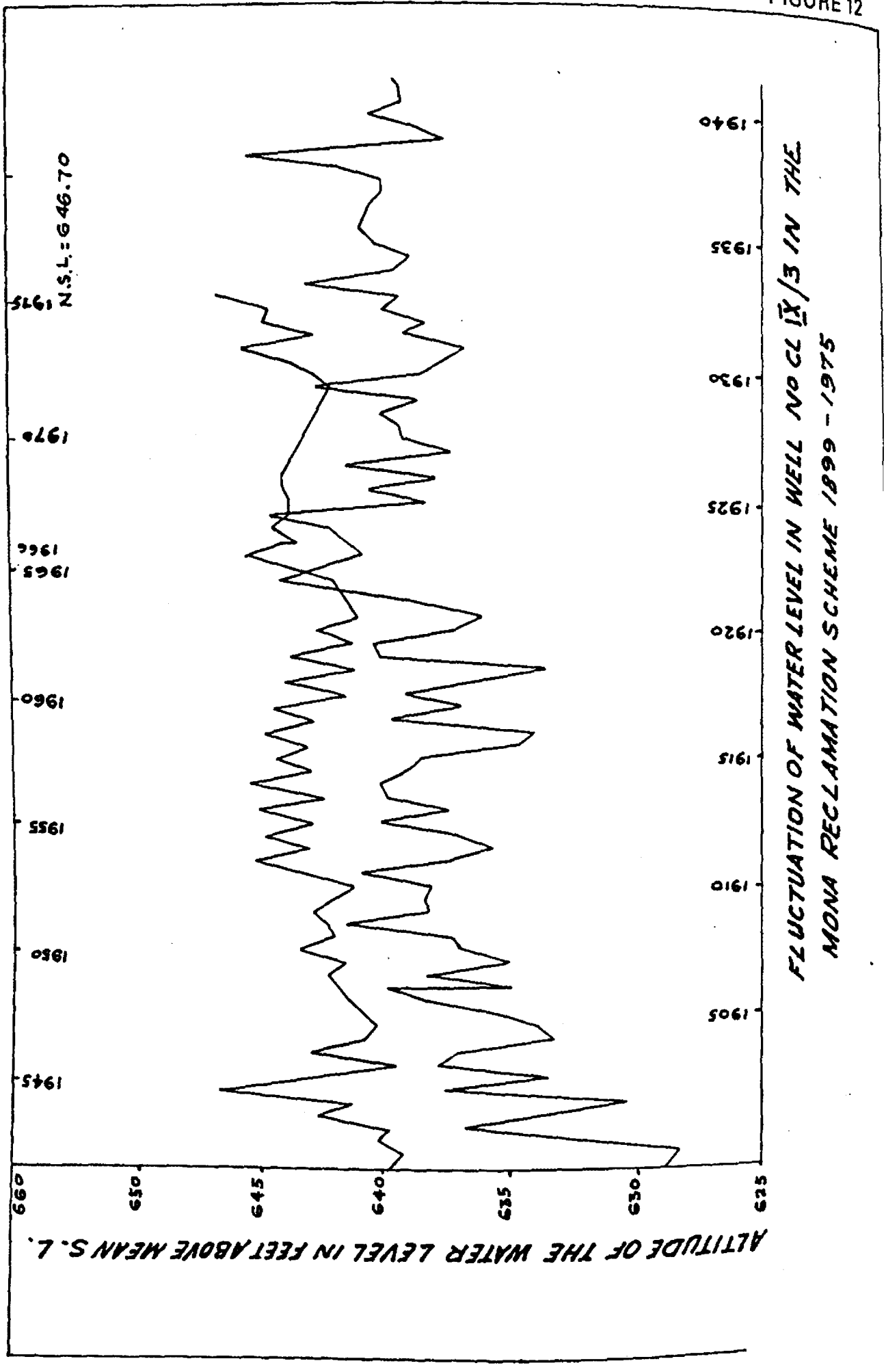

FLUCTUATION OF WATER LEVEL IN WELL NO CL IX/3 IN THE MONA RECLAMATION SCHEME 1899 - 1975
ALTITUDE OF THE WATER LEVEL IN FEET ABOVE MEAN S. L.
660
650
645
640
635
630
625
1940
1935
1930
1925
1920
1915
1910
1905
1945
1950
1955
1960
1965
1966
1970
1975
N.S.L.=646.70

FIGURE 13

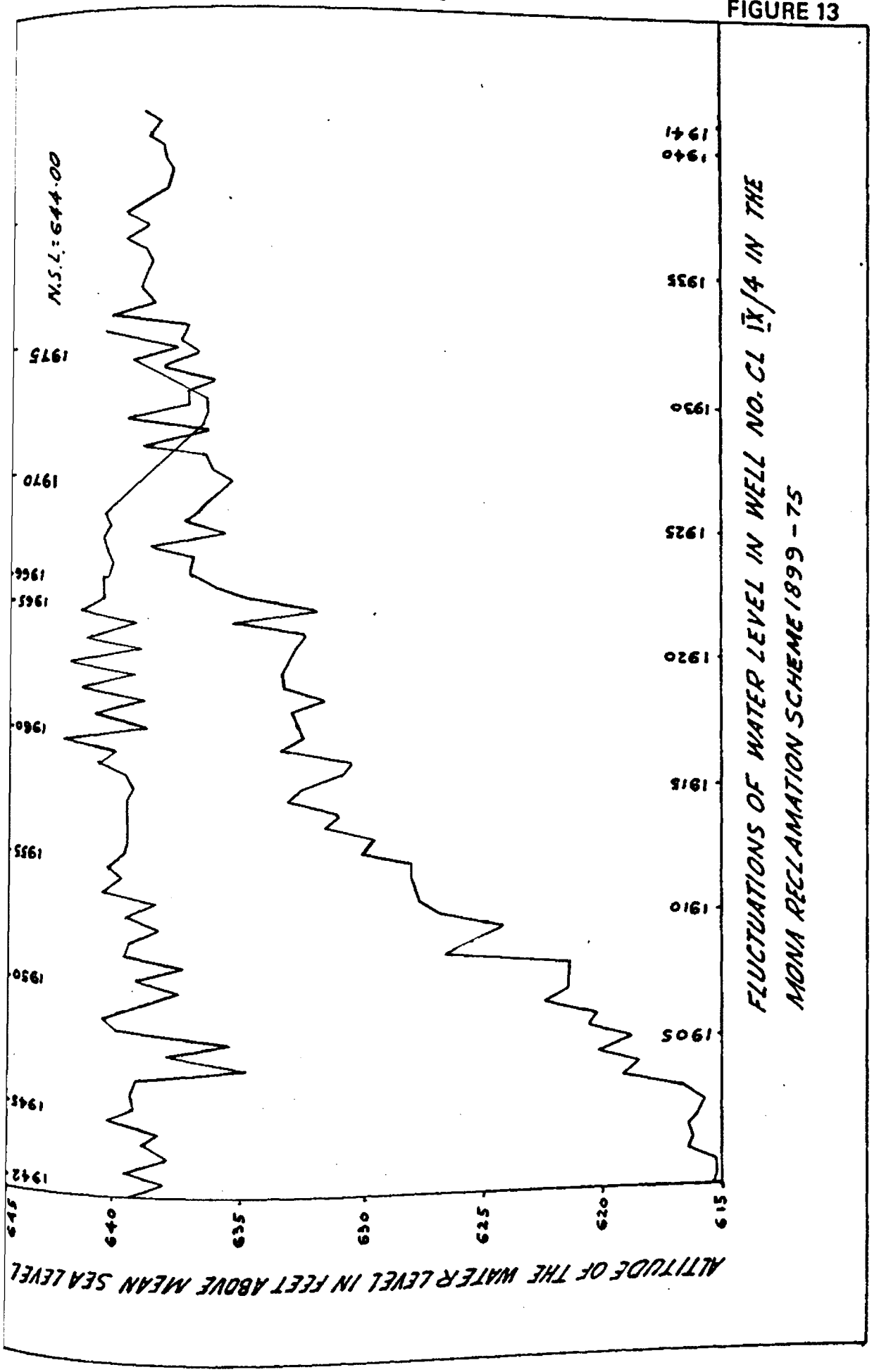
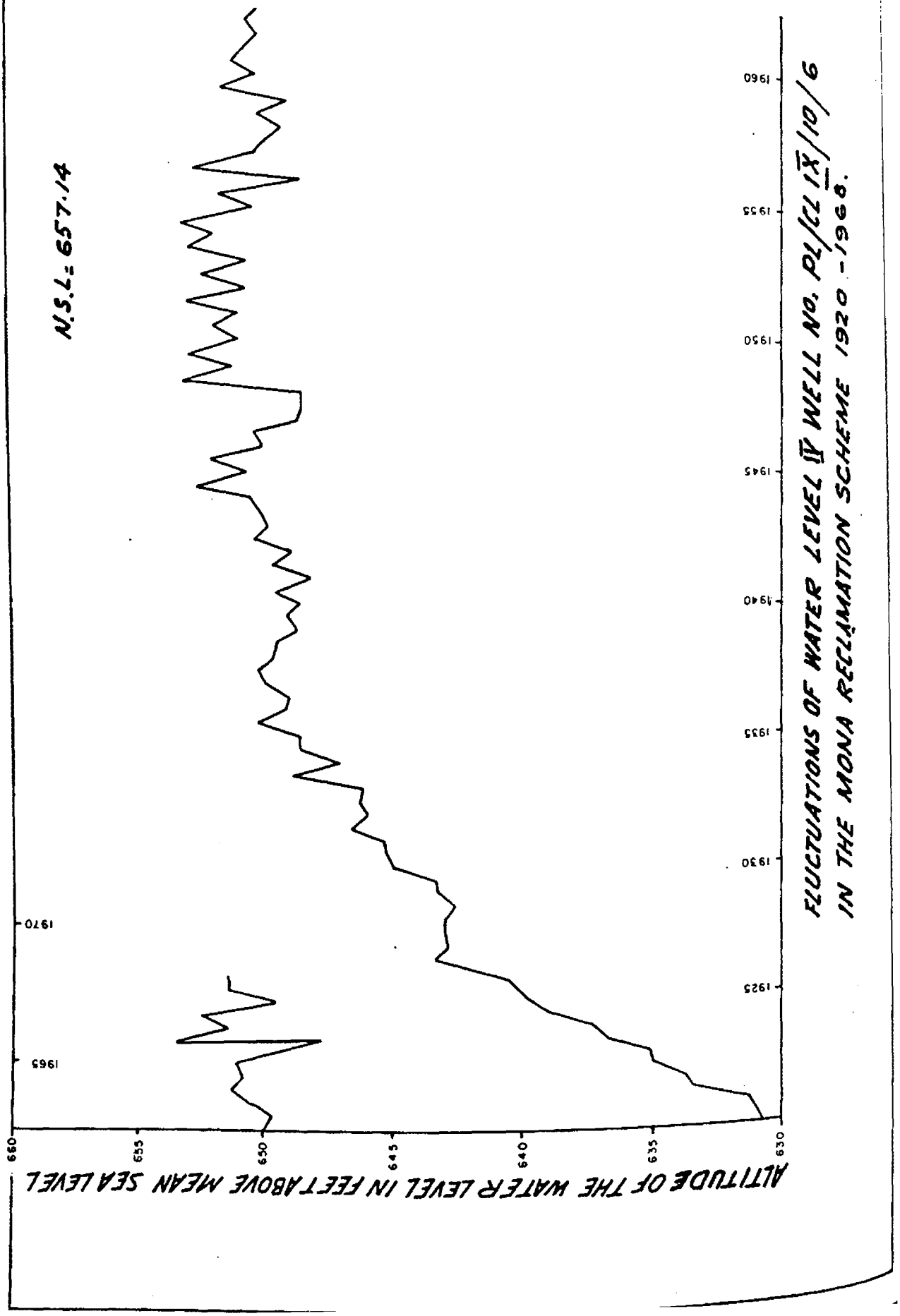
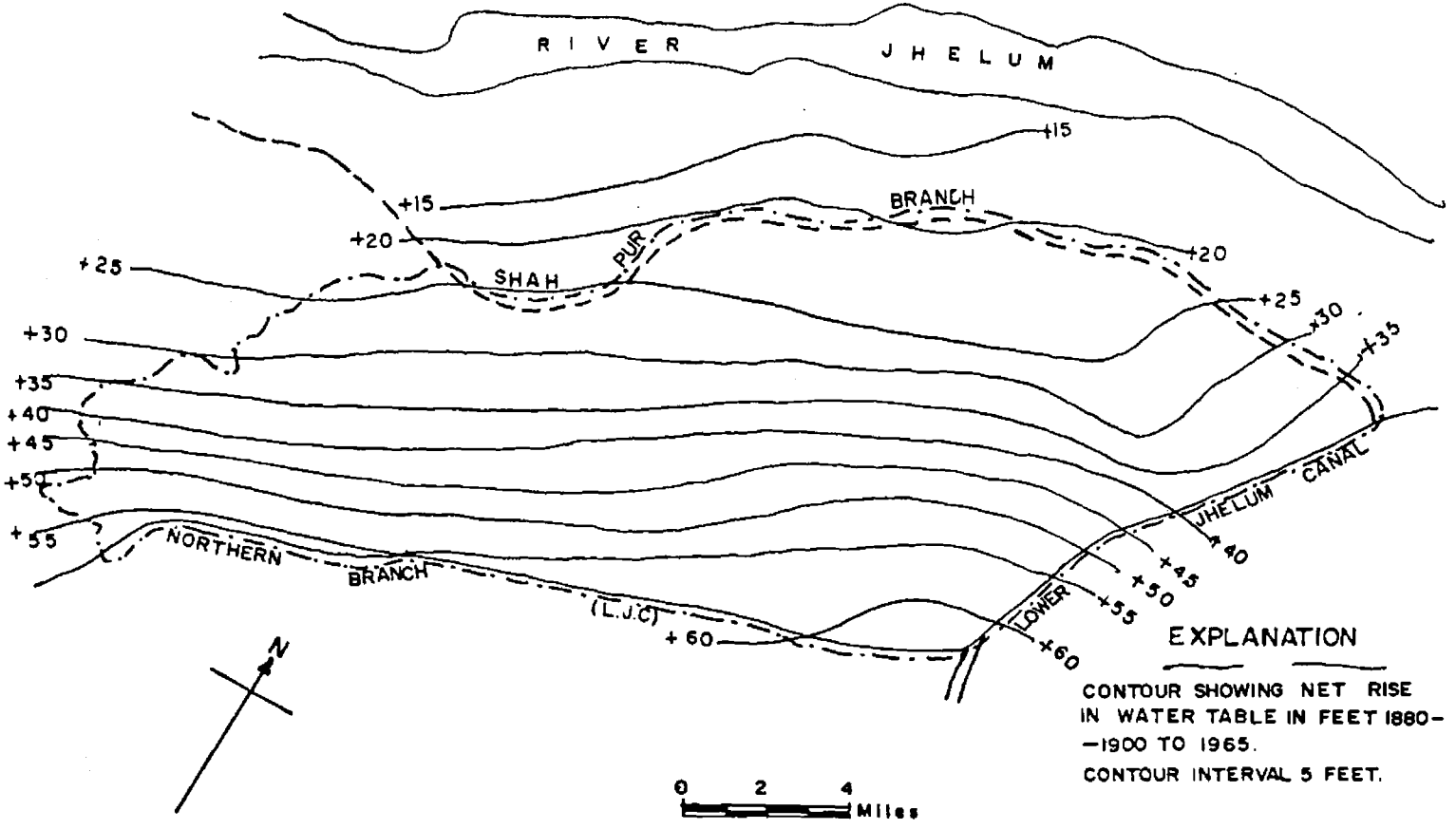

FLUCTUATIONS OF WATER LEVEL IN WELL NO. CL IX/4 IN THE MONA RECLAMATION SCHEME 1899 - 75
ALTITUDE OF THE WATER LEVEL IN FEET ABOVE MEAN SEA LEVEL
645
640
635
630
625
620
615
1905
1910
1915
1920
1925
1930
1935
1940
1941
1942
1945
1950
1955
1960
1965
1966
1970
1975
N.S.L: 644.00

FIGURE 14

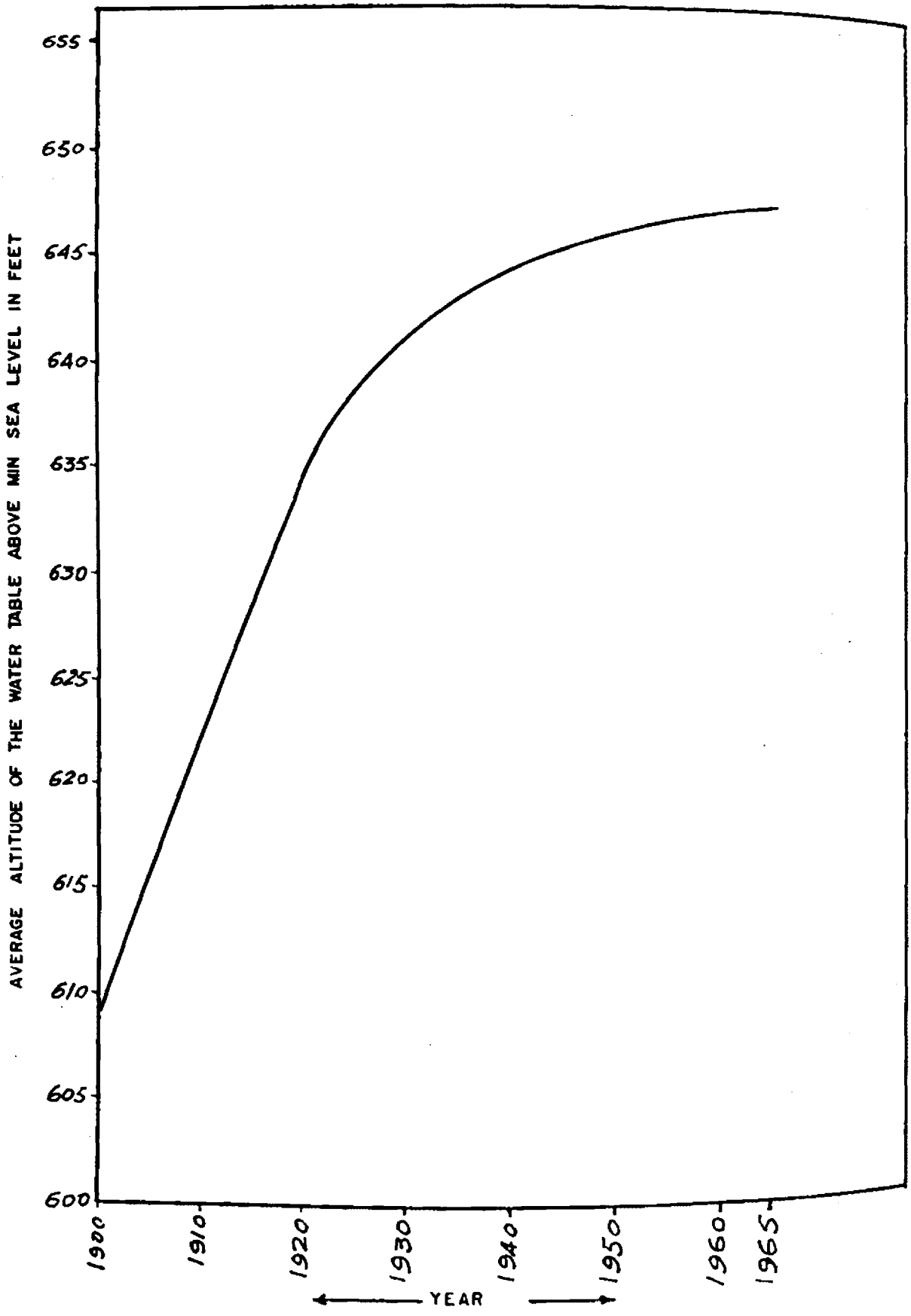

FLUCTUATIONS OF WATER LEVEL IN WELL No. P1/CL 1X/10/6
IN THE MONA RECLAMATION SCHEME 1920 - 1968.
N.S.L. = 657.14
ALTITUDE OF THE WATER LEVEL IN FEET ABOVE MEAN SEA LEVEL
660
655
650
645
640
635
630
1960
1955
1950
1945
1940
1935
1930
1925
1970
1965



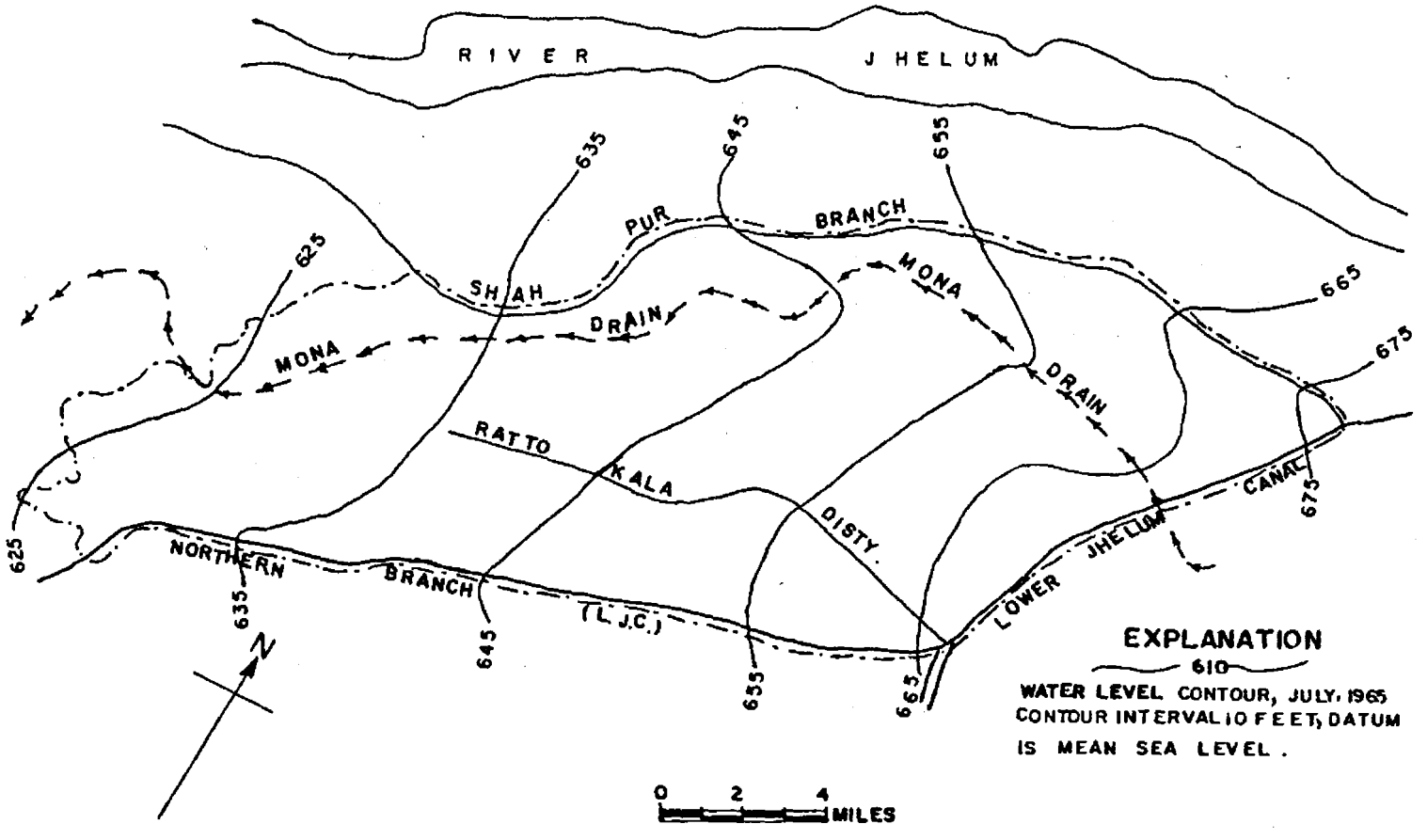
APPROXIMATE CHANGE IN ALTITUDE OF THE WATER TABLE IN THE MONA RECLAMATION SCHEME DURING THE PERIOD 1880–1900 TO 1965.

FIGURE 15

FIGURE 16



GRAPH SHOWING THE AVERAGE RISE IN WATER TABLE SINCE 1900



MAP SHOWING THE APPROXIMATE ALTITUDE OF THE WATER TABLE IN THE MONA RECLAMATION SCHEME IN JULY, 1965.

FIGURE 17

1.8.6 Fauna. With the development of widespread system of irrigation canals, a number of habitat changes took place. Most of the tropical thorn plain was converted into irrigated agricultural land, linked to the riparian habitat by the canal system. Villages became more numerous and more complex, linked by a system of roads and railroads; and the hummocky areas, although not physically modified, became more heavily grazed. Along with these changes, the spread of human settlement led naturally to a greater amount of contact between men and the larger mammals. This resulted in an increase of hunting pressure on certain species. Most of these developments had probably been taking place in a slow and irregular way in the study region for a long time and the peculiarity of the irrigation period caused their acceleration. Several large mammals, which were probably not very abundant to begin with, were apparently completely eliminated from the study area by hunting and trapping. These included the tiger, cheetah and hog deer. Other animals almost exterminated by hunting or trapping were the wolf and the nilgai. The remaining fauna of the tropical thorn plain suffered severe reduction due to habitat destruction. A few relict areas supported small populations of the little Indian field mouse, wagner's gerbil, the desert gerbil, and the Bengal fox. The Indian crested porcupine, the Indian hare and possibly the long-eared hedgehog, have managed to survive widely at the edges of the cultivated land. In contract, some surviving members of the river and flood-plain fauna have apparently benefitted from a great increase in available habitats. This new habitat includes the well-watered canal-banks, crop-land, and irrigated forests. The species which apparently increased or spread westward include Asiatic Jackal, jungle cat, wild bear, short-tailed bandicoot rat, the Indian gerbil and rabbits. The wild boars and jackals did much damage to the crops; the fauna of the village and its environs increased tremendously due to suitable habitat. It might well be that some members of this fauna such as soft furred field rat and the fawn-coloured mouse were not present in the study area a century ago, but were introduced subsequently. Squirrels which became common, damaged the flora at early stages of growth. The rats and porcupines caused damage to the crops at the sappling stage. The dogs also became a problem in the villages. During the irrigation period indigenous birds of all types still existed except that their activity in the cultivated area became less pronounced. Grey partridges concentrated in Pakhowal Forest but the black ones were found only in the vicinity of the riverain area. A good number of migratory birds such as quails (battair), sandgrouse (bhatitar), demoiselle cranes (kunj), falcons and ducks, mostly flocked down in winter from the western hilly areas in the Nabi Shah Lake and other

places, remained there during winter season. The teal, shovellers and smaller kind of pochards came early and stayed late. The mallard, like the geese, turned up with the colder weather and some birds like the red-crested pochard were seen usually at the end of the season only. Thereafter they went back for resting. Most of the species of ducks were subject to extermination due to excessive shooting. Crows, parrots, woodcutters, woodcock and sparrows were ubiquitious. A considerable damage was done by sparrows. Red jungle fowl and sissi were not uncommon in the area.

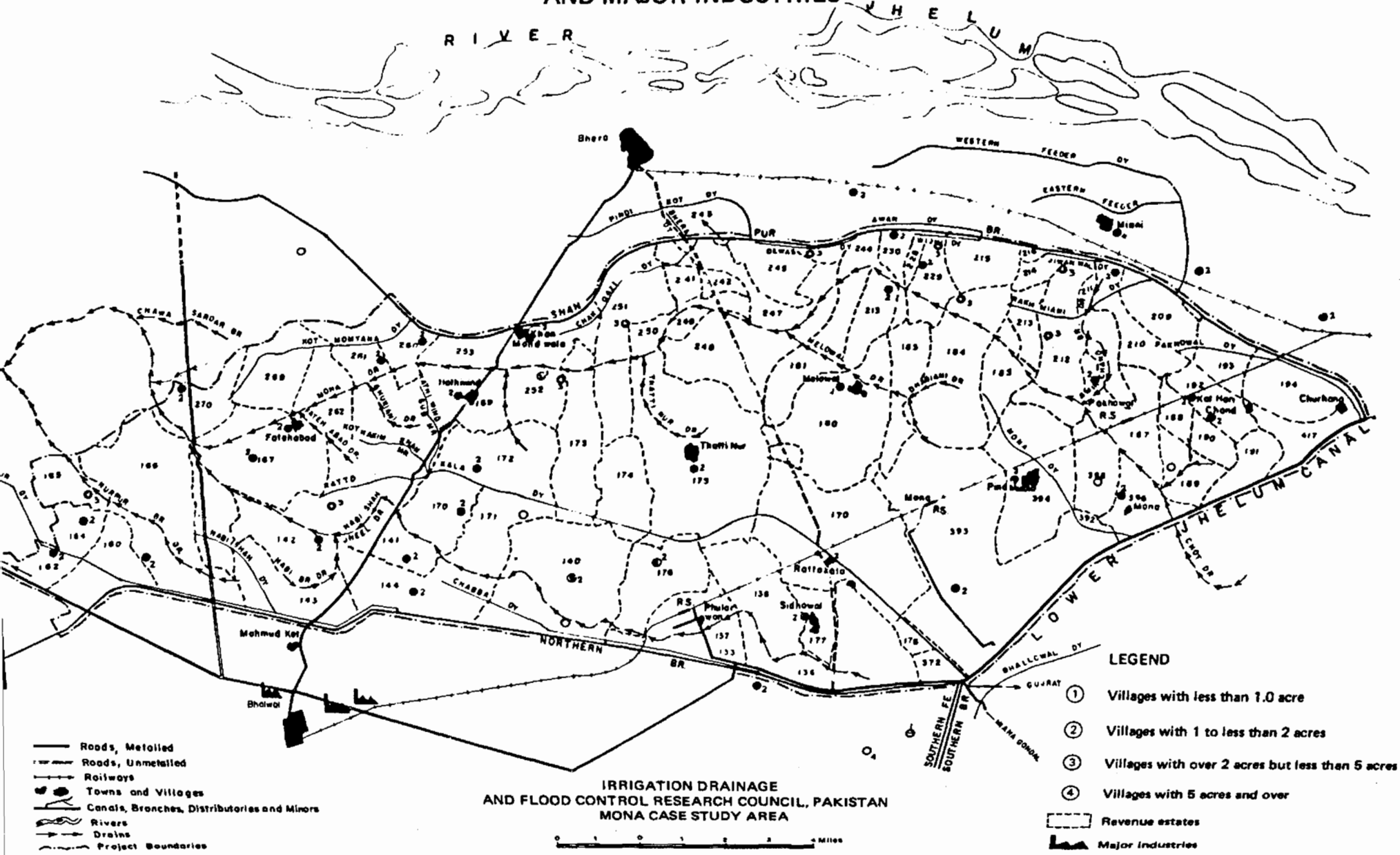
Locust swarms visited the area up to the sixties and caused colossal damage to standing crops.

1.9 Population

1.9.1 Density. According to 1961 census the total population of the study area was 122,000 (67,500 males and 54,500 females) which gave a man-land ratio of 0.36 ha per person. Taking into consideration the 1951 census, this amounted to an increase of about 25 per cent in the population. It may be of interest to observe that in this area 11 per cent of the villages had less than 0.4 ha of land per person; 58 per cent of the villages had over 0.4 ha but less than 0.8 ha per person; in 26 per cent of the villages the land per capita was 0.8 to 2.0 ha; in the remaining 5 per cent the per capita land was 2 ha or more. In a few villages, per capita land went beyond 8 ha as shown in Fig. 18; these were landlord dominated villages.

According to the available information, the density of population per km^2 in the contiguous area, which may also be true of the case study area, was 21 in 1891 and 69 in 1911. After the introduction of the Lower Jhelum Canal, pressure on land increased in the area and therefore, the density of population also went up. With assured water supply from the canal and obtaining settlement rights on land, the people gradually changed their pastoral habits to a settled agriculture. In 1951 the density of population in the case study area was 147 which rose to over 154 persons per km^2 in 1961. According to the census of 1961, the children below 15 years of age were 44 per cent of the population, while people between 15 and 54 years of age and those 55 years or over, were about 46 and 10 per cent respectively. With effective measures of control for epidemics, diseases and infantile mortality, the proportion of younger population increased and the life expectancy of the popple also increased.

Figure 18 PER CAPITA MAN-LAND RATIO, REVENUE ESTATES AND MAJOR INDUSTRIES



1.9.2 Migration. No statistical data is available on the migration of the inhabitants of the case study area to other parts of the country or abroad. However, it appears from the records of the district Shahpur that after the opening of the canal system, the migration of people increased. Out of about 687,400 persons enumerated in the district in 1911, about 542,000 belonged to this district by birth whereas the rest came from other areas. On the other hand, about 35,500 people of this district had gone out to other parts of the country or perhaps a few went abroad.

1.9.3 Fertility and mortality patterns. Table 14 shows the fertility/mortality picture of the district Shahpur before and after the introduction of the canal system.

Table 14: Fertility/Mortality rate

Years	Births per 1000	Deaths per 1000
1881 - 1890	37	26
1891 - 1900	40	32
1901 - 1910	45	37

The deaths during the years 1901 to 1910 were abnormal because in this period there were epidemics of plague, cholera and smallpox. Fertility and mortality figures for the year 1965, which is based on the countrywide sample survey shows that the crude birth rate per 1000 population *per annum* was 50 and the corresponding death rate was about 20.

According to the 1965-66 survey in the study area, the population planning program did not create any impact on the people; 98 per cent of the people did not use any population/family planning measures.

1.9.4 Health. Most of the farm families were living under unhygienic conditions with poor domestic water supply and drainage system and cattle tied in the courtyards of their houses. Improper operation and maintenance of canals and inadequate drainage system in the area led to the creation of marshy lands which were the breeding ground for insects harmful to public health. Certain water borne diseases

and malaria had increased and moisture conditions in the villages resulted in more fungus infection. The health services were quite inadequate. The dispensary at Bhera remained the only place available in the vicinity for quite some time, where the sick people of the study area could go. Even until 1965/66 there was only one small six-bed hospital in the entire case study area, and people had to use the facilities of the hospitals and dispensaries existing near the project boundaries.

1.9.5 Ways of life. As regular sociological surveys were not carried out, the information on trend and mode of change in the case study area is not available. However, the ways of life, in general, had changed in the course of time with better communication system and inter village cooperation because of dependence on a common irrigation system.

1.9.6 Education. In 1911 there were 64 literates to every 1000 males in the Shahpur district. The literacy rate among women was very low; there were only 8 literates to every 1000 females in this area. In 1917, in Bhera Tehsil of which the study area is a part, there were 2 anglo-vernacular middle schools, one vernacular middle school, 7 primary schools for boys, 4 schools for girls, and 2 high schools in Bhera town.

Gradually the educational facilities in the area improved but not adequate enough to meet the requirements. In the 83 villages of the study area there was in 1961, only one high school and 3 middle schools. There were a total of 36 primary schools in the area, which means one primary school for every 3391 persons. The total literacy percentage in 1961 was about 9 per cent for the rural areas; among the rural females only 2 per cent were literate. With time the literacy figures in the area improved. According to the Lyallpur Agricultural University survey of 1965-66, there were about 17 per cent literate in the case study area out of which about 92 per cent had schooling up to the 8th grade. Out of a sample of 394 respondents having male children of school age, 66 per cent were sending them to schools; whereas, out of 389 respondents who had school age female children, only 7 per cent were sending them to the schools.

1.9.7 Family structure. According to the survey of 1965-66, the family structure in the case study area was patriarchal*, patrilocal** and patri-lineal***. In

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* The head of the family is a male who makes decisions for the entire family.

** A married son brings his wife to live with his parents in his own community.

*** The lineage of children is drawn from the male side of the parents.

86 per cent of the families, all decisions and plans affecting the family were taken by the oldest male member, who was the head, and all other members had to abide by those decisions. Even the decision which affected the whole lives of the young people lay in the hands of the elders, e.g. the young were not supposed to talk about or take part in the decisions regarding the selection of their future partners. The size of the average family in the study area was 7.5 persons compared to 4.6 persons per family in Bhalwal Tehsil in 1961. Nearly five-sixths of the respondents had families of five or more persons and one-sixth families of less than five persons as evident from Table 15.

Table 15: Size of families

Number of persons per family	Number of families	Percentage
2	18	3.2
3	35	6.5
4	38	6.8
5	66	11.9
6	75	13.3
7	77	14.0
8	63	11.2
9 or more	184	33.1
TOTAL	556	100.0

1.9.8 Customs and traditions. In the survey conducted in 1965-66 it was found that there was an emerging consciousness on the part of the rural people that productivity and prosperity go hand in hand, and that the traditional belief that all that happens in life is predetermined and the man has to accept it as a *fait accompli* significantly weakened. Over two-thirds of the farmers were willing to leave their traditional agricultural practices in favour of the improved techniques, and to borrow money to invest in agricultural operations. Almost three-fourths of the farmers thought that only hard work could change their fate. An element of rationality could be observed from the fact that 87 per cent of the

respondents in the rural communities were of the opinion that it was better to send a sick person to a hospital where better treatment was possible. In the survey it was also observed that the marriages of the children were predominantly arranged by the parents and 87 per cent of the respondents supported this practice of arranged marriages. Over three-fourths of the marriages were of endogamous type. Most of the marriages were between the first or second cousins.

1.9.9 Nutritional habits. There was no significant change in the food habits of the common people which continued to be the same as for the pre-irrigation period. Their food continued to be simple and pure, which was the cause of their good physique and health.

1.10 Economy

1.10.1 Crops. Canal waters brought a revolution in the area and the results showed up almost immediately with an increase in the cultivated area in general and in the area under cash crops in particular. Sugarcane, cotton, orchards and fodder gained importance. Wheat, gram, bajra (millet), jowar (sorghum) etc., were the main food crops, while cotton, sugarcane, oilseeds, orchards were the cash crops. The most important crop in the area continued to be wheat which was the staple food crop in this area and could be grown on all sorts of lands. After canals were introduced, the area under sugarcane and orchards grew steadily. Area under fodders had also been increasing.

1.10.2 Cropped area, cropping pattern, cropping intensity and crop yields. There was an immediate increase in the area under cultivation after the introduction of canal system. According to the available statistics, the area under cultivation in Bhera which was about 74,500 ha during 189-94 increased to about 138,000 ha during 1909-14. The irrigation system also brought some changes in the cropping pattern of the pre-irrigation period. The cropping pattern in Bhera area in the pre-irrigation period and after is given in Table 16, which shows that cotton, oilseeds and grams gained acreage at the cost of millet and sorghum after the introduction of the irrigation system. The data of the district Sargodha also indicate that there was a gradual increase in the cropped area with time and there were changes in the cropping pattern. The area under sugarcane, orchards and fodders grew gradually. The area under oilseeds in the district also increased and rose to over 6 per cent in 1930-31. However, there was a marked decline in the area under this crop thereafter and it dropped down to about 2 per cent in 1955-56

This decrease was attributed to the sensitivity of the crop to salinity which had developed during this period.

Table 16: Cropping pattern in Bhera pre-irrigation and after

Crop	Percentage of total cropped area	
	1890-94	1909-14
wheat	43	43
cotton	6	10
oilseeds	4	8
grams	6	8
millet	17	8
sorghum	6	2
pulses	3	2
barley	2	1
other cereals	10	18

The cropped acreage in the district increased progressively with time. Table 17 gives the area under various crops in the case study area in 1965-66.

Table 17: Area under various crops in the case study area in 1965-66

Seasons/crops	Area in ha	Cropping intensity(%)
Kharif		
sugarcane	1,510	
cotton	6,263	
rice	1,182	
maize	1,261	
fodders	7,150	
orchards & vegetables	2,064	
miscellaneous	100	
TOTAL Kharif	19,530	45.9

Contd.

Table 17 (Contd.)

Seasons/crops	Area in ha	Cropping intensity(%)
Rabi		
wheat	9,960	
barley and oats	1,470	
pulses	494	
oilseeds	601	
fodders	6,213	
sugarcane	1,510	
gardens & vegetables	2,290	
miscellaneous	12	
TOTAL Rabi	22,550	53.1
Total area under Kharif and Rabi crops	42,080	99.0

According to the available information of the earlier period of canal irrigation, there was practically no systematic rotation of the crops. In contiguous areas of Mona, only 15-20 per cent of the cultivated area was left fallow throughout the year and about 60 per cent was put under Rabi crops and 20-25 per cent under Kharif. This meant that a large area was put under wheat year after year with an occasional change to oilseeds followed by cotton or fodder succeeded after a fallow by cotton. However, a common crop rotation was sorghum, or millet, fallow, wheat and so on. In 1965-66 the cropping intensity was about 100 per cent. The wheat yield per ha in the irrigated areas was 1100 kg compared with 550 kg in the pre-irrigation period in areas of dry farming. No improvement was registered in the barani (rainfed) areas. However, the yield of cotton decreased which may be due to lack of on-farm management practices and the appearance of waterlogging and salinity in the later period.

1.10.3 Livestock. According to the 1965-66 survey, livestock constituted a sizeable segment of the farm industry in the study area. Over two-fifths of the total farm cost was incurred on capital, feed and shelter for animals. Livestock

included both draught and milch animals, and amounted to 8 adult units per holding. A relatively large strength was maintained in the non-perennial area . This was necessitated by factors such as larger farm size, greater fragmentation, and the need to conserve moisture for the rabi crops. The strength of draught animals was smaller on the owner-cum-tenant farms, primarily due to the small size of those holdings. On other irrigation and tenure farms, the strength of draught animals was almost the same. The cost of draught animals amounted to 15 per cent of the total farm costs. The figure was slightly higher in the non-perennial area and on the owner-operated farms, due to the large number of livestock units and the fact that animals on these farms were generally high priced and well fed.

The number of adult units of buffaloes and cows per holding amounted to 4 and 0.6; those in milk averaged 1.9 and 0.3 respectively. Relatively large units of buffaloes were maintained in the non-perennial area and by the owner-operators, while cows were popular in the perennial area and with the tenants. The units of donkeys and horses amounted to 0.2 and 0.4 per holding respectively. The number of these animals was relatively high on the holdings of owner-operators; horses in particular were numerous in the uncommanded area. The number of sheep and goats was small, especially of the latter. Their total units came to 0.3 per holding. Sheep seemed to be more common in the perennial areas, and with the owner-cum-tenants and tenants.

1.10.4 Attitude regarding agricultural inputs. The adoption of agricultural innovations was slow in the case study area during the post-irrigation period. Some of the improved inputs like chemical fertilizers and biologically superior varieties of seeds were almost unheard of. The use of synthetic fertilizers in the area was introduced as late as the fifties. Initially the fertilizers were distributed free of charge and farmers were induced to make use of this important input through demonstration plots. In the beginning, the farmers were reluctant to use chemical fertilizers and change their centruees-old system, mainly due to illiteracy. Gradually, however, the farmers began to realize the benefits of the use of improved inputs, as, through demonstration, they themselves saw the advantages of the change in increased yields and consequently higher income.

1.10.5 *Per capita* income. No systematic socio-economic survey was carried out to determine *per capita* income before 1965. However, the general impression is that the most potent impact of the introduction of canal irrigation had been on

the prosperity of the people who were living a contented life in the study area. With the passage of time, unfortunately, the ill-effects of irrigation decreased productivity of the land and consequently the income of the people declined. According to a 1965 survey, most of the people in the study area were earning less than Rs. 5,000 per family *per annum*, which hardly made a satisfactory livelihood.

1.10.6 Marketing of agricultural products. During the detailed survey of 1965, it was found that five mandi (market) towns were serving the area. The marketing of various agricultural products was as follows:

Nearly 80 per cent of wheat production was retained at the farm; only 20 per cent was sold in the market. The survey showed that the monthly average prices of wheat did not exhibit marked seasonal variations. The market price was the lowest in April and the highest in December. The largest variation between the highest and the lowest price was 25 per cent, with an average variation of about 7 per cent.

Fresh harvest of gram became available a fortnight to a month earlier than wheat. Arrivals and price behaviour of gram were similar to that of wheat.

A fresh crop of rice was available by the end of September. During the following three months (October to December) about 60 per cent of the marketable surplus arrived in the market. Of this, about 36 per cent occurred during November alone. Arrivals then tapered off and were at their lowest level in June, with the only exception that one-fifth of the arrivals were observed during February. The average price varied from 5 to 57 per cent from the base price; this average variation being 31 per cent. Like wheat, in price too, the arrivals and price indices moved in opposite directions.

Maize was not an important crop of the area. The new harvest became available by November and started moving into the market in the same period. Over one-fifth of the marketable surplus was taken to market in December. In the following three months, the arrivals were almost the same being 9 to 10 per cent in each month with slight improvement in May and July. The rest of the period ranged between 2 and 5 per cent.

Gur (raw molasses) from new harvest became available from October to

December. The produce of gur from ratoon (subsequent) crop, which matures earlier by one to one and a half months as compared to the fresh one, started arriving in the market in October but the bulk (about 75 per cent) was received in the market from November to February. During these months, the arrivals were almost of the same order, except in December when they were slightly lower. Thereafter, the arrivals diminished drastically and revived only with the new crop.

New cotton was available by October, when it started moving in the market. The main rush, however, started from November and was over by January. During this span of three months, nine-tenths of the produce reached the marked for sale. Though prices in the harvest period were generally higher than those in the post-harvest period, they were at their lowest level when the arrivals were at their highest. Lack of demand in contrast to the arrivals was the chief reason for lower prices after harvest period.

1.10.7 Agro-based industries. The agro-based industries in the case study area existed as early as 1917, including flour milling, cotton ginning and presssing, rice husking, and oil pressing facilities. Rice husking and wheat flour mills were not independent and were attached to ginning factories. Of these industries, some were located within or at the periphery of the area. It may be noted that the number of agro-based industries went on increasing with the advent of canal irrigation in a way to keep, more or less, pace with the agricultural development and consequently the needs of farming community. According to the 1965 survey, there were about 17 cotton ginning factories, 9 rice husking/wheat flour mills and 7 oil expellers either within or at the periphery of the area.

2. IRRIGATION PERIOD - POST-REHABILITATION PROJECT

2.1 Mona Reclamation Experimental Project - objectives and measures

The main objectives of the Mona Reclamation Experimental Project (MREP), the case study area, was to derive information from operation research adaptable to the areas being developed under Salinity Control and Reclamation Projects (SCARP) in the irrigated areas of the Indus Plains. The following research and investigations were proposed at the time of planning:

(a) Developing methods and procedures to achieve effective use of water and land, the reclamation of saline land and agricultural development;

(b) detailed groundwater hydrologic studies;

(c) tubewell operation, maintenance, rehabilitation and replacement;

(d) management of water supplies;

(e) determining optimum cropping input-output relationships; and,

(f) transferring and inducing knowledge to farmers.

Before initiating the program of research, an intensive socio-economic survey of the area, in cooperation with the Deparment of Agricultural Economics and Rural Sociology of the University of Agriculture, Lyallpur, was carried out in 1965. An evaluation of the hydrologic factors and the groundwater quality was also carried out and the installation of observation pipes, water stage recorders and rain gauge stations was completed. Since 1973, research studies in the field of water management are being carried out in cooperation with advisers from Colorado State University, U.S.A.

The research work in the Project activity started during 1966-67 with the development of laboratory facilities for soil, water and plant analyses. The principal areas of research and objectives are reported in the following paragraphs.

2.1.1 Hydrology and tubewells. The principal objectives of research in these fields are to provide data and interpretation thereof necessary to ensure effective management and operation of the project by:

(a) supressing the water table to sufficient depth, so as not to interfere with plant growth nor contribute harmful concentrations of salts to the root zone of the crops by evaporation;

(b) providing sufficient supplementary irrigation supplies to satisfy leaching and consumptive use requirements; and,

(c) achieving operation and maintenance of the tubewell system at minimum possible cost, and studying the factors involved in maintaining a favourable salt balance.

To achieve the objectives, the hydrologic changes in the project and the performance of tubewells are being continually monitored. An electric analog model of the project has also been made to evaluate fully the hydrologic system.

2.1.2 Water management. Efficient management of water of varied chemical composition is a vital factor in agriculture. The present water management practices being inefficient, the main objectives of research are:

(a) development and testing of materials and methods for watercourse rehabilitation and the feasibility of their adoption in Pakistan;

(b) measurement and evaluation of the effects of improved water management practices;

(c) evaluation of the seepage and other losses from existing and improved water course systems;

(d) demonstration plots for improved water management practices and water course system;

(e) development of a complete water management technology which is acceptable from social and economic viewpoints; and

(f) preparation of manuals, literature and extension aids for the management of soil, water and crop based on the findings.

2.1.3 Soils and reclamation. The main objectives are:

(a) determination of the most effective methods for reclamation of saline-sodic soils; and

(b) promotion of the application of proven methods of reclamation among the farmers.

2.1.4 Agro-physiology (agronomy). The basic objective is to develop methods of effective land and water use for more efficient crop production. The studies include a number of experiments on some of the crops like cotton, rice, wheat,

maize, etc. in order to obtain information with regard to: (a) best variety; (b) optimum time of sowing; and (c) increase in yields by various combinations of nitrogen, phosphorous and potassium (NPK) to the soil, different seed treatments, fertilizer and different spacings between rows and depths of sowing, with particular reference to the quality of irrigation waters and the irrigation practices.

2.1.5 Agricultural economics. The various studies that have been taken up and are proposed to cover the areas of: (a) resource development; (b) water use efficiency; (c) input-output relationship; (d) enterprise selection; (e) capital formation and investment; (f) labour utilization; (g) agricultural development; (h) agricultural marketing; and (i) cooperation and credit.

2.1.6 Agricultural extension. The objectives in this direction are:

(a) development of the most rapid and efficient means of transferring technical knowledge to the cultivators; and

(b) designing workable mechanisms and organizational arrangement for providing cultivators with requisites of production and other supporting inducements for agricultural change.

The long-term objectives are the establishment of confidence among farmers in market-oriented production as a means for increased satisfaction of wants and bringing farm leadership to bear on local problems and providing media for concerted action by villagers in the interest of agricultural reformation and improved living conditions. Various extension approaches are being followed which will be evaluated, along with a study of the personal and situational factors impeding the adoption of improved agricultural practices.

2.2 Soils

The textural classification of the soils in the case study area is illustrated in Fig. 9. The percentage of each surface salinity class as mapped at the start of the project operations and during the latest survey carried out by Central Monitoring Organization of Water and Power Development Authority are depicted in Fig. 19 and given in Table 18.

Figure 19 SOIL SALINITY PRESENT STATUS

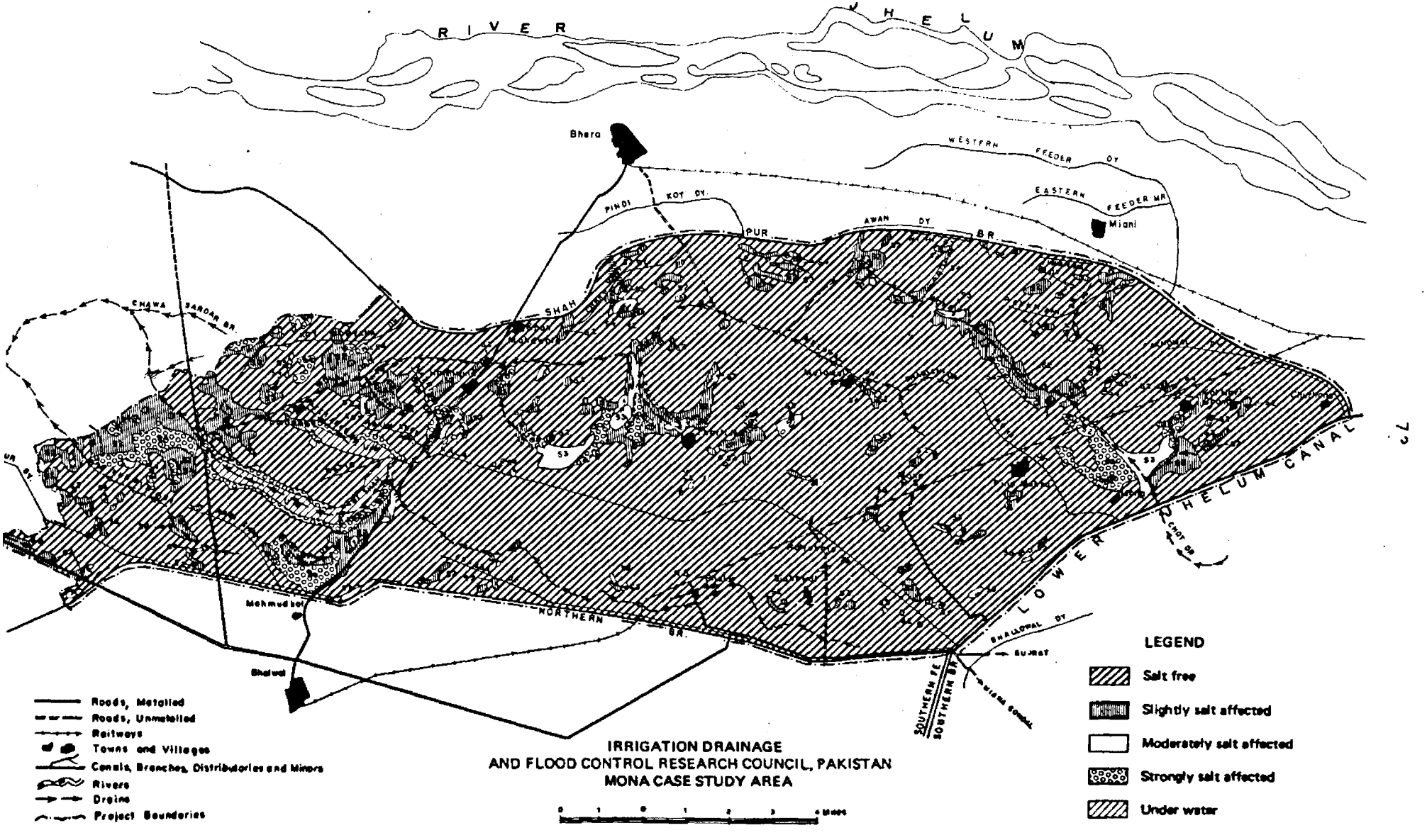


Table 18: Proportionate extent of different categories of surface salinity in Mona project

Surface salinity class	Percent	
	Base year	Percent
salt free area	80.6	84.5
slightly salt affected area	8.1	7.7
moderately salt affected area	2.1	1.8
strongly salt affected area	6.6	3.4
miscellaneous	2.6	2.6

This shows that about 85 per cent of the area is free from harmful salt accumulation and the increase in this category over the base year has been the result of reclamation of salt affected area, in particular the decline in the strongly salt affected area. The reclamation of salt affected soils was achieved by the simple process of leaching and growing of suitable crops. For improving fertility of soils, farm-yard manure and chemical fertilizers had been applied, which gave favourable results.

2.3 Water regime

The Project tubewells started pumping in 1965 to control waterlogging and to supply additional irrigation water. This imposition of new discharge source on the groundwater reservoir changed the then existing hydrologic balance and the water table began declining gradually. As a result of continuous tube-well operation over the past years the water table has gone down by 0.9 to 1.8 m and now stabilised over most of the area. The monitoring studies of tubewell waters have shown minor deterioration in water quality. Tubewell performance studies have shown that discharge and specific capacities of wells have decreased, showing that the wells have started deteriorating; corrosion and incrustation was considered as one of the causes.

2.4 Climate

No significant change in the climate has been observed in the period since the rehabilitation project went into operation.

2.5 Population

The population of the case study area continued rising with more people turning towards agriculture and greater check on epidemics and diseases. This resulted in the increase in the pressure on land. In 1972 the population was already about 173,000 and the man-land ratio about 0.26 ha per person; the density of population was about 174 persons per km^2.

2.5.1 Migration. The increase in the village communication networks has resulted in greater mobility of the population. The urbanisation and industrialisation around the case study area has intensified the process of migration out of villages. It was observed from a recent limited survey of a few selected villages that during the period 1966-76, out-migration from the village was nine times more than inwards; a total of 229 people went out of the sampled villages during this period. The installation of heavy industries in the vicinity of the area has absorbed some of the surplus agricultural labour. Some people from the rural community have even gone abroad for employment. However, the outward migration to urban areas has been off-set by the inflow of the people from other areas. Those who have migrated, from the rural communities were mostly the landless tenants or the various categories of artisans.

It was noted that no large scale migration due to desertification has taken place and before such a situation was to reach, the problem of salinization and waterlogging was arrested and brought under control by the implementation of Salinity Control and Reclamation Project (SCARP) in the area.

2.5.2 Fertility and mortality patterns. No recent estimates of fertility and mortality patterns are available for the case study area. However, the country-wise 1976 estimates are 44 births as against 15 deaths per thousand *per annum*.

2.5.3 Health. No case of smallpox has been reported since October 1974. This is entirely due to intensified mass primary vaccination and ultimate adoption of high degree of preventive measures. The cultivation of rice has led to the breed-

ing of mosquitoes in the area which increased the incidence of malaria. By and large epidemics have been controlled and infantile mortality has been reduced considerably. Sanitary conditions in this area have improved although they are still far from satisfactory. No new hospitals have come up in the area but the facilities in the existing hospitals have expanded. New rural health schemes are expected to come up in the area in the context of overall rural development programs.

2.5.4 Ways of life. Still about 70 per cent of the people are directly engaged in agriculture. Although there have been changes in the ways of life of the people in the study area due to change in their outlook, food habits and increase in living standards, no assessment has been made to evaluate the extent of these changes since the last decade.

2.5.5 Education. The inhabitants of the study area have gradually become aware that education is not a wasteful expenditure but rather an investment for fortune. According to the 1976 survey there are two high schools for boys and one high school for girs, and eight middle schools for boys and one for girls. In addition, there are about 60 primary schools for boys and about 22 for the girls. During the last few years considerable emphasis has been laid on universal education and the Government is trying to provide at least one primary school each for boys and girls separately, at every village level; the primary education is free as elsewhere in the country. In spite of the expansion in educational facilities and the awareness among the people, the literacy figures are still low in the study area.

2.5.6 Family structure. The family structure continued to be patriarchal, patri-local and patri-lineal, although more consideration is now being given to the views of the youngsters. No specific survey has, however, been carried out to evaluate the extent of changes.

2.5.7 Nutritional habits. A decade back the people in the area were accustomed to using pure ghee (butter oil) as cooking medium, but due to the rising cost, a vast majority of the people have now turned to vegetable ghee (vegetable oil). However, with more income due to semi-commercialization of agriculture, the quality of their diet has improved with more proteins and fruit. No specific survey has been carried on this aspect, but this general trend is evident.

2.6 Economy

The rehabilitation project had the desired impact on the economy of the case study area. With the installation of tubewells, the problem of waterlogging and soil salinization has been arrested. The additional water provided by the tubewells encouraged crops which require more water. The area under wheat, rice, maize, sugarcane orchards has proportionately increased while the area under cotton, bajra (millet) etc. decreased. The land utilization pattern has improved. In 1965-66 the area sown more than once was 14 per cent of the total farm area which rose to about 30 per cent in 1970-71. The cropping intensities also increased from about 100 per cent to nearly 130 per cent. The rotation of crops has become more pragmatic. Now wheat does not follow year after year, but it is rotated with crops like sugarcane, cotton, rice, etc. Marketing facilities have improved. The value of livestock increased from Rs. 10 million in 1965-66 to about Rs. 17 million in 1975-76. The values of crops have also risen two-fold in the same period.

2.6.1 Type of crops. The main food and cash crops in the study area are wheat, fodder, cotton, orchards, sugarcane, rice, vegetables, maize and barley. During the post-rehabilitation project period, crops like sugarcane, fodders, orchards, rice and maize have gained prominence over such crops as grams, bajra (millet), jowar (sorghum), poppy etc.

2.6.2 Cropped area, cropping patern, cropping intensity and crop yields. The crop acreage in the area progressively increased. The total cropped area during 1975-76 under perennial, non-perennial and uncommanded conditions, as given in Table 19, was 52,297 ha. This shows an increase of 10,215 cropped ha since the inception of the rehabilitation project in 1965-66.

The cropping pattern during 1965-66 and 5 years after is given in Table 20 under both with and without project conditions. A comparison of the corresponding figures reveals that the cropped area under wheat, rice, maize, sugarcane and orchard has proportionately increased while the area under cotton and miscellaneous other crops decreased. The reclamation efforts in the case study area have paid dividend. The land utilization pattern has also improved as indicated below:

Farm area	Percent of farm area in	
	1965-66	1970-71
cultivated	97.00	98.54
area sown more than	14.00	29.78

The cropping intensities in the area have also progressively increased. When reclamation activities were started in 1965-66, the cropping intensity was about 100 per cent. This rose gradually to about 127 per cent in 1972-73, as illustrated in Fig. 20. This trend was also observed in subsequent years.

The yields of crops like wheat, sugarcane, cotton, rice etc. have gone up but are still lower as compared to many irrigated areas of the world. One of the important causes of low yields is the imbalance in agricultural inputs, meaning that, if all the factors of crop production are optmised in balancing the interaction of inputs, crop fields will increase many times more than what could be obtained otherwise. However, the value of crops has risen two-fold since 1965-66. The yields of selected crops at various time intervals in the case study area are shown in Table 21 and Fig. 21, and the gross value of crops is given in Table 22.

2.6.3 Livestock. Cows, buffaloes and horses have continued to receive importance in the post-rehabilitation period. One of the best horse breeding sites is located within the case study area. Too frequent outbreak of contagious diseases in the cattle has been checked to a great extent through government efforts. The gross value of livestock in 1975-76, according to an estimate, was about Rs. 17 million compared to Rs. 10 million in 1965-66.

Table 19: Crop areas in the case study area, 1975-76 (ha)

Crops	Overall project		Perennial		Non-perennial		Uncommanded	
	Area	Percentage	Area	Percentage	Area	Percentage	Area	Percentage
Sugarcane	2,786	6.75	1,961	6.76	527	7.17	276	5.48
Rice	1,618	3.92	1,111	3.84	417	5.68	89	1.87
Cotton	5,439	13.17	3,974	13.75	815	11.09	650	12.91
Maize (F)	1,244	3.01	829	2.87	304	4.15	110	2.19
Fodder	7,794	18.88	5,484	18.97	1,211	16.48	1,099	21.81
Garden and vegetable	2,777	6.73	2,431	8.41	196	2.62	150	2.97
Miscellaneous	1,406	3.41	644	0.24	199	2.71	563	11.17
Total kharif	23,064	55.67	16,435	54.84	3,669	49.95	2,937	58.40
Wheat	13,254	32.10	9,060	31.34	2,384	32.46	1,826	38.25
Barley	2,004	4.85	1,735	6.00	174	2.37	96	1.90
Pulses	191	0.46	106	0.37	62	0.84	23	0.46
Oilseed	598	1.45	310	1.07	136	1.85	152	3.02
Fodder	6,907	16.73	4,626	16.00	1,304	17.76	977	19.39
Sugarcane	3,595	6.75	1,961	6.76	527	7.17	276	5.48
Garden and vegetable	3,105	7.52	2,796	9.67	219	2.98	293	1.80
Miscellaneous	386	0.94	70	0.25	-	-	314	6.24
Total rabi	29,233	70.80	20,666	71.46	4,806	65.43	3,755	74.54
Grand total	52,298	126.67	37,102	126.30	8,475	115.38	6,692	132.94
				Perennial		Non-perennial		Uncommanded
				28,907		7,345		5,038

Table 20: Cropping pattern in the case study area (percent)

Crops	1965-66 Base year	1970-71 without project	1970-71 with project
	cropped area	cropped area	cropped area
Food grains			
wheat	35.86	40.79	42.54
bajra	1.85	3.52	1.75
rice	1.39	3.26	4.48
maize	0.88	2.90	6.92
Total	39.98	50.47	55.69
Cash crops			
American cotton	21.92	9.07	9.78
Desi cotton	1.00	0.21	0.20
sugarcane	4.24	8.07	8.70
garden	4.20	6.83	8.67
mehndi (*Lawsonia inermis*)	0.67	0.89	1.37
vegetables	0.23	0.14	0.19
tobacco	0.12	0.15	0.18
oilseeds	0.12	0.55	1.43
Total	32.50	25.91	30.52
Pulses			
grams	0.31	0.74	0.59
other pulses	0.30	0.24	0.26
Total	0.61	0.98	0.85
Fodders			
Kharif	21.21	18.99	24.62
Rabi	16.51	17.37	16.69
Total	37.72	36.36	41.31
Annual total	110.81	113.72	128.38

Figure 20: CROPPING INTENSITY AND CROPPING PATTERN IN THE CASE STUDY AREA

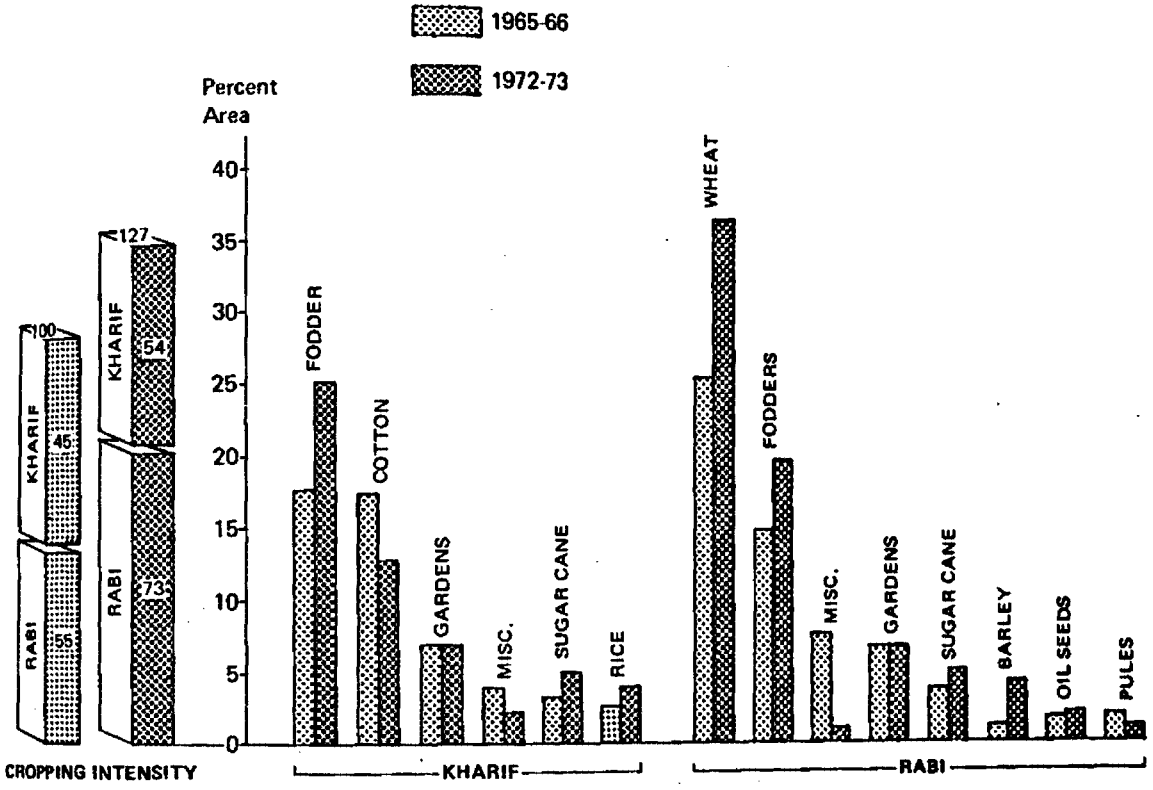
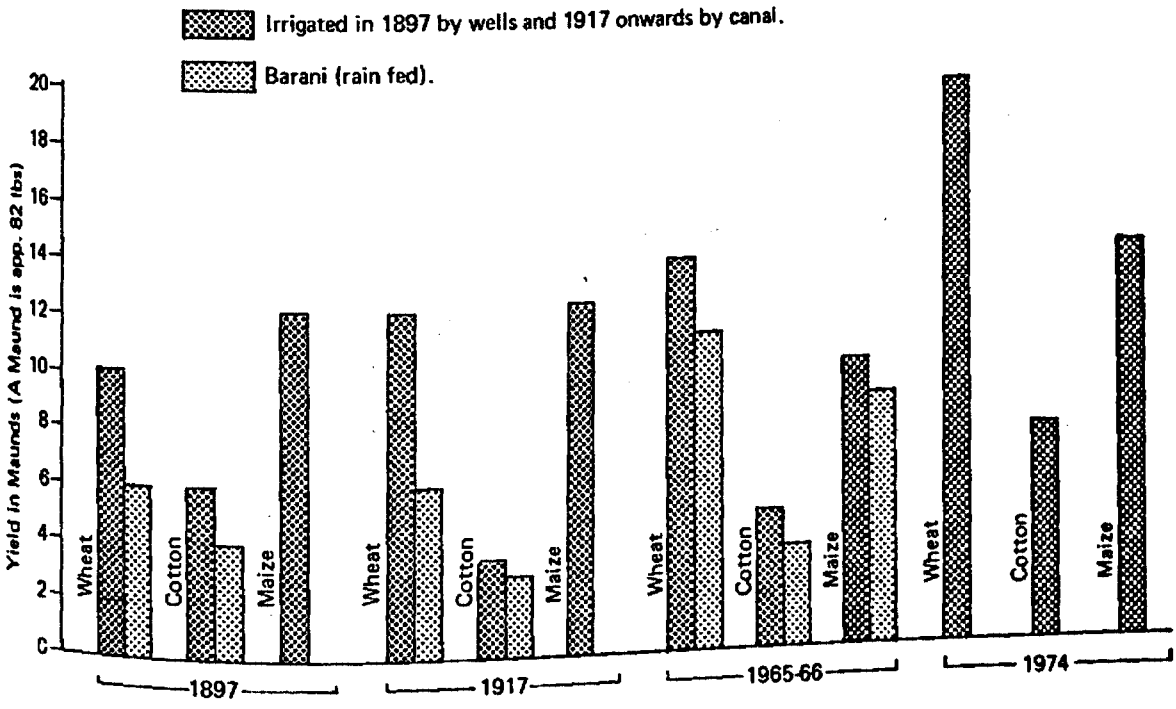


Figure 21: YIELD OF SELECTED CROPS AT VARIOUS TIME INTERVALS IN THE STUDY AREA



Source: District gazetters, man, water and economy and Mona reclamation experimental project reports.

Table 21: Yield of selected crops at various time intervals (yield in kg/ha)

Land type	Year	Wheat	Cotton	Maize
irrigated (wells)	1897	922	553	1,106
barani (rainfed)	1897	553	369	-
irrigated (canal)	1917	1,106	323	1,106
barani (rainfed)	1917	553	230	-
irrigated	1965-66	1,272	424	949
barani (rainfed)	1965-66	1,023	341	802
irrigated	1974	1,843	710	1,355
irrigated	1975-76	2,645	737	not available

Source: District Gazetteers, Man. Water and Economy and Mona Reclamation Experimental Project Reports.

Table 22: Gross value of crops/livestock in 1965-66 and 1975-76 in the case study area (in Rupees)

	Perennial	Non-perennial	Uncommanded	Total
	1965-66			
Crops	18,332,201	3,498,225	1,521,151	23,351,577
Livestock	7,785,870	1,070,850	1,170,300	10,027,020
Total	26,118,071	4,569,075	2,691,415	33,378,597
	1975-76			
Crops	33,158,366	7,572,368	5,512,333	46,243,067
Livestock	11,785,950	2,994,750	2,054,250	16,834,950
Total	44,944,316	10,567,118	7,566,583	51,078,017

2.6.4 Attitude regarding agricultural inputs. In traditional rural communities, where instead of scientific rationality, folklore and superstitions dominate, the introduction and adoption of agricultural innovations is an intricate problem. The rural people are reluctant to adopt farm innovations unless they see a clear substantial and unequivocal return from them. The installation of public tube-wells had clearly demonstrated that with land and drainage and additional supply of water, the net farm income was almost doubled. The transistor radio has also played an important role in creating awareness about new innovations in agriculture. A decade ago less than one-third (31 per cent) of the farmers were using chemical fertilizer and more than two-thirds of them did not know about the availability of improved seeds. In 1976, about 95 per cent farmers were using chemical fertilizers and over 90 per cent used improved seeds of wheat. A critical difference has been made by irrigation water and proper drainage conditions as all dwarf and early maturing varieties need more water, besides other inputs. The adoption of the new innovations on the whole was higher on the perennial irrigated farms than on non-perennial farms. The adoption of improved varieties of crops in the area has been steadily rising and was higher than in adjacent areas. This is reflected in Table 23.

Table 23: Adoption of improved varieties of crops in the case study area

Types of farms	Cotton		Sugarcane		Rice		Wheat	
	Imp.	Unimp.	Imp.	Unimp.	Imp.	Unimp.	Imp.	Unimp.
Perennial								
base year (1965-66)	-	100	40	60	75	25	5	95
adjacent areas	16	84	83	17	84	16	82	18
case study area (1975-76)	33	67	74	26	93	7	90	10
Non-perennial								
base year	-	100	37	63	28	72	5	95
adjacent areas	17	83	91	9	87	13	76	24
case study area (1975-76)	21	79	76	24	87	13	86	14
Uncommanded								
base year	1	99	17	73	46	54	10	90
adjacent areas	9	91	81	19	85	15	76	24
case study area (1975-76)	19	81	75	25	81	19	88	12

Imp. = improved Unimp. = unimproved

2.6.5 Marketing of agricultural products. Marketing facilities for selling surplus produce have been greatly improved and the area is now well linked with important markets by rail and road.

2.6.6 Agro-based industries. Since the inception of drainage and reclamation scheme some major industries have been established in the vicinity of the area which have absorbed considerable extent of surplus agricultural labour (see Fig. 18). The notable ones are sugar mills, dairy plant and textile mills. More rice husking/wheat flour mills etc., have also been set up either within or at the periphery of the study area.

2.6.7 Income analysis. In the case study area it was observed that net farm income *per annum* for a 5 ha owner-operated farm was Rs. 1,974 without tubewell and Rs. 3,654 with tubewell, whereas, for a 10 ha owner-operated farm, it was Rs. 3,792 without tubewell and Rs. 7,741 with tubewell. The gross annual income per cultivated acre in the area in 1973-74 was Rs. 652 as compared to Rs. 369 in 1965-66. The net income and the *per capita* income has also gone up; the net income per cultivated ha was Rs. 949 and Rs. 502 on tractor operated and non-tractor farms respectively. The annual benefits from rehabilitation project in the area came to Rs. 6.30 million when discounted at 6 per cent interest against the annual costs of Rs. 2.59 million, showing a benefit cost ration of 2.43:1 and at 8 per cent discount rate benefits and costs, came to Rs. 5.78 million and Rs. 2.57 million respectively giving a ratio of 2.25:1.

2.6.8 Conclusion. It is evident from the above discussion that drainage and water development technology has made a critical difference in the economy of the case study area. Land utilization has improved, cropping intensity has gone up, the adoption of improved innovations has been hastened, net returns to the farmers have increased, thus making a substantial contribution to the welfare of the area; making it a demonstration model for other developing rural areas of the country.

3. LAND TENURE, HOLDINGS

3.1 Tenure system, number and size of holdings

In pre-irrigation period various types of estates, i.e. areas for which a separate record of rights had been made, were held in the joint zamindari, pattidari and bhaiyachara tenures; the prevalent tenure was the bhaiyachara where the extent of possession was the measure of each man's rights. After the introduction of irrigation the joint rights of ownership in land were separated. The restoration of individual ownership rights in land encouraged farmers to develop their land faster and the standard of cultivation went up to a certain extent. For the district of Sargodha, as a whole, it appears that 39 per cent of the cultivation was done by the owners or grantees themselves, 2.3 per cent by the occupancy tenants, 58 per cent by the tenants-at-will; while the remaining (less than one per cent) were the squatters.

The defective land tenure system, highly biased in favour of landlords, persisted for many generations and created over worked, under paid and oppressed peasantry, along with an opulent, lazy and parasitic class of landlords.

In 1965-66, in the case study area, three tenurial classes existed, i.e. owner-operators, owner-cum-tenants and tenants. Under owner-operators or peasant-proprietors, farm land is cultivated by the owner himself, with the help from family members or hired labour. The owner-operators are natives, settlers, as well as refugees. The natives are the original inhabitants of the area, and hold right of ownership to the land since times immemorial. Their forefathers held large pieces of land, which had been sub-divided continuously amongst the heirs, generation after generation. The settlers were given title to the land at the advent of canal irrigation in the area, and a 2-square (20 ha) holding was granted to each of them, with the condition that a mare would be maintained on it for the supply of horses to the cavalry. The settler holdings were also reduced in size due to sub-division. Owing to sub-division, sale or purchase of land, the holdings of the settlers were no longer uniform in size. The refugees were allotted the evacuee land on the basis of their landed property in India on the eve of Independence in 1947. The size of these holdings also varies considerably.

The owner-operators were an important class of cultivators of the area, as

they constituted 42 per cent of the total cultivators and operated 43 per cent of the farm area. Nearly 56 per cent of them were concentrated in the perennial and 12 per cent in the non-perennial areas. The remainder were met within the uncommanded areas. On the whole, more than half of these cultivators had land holdings below the subsistance level.

The survey in 1965-66 revealed that very few cultivators liked to be tenants when they had land of their own. Though as many as 50 per cent of the owner-operators held operational units below the subsistance level, they did not like to have additional land on rent. Again, only about one-fifth of the cultivators were owner-cum-tenants, operating about 17 per cent of the total farm area. As many as 37 per cent of the cultivators in the case study area were tenants, a landless class depending directly on cultivators of land for their livelihood. They operated 40 per cent of the total farm area.

In all 1,211 cultivation units, ranging from less than 0.4 ha to about 35 ha, were recorded, and 229 different sizes of holding were observed during the survey. The average size of holding by tenure and irrigation is given in Table 24. As may be seen from this table, the average size of holding was about 5.7 ha, which compares well with the average size of holding in the Sargodha district which was 5.4 ha. The distribution of land holding by size, type of irrigation, and land tenure is given in Table 25, which indicates that a number of small holdings were disconcertingly high in proportion to their share in the cultivated area. This distribution of holdings was analogous to that of the Sargodha district, especially in the larger size groups. On the district level, 36 per cent of the holdings were under 2 ha, 65 per cent under 5 ha, and 87 per cent under 10 ha. Of the 12 per cent of the holdings in 10 ha or more, only 2 per cent were of economic size.

There was no direct impact on land tenure due to the project, as its changes are subject to legislation for larger areas than involved in the project. Substantial changes have taken place in the land tenurial and inheritance patterns in the area since the introduction of canal irrigation. The most spectacular change has been that the joint estates which were held with communal rights or on the pattidari or bhaiyachara tenure were given to individual owners. The whole system of land revenue was re-examined and was made realistic while keeping in view the paying capacity of the farmers. The individual ownership of land encouraged owner-operators

Table 24: Average size of holdings by tenure and irrigation

Irrigation type	Owner-operators			Owner-cum-tenants			Tenants			Total		
	Nº of holdings	Acreage	Average size of holdings (ha)	Nº of holdings	Acreage	Average size of holdings (ha)	Nº of holdings	Acreage	Average size of holdings (ha)	Nº of holdings	Acreage	Average size of holdings (ha)
Perennial	279	1,708	6.1	93	411	4.4	257	1,348	5.3	629	3,467	5.5
Non-perennial	61	355	5.9	22	132	6.0	62	481	7.8	145	972	6.7
Uncommanded	162	895	5.5	141	598	4.2	134	919	6.9	437	2,413	5.5
All farms	502	2,958	5.9	256	1,141	4.5	453	2,748	6.1	1,211	6,852	5.7

Table 25: Distribution of land holdings by size, type of irrigation, and tenure

Type of farm	total holdings	Farm size in acres				
		up to 6.25	6.25-12.5	12.5-18.75	18.75-25	over 25
		Percent of total holdings				
All farms	1,211	17.8	39.5	21.5	8.9	12.3
Irrigation type						
perennial	629	20.0	37.0	23.4	7.5	12.1
non-perennial	145	6.2	48.3	16.6	8.3	20.3
uncommanded	437	18.5	40.0	20.4	11.2	9.9
Tenure type						
owner-operators	502	22.7	31.9	21.2	9.8	14.5
owner-cum-tenants	256	19.5	53.5	17.2	6.3	3.5
tenants	453	11.5	40.0	24.3	9.5	14.8

to make independent decisions and subsequently the gradual process for the development of agriculture had started. This in a way had increased the risk taking potential of the farmers. After the start of canal irrigation, the tenants with occupancy rights on land were given titles to such lands. Moreover, the rights of tenants-at-will were given due to protection and several laws were enacted. The last ones were introduced in 1972 and 1977, which fully protected the rights of tenants. The ejectment of tenants by the land owners is not at will now.

3.2 Fragmentation

In the case study area over 57 per cent of holdings, constituting about an equal proportion of the farm area were found to be fragmented in 1965-66. The problem of fragmentation was most serious with owner-cum-tenants, with 92 per cent of the holdings, and 90 per cent of the area fragmented. The size of individual

fragments ranged from less than 0.4 ha to over 10 ha; the average size in the case study area was 1.5 ha. About 65 per cent of the fragmented pieces of land were situated within a radius of half a mile from the main operational fragment. In the case study area, 47 per cent of the fragmentation was due to inheritance. As time pass s, there is going to be further sub-division of land, hence, more fragmentation. To minimize scatteredness, several years ago the Government launched a massive scheme for the consolidation of holdings in each village. The subsistence holdings of 5 ha given to the tenants after the Land Reforms, cannot be sub-divided any further.

3.2.1 Inheritance customs. During the pre-irrigation period and after, the inheritance customs remained the same. Ordinarily the whole family remained together until the father's death, with the property under his control. After his death the whole of the father's estate devolved on the sons, who sometimes continued to live as a joint family, but more often made a division among them of the moveable property and dwelling-houses, and either then or afterwards, divided the land also. All the sons took equal share. If one of the sons had died before his father, his sons or widow took his share of the estate by representation. The daughters generally got no share of the property; they were maintained by the family until marriage. The widowed mother did not get a share of the estate, and was looked after by her sons. In case the estate was divided, a portion was usually set apart for their mother's maintenance during her lifetime. Where there were no sons, or grandsons the whole of the estate devolved on the widow; two or more sonless widows taking equal share. The widow held the whole estate until her death or re-marriage, and had power to make all ordinary arrangements for its management and to enjoy the whole of its produce. Generally she could do as she pleased with the moveable property, but could not alienate the immoveable property without the consent of the husband's agnates.

After the creation of Pakistan in 1947, the Islamic Law of Inheritance was introduced. According to this Law, after the death of a person, his property is divided among his sons, daughters and widow. The property is divided among all the heirs in such a way that every son gets double the share of a daughter or the widow.

3.3 Renting practices

The most popular renting practice according to 1965-66 survey was that of batai (share-cropping). If the owner-cum-tenants and tenants are classified with regard to renting system in vogue, the following categories would emerge:

The batai tenants or share-croppers under the batai system paid, in almost all cases, 50 per cent of the produce to the landlords, the majority of whom shared the costs of land revenue, water rates, and seeds. Some landlords paid the entire bill of land revenue and taxes; while the tenants bore the remaining costs. The share-croppers were by far the most important class, forming 89 per cent of the cultivators taking land on rent. About 95 per cent of the tenants had taken land on batai, as compared to 79 per cent of owner-cum tenants holding lands on crop-share basis.

Cash and batai tenants who were about 4 per cent of the cultivators had more than one landlord, and were paying crop-share to some and cash to others. Only 2 per cent of the tenants, as compared to 8 per cent of the owner-cum-tenants, had more than one landlord, with batai terms with some and cash terms with others.

The cash-tenants were only 7 per cent of the cultivators tilling rented land on fixed cash terms. Relatively speaking, a large number of owner-cum-tenants (13 per cent) had taken land on fixed cash rent basis, as compared to the cash rent tenants (3 per cent), mainly because the former were in a better position to assume risks than the latter.

While realizing the oppressed conditions of the tenants and for embedding the idea of social justice in the agricultural economy of Pakistan, the Government introduced land reforms in the country in 1972. According to these reforms, the rights of tenants are protected by the following provisions:

(a) A tenant shall not be ejected from his tenancy unless it is established in a Revenue Court that he has - (1) failed to pay the rent in accordance with the terms of his tenancy; or (2) used the land comprised in the tenancy in a matter which renders in unfit for the purposes for which he held it; or (3) failed to cultivate or for the cultivation of the land comprised in the tenancy in accordance with the terms thereof, or if there are no express terms in this behalf, in accordance with the customary manner of cultivation in the locality; or (4) sub-let his tenancy.

(b) The crop grown at any time during Rabi 1971-72 on any land comprised in a tenancy shall, on its maturing, be apportioned between the tenant and the landlord in accordance with the law for the time being in force.

(c) As from Kharif 1972 - (1) land revenue and other taxes, cesses, surcharges and levies on land shall be payable by the owner; (2) the liability for payment of water-rate, and providing seed for any land shall be that of the owner or other person in possession thereof, other than the tenant; (3) the cost of fertilizers and pesticides required for the land comprised in a tenancy shall be shared equally between the owner and the tenant; (4) subject to the other provisions of this Regulation, a tenant shall have the first right of pre-emption in respect of the land comprised in his tenancy.

(d) No owner or person in possession of any land shall levy any cess on, or take any free labour from, any of his tenants.

These reforms have further been augmented in January 1977.

4. EVOLUTION OF ADMINISTRATIVE STRUCTURE RESEARCH AND AGRICULTURAL EXTENSION

4.1 Administrative Structure

Pakistan has a long and rich experience in public administration; it is centuries old. The present administrative structure dates back to the days of Akbar, the great Mughal Emperor who had introduced sweeping reforms in the country and evolved methodology for the assessment and collection of land revenue. There was at that time the concept of career service and a system of personnel classification. The empire was divided into provinces, divisions and districts and there was emphasis on village administration which centered around headman, accountant and watchman. This pattern continues to persist even today with modifications made by the British Colonists to suit their needs. The present structure of government to reach down to the villages and the tillers is an adaptation of the structure in the British regime. Of course, there have been substantial changes in the whole set-up since independence, as the result of many a revolutionary reform introduced in the country to meet the needs of the changing times.

In the present pattern of government the centre is assigned special responsibilities of policy-making and in planning and financing of major development projects, and in the provincial governments are associated with the execution of the programmes. The Planning Commission and the National Economic Council have the responsibilities of preparing and reviewing the Five Year Plans and the Annual Development Programmes, which include the drainage and reclamation works. In the water sector, in which drainage and reclamation works have been included, the Water and Power Development Authority (WAPDA), under the Federal Ministry of Fuel, Power and Natural Resources, has direct responsibilities of planning and construction of development projects on a unified and multipurpose basis and the provincial departments of Irrigation and Power are responsible for operation and maintenance of the projects. The responsibilities of Water and Power Development Authority in the drainage and reclamation fields include groundwater and soil investigations, planning of land drainage projects and reclamation. After the construction of the projects, the execution, operation and maintenance responsibilities are transferred to the provincial irrigation departments which are headed by a Secretary of the Department assisted by regional chief engineers,

superintending engineers, executive engineers, sub-divisional officers, sub-engineers, zilladars and patwaris. These departments have a Reclamation Directorate under them.

The activities in the case study area are spread under two main heads: (i) operation and management of tubewells; and (ii) research and investigation Ordinarily, the operation and management of the tubewells in a Salinity Control and Reclamation Project area is the responsibility of provincial departments but because of research activities in the case study area, the operation and management along with necessary funds is with the project. In the project, water distribution, reclamation, extension research and experimentation have been centralized to achieve results of co-ordinated research. Apart from project staffing services specialists in disciplines, especially the socio-economic aspect, have been hired from Agricultural University, Lyallpur (Pakistan). Under another agreement a team of scientists from Colorado State University (United States of America) are collaborating in a research programme of farm water management studies. The present administrative set-up is reported in Appendix XIII.

4.2 Research

In order to achieve ever increasing agricultural productivity for keeping pace with the population growth, agriculture in Pakistan was required to be put on road to continuous growth. The key for this was research and application of results in field. In Pakistan, the Department of Agriculture was carrying out conventional research but no attention was paid to the much-needed applied research for rehabilitation measures to combat the problem of waterlogging and salinization in the irrigated areas.

Recognizing the great need of applied research and investigation for rehabilitation measures to combat the problem of waterlogging and salinization, the research programme in Mona Reclamation Experimental Project was conceived. To start with, the scope of work proposed in the project included monitoring of tubewell performance and groundwater quality and water table behaviour; and research studies in the fields of hydrology, soils and reclamation, agronomy and agricultural economics. Although overall research proposed was to be initiated in 1965, the gateway for intensified work opened in 1967 when approval from the National Economic Council was granted. Prior to initiating the actual programme

of research and investigation a bench mark assessment of pre-project conditions like socio-economic survey, hydrology and groundwater quality status, were determined for evaluation of results in days to come. As the programme of research investigations progressed, long range studies in all the related disciplines of agriculture were incorporated. In the early seventies the entire programme of research was brought on highly specialized footings. Keeping in view the observations made, the results achieved and the inferences drawn, the soil and water management programme was introduced for increasing crop production through better techniques and optimization in agricultural inputs. Of late, great emphasis has been placed on improvement of water management practices. At present the research activity in the project is at full swing and the findings are being made available for practical utilization in the fields.

4.3 Agricultural Extension

Agricultural extension is the bridge and the direct point of contact between provincial departments of Agriculture, the research organizations and the farmers. The available evidence, however, indicates that with some exception, this contact was generally of limited effectiveness. The reason was partly due to the general recruitment problem and administrative set-up. Added to these was the problem of transport, due to which the extension workers were unable to carry their responsibilities in whole of the area assigned to them. Many farmers who were keen to accept new ideas and advice could seldom get an opportunity of meeting the extension workers.

Realizing the need for reorientation in approach in extension services and considering that the output of research was of no practical benefit unless transmitted to the farmers, special attention was given to the constitution of an effective extension service in the Mona Project. It was considered vitally necessary that the activities and approach be such that the transmission of the results of research could be made with least delay.

For the purpose of disseminating the results to the authorities, different techniques and approaches are being tried in the project. Some of the most effective techniques adopted are seventh-day schools, periodic farmers' gatherings, model farms and field demonstrations, libraries, agricultural com-

petition, farm guide clubs and seed bank schemes. To evaluate the effectiveness of extension activities and the impediments to the adoption of improved agricultural practices, a special study has also been initiated.

CONCLUSIONS

As a result of this study the following conclusions have been derived:

1. LESSONS LEARNT

1.1 Soils and Agronomy

- The soil salinization in the irrigated areas is caused by the upward movement of salts present in the soil due to capillary action and greater evaporation from the high water table; import of salts present in the irrigation water; and, thin irrigation applications which are inadequate to leach down salts accumulated in the root zone.

- The reclamation of salt affected soils can be carried out by the simple process of leaching, growing suitable crops, and addition of amendments.

- One of the important causes of low yields in the study area is the imbalance in the agricultural inputs. Optimisation of the factors of crop production to balance the inputs and their interaction will result in manifold increase in yields.

- The marginal quality waters can be used for successful crop production with applications of suitable amendments.

- The fertility of the soils in the area can be improved and maintained by farm-yard manure and fertilizers.

- Advisory services on choice of crops for particular soils should be established.

1.2 Hydrology and Drainage

- Water table can be controlled through vertical drainage by tubewells to create favourable conditions for plant growth. Observations of groundwater levels in the Mona Project area show that there is a general decline of about 3 to 6 feet in the water table since the implementation of the project. However, changes may occur in the groundwater quality pattern due to pumping which should be carefully watched.

- Tubewell performance in the study area is not as anticipated during planning; the discharge and specific capacity of wells have significantly decreased after 10 years of operation.

- For the proper planning of future vertical drainage projects and their effective operation and maintenance, studies on the design of tubewells and development of suitable methods and procedures for their servicing, maintenance and rehabilitation are necessary.

1.3 Water Management

- Applied research on continuous basis is necessary to evaluate the irrigation scheduling and the control of water applications for irrigating both traditional and new crops.

- There is need to set up pilot projects before embarking on large scale project development to pave the way for a detailed analysis of future project operations. Apart from water requirements and applications, problems concerning the distribution and use of waters; water and salt balance; and, water losses may be considered.

- Research on water management has been started only a short time ago and limited observations recorded. The research on water management should be meaningfully interpreted only after a reasonable period and wide range of observations. As such, prior to using the research results in the field, these should be retested to prove their long term validity and adoption in different areas with modifications as may be needed.

1.4 Climate

- The observation coverage within the Project area is inadequate and the available data indicate no significant changes in climatic factors.

- Extensive meteorological data observation is required for agricultural planning.

1.5 Population, Land Tenure and Health

- As the population is on constant increase there is a dire need for population planning in the area.

- Hospital facilities are meager in the area and rural health programme needs expansion and re-orientation; sanitary conditions also need improvement.

- The case study area, as in other parts of Pakistan, has absolute over population in agriculture, meaning that, it would be possible to reduce the number of workers in agriculture and still obtain the same out-put. Therefore, efforts should be made to plan a programme for the areas where surplus force can be utilized for some economical agro-based industries. The Integrated Rural Development Programme has been launched to achieve this objective but still there is room in it for stream-lining and improvement.

- There is no change in the land tenure pattern due to the project; however, changes have taken place as a result of legislation on national basis. For the protection of the rights of the tenants several laws were enacted on national basis from time to time since the introduction of canal irrigation; the latest ones were promulgated in 1972 and 1977.

1.6 Agricultural Extension

- The experience gained in Mona Project suggests a qualitative and quantitative improvement in the extension service as this is a critical link in the success of the programme for obtaining increased agricultural production.

- Extension facilities have been weak on the motivation approach; these have been person oriented rather than programme oriented.

1.7 Flora and Fauna

- Efforts should be made to preserve and propagate beneficial flora and fauna in the irrigated agriculture.

- In executing schemes for draining wet lands, due care should be given for preservation of the water fowl habitat.

- In land use policy due attention needs to be given to the wild life conservation.

1.8 Livestock, Poultry and Sericulture etc.

- There is need to develop ancillary agricultural activities in the area.

- Particular attention should be given to the livestock, poultry, sericulture etc.

2. FIELDS WHICH NEED RESEARCH

The accomplishments in Mona Project notwithstanding, there is still room for intensive and extensive investigations and research in many fields. Some of the fields hitherto not explored and/or require further investigations are:

2.1 Soils and Agronomy

- Mineral uptake by plants under differing conditions, and the depletion of macro and micro-nutrients.

- Types of drains, their performance and maintenance, and water balance of drainage area, keeping in view the technical and economic feasibility under local conditions; saline effluent disposal.

- Salt tolerance of plants, and salinity/fertility interaction.

- Use of marginal quality irrigation waters; leaching requirements; use of amendments and fertilizers.

- Optimization of balanced agricultural inputs for increasing crop yields.

2.2 Hydrology and Drainage

- Water budget and future response of groundwater system to the development activity.
- Long term effects of sub-surface drainage and tubewell waters on agricultural production.
- Long term changes in water quality due to groundwater pumpage and leaching/salt balance.

2.3 Water Management

- Water losses in main conveyance channels and water courses, their extent and methods of effective control.
- Water distribution and scheduling of irrigation.
- Conjunctive use of surface and groundwater for successful crop production.

2.4 Population and Health

- Effective measures of controlling the population explosion.
- Statistical health surveys especially for intestinal worm diseases and anaemia due to malnutrition, and their effective control.

2.5 Climate

- Micro-climatic investigations to study effect of individual as well as coordinated parameters on desertification process both at transnational and international levels.
- Agro-meteorological investigations for agricultural planning.

2.6 Flora and Fauna

- Methods of propagation and preservation of beneficial flora and fauna.
- Study of life cycle of flora and fauna.

APPENDIX I

Land utilization statistics - Pakistan (million ha)

Year	Total area	Reported area	Forest area	Not available for cultivation	Culturable waste	Cultivated area			Area sown more than once	Total cropped area - cols. (8-10)
						Current fallow	Net area sown	Total area cultivated cols.(7-8)		
1947-48	79.60	46.07	1.37	20.82	9.18	4.01	10.68	14.69	0.95	11.63
1948-49	79.60	46.28	1.35	20.63	9.12	3.75	11.41	15.16	0.93	12.34
1949-50	79.60	46.56	1.37	20.88	9.32	3.62	11.36	14.98	1.12	12.48
1950-51	79.60	46.45	1.39	20.76	9.16	3.54	11.61	15.15	1.27	12.88
1951-52	79.60	46.44	1.40	20.57	9.36	3.84	11.29	15.11	0.95	12.24
1952-53	79.60	46.58	1.28	20.76	9.25	4.03	11.25	15.28	0.83	12.09
1953-54	79.60	46.60	1.24	20.67	9.15	3.42	12.12	15.54	1.14	13.26
1954-55	79.60	46.66	1.26	20.71	9.37	3.46	11.86	15.32	1.42	13.27
1955-56	79.60	46.56	1.28	20.63	8.99	3.34	12.39	15.66	1.57	14.29
1956-57	79.60	46.65	1.30	20.61	8.73	3.37	12.63	16.01	1.53	14.16
1957-58	79.60	48.48	1.29	20.50	10.44	3.69	12.55	16.24	1.38	13.93
1958-59	79.60	48.46	1.29	20.38	10.59	3.29	12.92	16.20	1.41	14.33
1959-60	79.60	48.47	1.34	20.59	10.02	3.43	13.07	16.51	1.60	14.69
1960-61	79.60	50.99	1.68	18.73	12.46	4.85	13.26	18.11	1.59	14.86
1961-62	79.60	50.92	1.67	18.57	12.79	4.26	13.64	17.90	1.61	15.25
1962-63	79.60	50.83	1.67	18.43	12.70	4.25	13.77	18.03	1.69	15.46
1963-64	79.60	51,38	1.80	18.38	12.87	4.92	13.41	18.33	1.72	15.13
1964-65	79.60	52.84	1.97	18.78	13.36	4.56	14.16	18.72	2.09	16.24
1965-66	79.60	53.04	2.08	18.70	13.01	5.31	13.93	19.24	1.61	15.54
1966-67	79.60	52.93	2.08	18.53	13.05	5.03	14.23	19.26	2.18	16.41
1967-68	79.60	53.16	2.28	18.87	12.58	4.55	14.88	19.42	2.06	16.94
1968-69	79.60	52.95	1.87	20.53	11.25	5.04	14.25	19.29	1.99	16.24
1969-70	79.60	52.93	1.84	20.40	11.46	4.70	14.54	19.23	2.24	16.77
1970-71	79.60	53.55	2.83	20.40	11.11	4.77	14.44	19.21	2.18	16.62
1971-72	79.60	53.50	2.71	20.44	11.26	4.75	14.33	19.08	2.26	16.60
1972-73										
1973-74										

APPENDIX II

Extent of waterlogging and salinity in Pakistan

A. Waterlogging

Province	Gross commanded area (million ha)	Area affected (million ha)						Source
		severely (0-5')	per cent	moderately (5-10')	per cent	total	per cent	
Punjab	9.63	0.58	6.05	2.42	25.18	3.01	31.23	Central Monitoring Organization, Water & Power Development Authority, 1975
Sind	6.04	0.71	11.73	2.27	37.67	2.98	49.40	Lower Indus Project Report, 1960
North Western Frontier Province	0.40	0.04	10.00	0.004	1.00	0.04	11.00	Director Land Reclamation
Baluchistan	-	-	-	-	-	-	-	

B. Soil salinity

Province	Area surveyed (million ha)	Normal soils less than 0.2%(*)		Slightly saline less than 0.2%(*)		Moderately saline (0.2-2.5%*)		Highly saline-more than .5%(*)		Total		Source
		Area (m.ha)	Percent	Area (m.ha)	Percent	Area (m.ha)	Percent	Area (m.ha)	Percent	Area (m.ha)	Percent	
Punjab	9.51	7.87	72.64	1.41	14.80	0.40	4.30	0.62	6.50	2.44	25.63	Central Monitoring Organization, Water & Power Development Authority, 1975
Sind	5.34	0.10	1.73	1.10	20.64	1.45	27.12	2.69	50.49	5.24	98.26	IBRD (1974) Lower Indus Project Report 1966
North Western Frontier Province	0.40	-	-	-	-	-	-	-	-	0.04	9.00	Director Land Reclamation
Baluchistan	0.65	-	-	-	-	-	-	-	-	0.04	6.88	do
TOTAL	15.90	7.97	74.37	2.51	15.81	1.85	11.66	3.31	20.85	7.76	48.83	

(*) = soluble salts; m.ha = million hectares

Note: Waterlogging figures pertain to the months of April-June when the water table is the lowest. It is highest in September-October when waterlogging area increases up to 1.5 to 2 times the waterlogged area in April-June.

APPENDIX III

Distributaries in the Mona Project and their authorised full supply*

Sr. no	Canal	Perennial/ non-perennial	Distributary	Authorised full supply m^3/sec	Gross area (GA)	Culturable area (CA)	Culturable commanded area (CCA)
					hectares		
1.	Lower Jhelum - Main Line	perennial	Pakhowal	0.65	3,511	3,313	3,313
2.	-do-	-do-	Mona	0.88	4,846	4,580	3,856
3.	-do-	-do-	Rattokala	2.77	14,340	13,758	12,737
4.	Lower Jhelum Northern Branch	-do-	Fatehpur	1.53	5,515	5,405	4,311
5.	-do-	-do-	Chabba	0.48	2,174	2,155	2,151
6.	Shahpur Branch	non-perennial	Wijhi	0.25	866	860	714
7.	-do-	-do-	Rakh Miani	0.54	1,841	1,769	1,582
8.	-do-	-do-	Kot Mamyana**	0.23	1,734	1,491	1,044
9.	-do-	-do-	Dewas	0.25	821	798	798
10.	-do-	-do-	Chak Qazi	0.54	1,709	1,614	1,589
11.	-do-	-do-	Jiwanwala	0.11	378	362	362

* Information in this table is based on Hydrologic and tubewell performance appraisal in Mona Reclamation Experimental Project 1965-70 by Ch. Ata-ur-Rehman, Central Monitoring Organization, Water and Power Development Authority, Publication No 96, 1971.

** Data from Irrigation Department, Lahore.

APPENDIX IV

Villages in Mona Case Study area

Sr. no	Name of village	Tehsil	District	Gross Area	Area within Mona Project	
					Total	Percent
1	2	3	4	5	6	7
1.	Salam	Bhalwal	Sargodha	4,443	177	3.98
2.	Dhori	" "	" "	2,688	1,670	62.15
3.	Chak No 1(Northern)	" "	" "	338	338	whole
4.	Phullarwan	" "	" "	78	78	whole
5.	Chabba	" "	" "	2,806	1,530	54.55
6.	Chak No 3(Northern)	" "	" "	728	728	whole
7.	Chak No 14 "	" "	" "	524	524	"
8.	Chak No 213 "	" "	" "	835	773	92.54
9.	Chak No 2 "	" "	" "	665	665	whole
10.	Chak No 15 "	" "	" "	855	751	87.83
11.	Chak No 17 "	" "	" "	613	192	31.29
12.	Chak No 16 "	" "	" "	409	180	44.50
13.	Fatehpur	" "	" "	390	390	whole
14.	Bhalwal (Old)	" "	" "	3,251	1,533	47.16
15.	Nabi Shah Bala	" "	" "	1,540	1,540	whole
16.	Chak No 11 M.L.	" "	" "	757	757	"
17.	Hathi Wind	" "	" "	1,783	1,783	"
18.	Chak No 10 M.L.	" "	" "	587	587	"
19.	Chak No 8 M.L.	" "	" "	602	602	"
20.	Chak No 9 M.L.	" "	" "	799	724	90.68
21.	Khawaja Salah	" "	" "	889	889	whole
22.	Chak No 7 M.L.	" "	" "	491	491	"
23.	Thatti Noon	" "	" "	2,239	1,601	71.53
24.	Chak No 6 M.L.	" "	" "	772	772	whole
25.	Sadio Wal	" "	" "	320	320	"
26.	Chak No 6 A.M.L.	" "	" "	125	125	"
27.	Ratto Kala	" "	" "	1,932	1,932	"
28.	Melowal	" "	" "	1,509	140	9.25
29.	Rakh Melowal	" "	" "	368	59	15.94
30.	Manwais	" "	" "	522	99	18.91
31.	Varowal	" "	" "	1,276	901	70.91
32.	Kellri	" "	" "	386	386	whole
33.	Amir Chand Wala	" "	" "	200	200	"

1	2	3	4	5	6	7
34.	Rakh Maini	Bhalwal	Sargodha	642	642	whole
35.	Chak Pir Shah	"	"	233	190	81.28
36.	Rakh Pakhowal	"	"	316	315	whole
37.	Gulabpura	"	"	209	209	"
38.	Gurmukh Singh Wala	"	"	327	312	95.30
39.	Jaget Pura	"	"	417	407	97.58
40.	Bana Mianwala	"	"	400	392	96.98
41.	Chak Saiyid	"	"	1,732	579	33.41
42.	Bola	"	"	1,062	4	0.42
43.	Kal ain	"	"	844	23	2.73
44.	Singh Mafi	"	"	273	0.4	0.15
45.	Singh Bala	"	"	185	23	12.45
46.	Barhat Shargi	"	"	438	397	90.68
47.	Pakhowal	"	"	649	544	83.85
48.	Heera Garh	"	"	77	77	whole
49.	Jeewanwal	"	"	1,109	1,028	92.10
50.	Nanovas	"	"	203	203	whole
51.	Kot Gulmoiz Khan	"	"	157	156	99.74
52.	Whijji	"	"	710	405	57.03
53.	Kot Ahmed Khan	"	"	658	652	99.14
54.	Awan	"	"	184	61	33.19
55.	Chak Sahib Khan	"	"	388	259	66.65
56.	Rakh Bhadpur	"	"	254	148	58.19
57.	Pindi Hertar	"	"	254	253	96.18
58.	Hazoorpur	"	"	1,105	0.4	0.04
59.	Davispur	"	"	301	301	whole
60.	Beerbaran	"	"	542	397	73.28
61.	Rangpur Allah Yar	"	"	193	125	64.85
62.	Fathagarh	"	"	609	3	0.53
63.	Kharo Kot	"	"	425	101	23.69
64.	Bhoji Kot	"	"	604	601	99.37
65.	Diwan Pur	"	"	212	212	whole
66.	Rakh Churagah	"	"	964	964	"
67.	Malkopur	"	"	259	259	"
68.	Amra	"	"	269	156	58.13

1	2	3	4	5	6	7
69.	Chak Qazi	Bhaiwal	Sargodha	1,071	832	77.92
70.	Jahanpur Dehar	"	"	317	317	whole
71.	Khan Muhammad Wala	"	"	1,791	749	41.83
72.	Kot Maniana	"	"	586	577	98.55
73.	Chak Nearian	"	"	563	334	59.27
74.	Kot Harim Khan	"	"	578	286	49.44
75.	Jaddah	"	"	1,505	726	48.26
76.	Chava	"	"	4,347	611	14.05
77.	Faqirian	Phalia	Gujrat	697	160	22.81
78.	Mona	"	"	1,161	496	40.20
79.	Rakh Mona	"	"	80	80	whole
80.	Mona Depot	"	"	4,185	3,082	73.66
81.	Pind Makko	"	"	1,127	1,118	99.16
82.	Chot	"	"	2,212	54	2.45
83.	Khaizer	"	"	401	401	whole
84.	Ghorbakhsh Pura	"	"	1,381	405	29.33
	GRAND TOTAL			75,842	45,127	

APPENDIX V

Annual precipitation data (1916-1975) in cm

Year	Rainfall		
	Sargodha	Miani	Bhalwal
1916	52.43	-	-
1917	65.25	-	-
1918	27.41	-	-
1919	39.47	-	-
1920	23.47	-	-
1921	49.68	-	-
1922	27.74	-	-
1923	52.25	-	-
1924	39.70	-	-
1925	30.15	-	-
1926	46.99	-	-
1927	16.74	-	-
1928	29.69	-	-
1929	43.07	-	-
1930	23.98	-	-
1931	28.12	-	-
1932	36.35	-	-
1933	58.37	-	-
1934	36.91	-	-
1935	37.47	-	-
1936	38.20	-	-
1937	45.24	-	-
1938	20.62	-	-
1939	23.01	-	-
1940	41.35	-	-
1941	57.51	-	-
1942	31.62	-	-
1943	40.56	-	-
1944	61,47	-	-
1945	46.08	38₹94	27₹91
1946	28.09	2.08	14.45
1947	9.45	57.53	64.11
1948	41.12	45.03	34.11
1949	26.95	61.62	39.19
1950	36.47	51.44	31.70
1951	34.72	23.85	29.16
1952	41.43	45.39	33.33
1953	32.11	43.66	31.90
1954	32.16	52.96	46.02
1955	41.45	68.76	67.13
1956	55.27	29.44	40.56
1957	35.36	36.45	33.96
1958	48.77	76.71	75.49
1959	50.52	34.06	51.26
1960	32.99	16.76	30.40
1961	25.37	24.33	31.83
1962	46.53	-	34.70
1963	23.37	-	29.44
1964	31.65		

(Contd.)

Year	Sargodha	Miani	Bhalwal
1965	39.27	-	40.11
1966	29.44	15.47	28.19
1967	51.77	80.21	45.01
1968	32.23	50.52	48.03
1969	53.54	42.49	36.80
1970	25.35	42.93	14.68
1971	30.28	29.11	29.01
1972	34.24	30.66	50.17
1973	55.60	43.08	37.49
1974	29.11	39.98	35.20
1975	40.21	76.50	52.60

APPENDIX VI

Mean monthly maximum and minimum temperatures for Sargodha (1931 to 1960)

Month	Average temperatures in °C	
	maximum	minimum
January	19.2	4.7
February	22.8	6.4
March	26.9	12.5
April	33.2	17.6
May	37.5	21.9
June	41.5	26.7
July	37.7	27.6
August	36.0	26.3
September	36.1	24.1
October	33.4	17.3
November	25.4	10.1
December	21.4	5.4

APPENDIX VII

Annual extremes: Sargodha Station
(1957-1975)

Year	Maximum temperature °C	Date	Minimum temperature °C	Date
1957	46	6-7/6	-0.6	6/1
1958	46	26-27/6	1.7	23/1
1959	45	21/6	0.6	4/1
1960	Date of maximum for June, July and August not available		-0.6	9/12
1961	46	1-2/6	0.6	12-14/1 and 30/12
1962	47	9/6	3.3	16-17/1
1963	45	5/7	-0.6	13/1
1964	48	29/6	-2.2	27-28/1
1965	46	21/6	1.7	7/1
1966	45	14/6	-1.1	26/12
1967	46	3-10/6	-	-
1968	46	18/6	-1.1	28/12
1969	47	21/6	-2.8	4/1
1970	47	May	-1.7	December
1971	45	June	-0.6	Jan. & Dec.
1972	48	June	-1.7	January
1973	48	June	-1.7	December
1974	47	June	-2.8	February
1975	47	June	-1.0	January

APPENDIX VIII

Normal relative humidity: Sargodha Station
(1931-1960)

Month	Relative humidity in percentage at GMT		
	03	12	Average
January	91	55	73
February	83	40	61
March	87	47	67
April	60	35	48
May	46	25	36
June	45	23	34
July	70	49	59
August	77	54	61
September	74	47	60
October	66	38	52
November	76	48	62
December	89	56	78

APPENDIX IX

Mean monthly solar radiation for Sargodha by the Jensen-Haise equation

Month	Mean monthly temperature (°C)	Solar radiation (cm per day)
January	11.7	0.43
February	14.7	0.53
March	20.0	0.69
April	25.3	0.81
May	29.7	0.89
June	34.2	0.84
July*	33.0	0.76
August*	31.4	0.74
September	29.4	0.71
October	25.3	0.61
November	18.9	0.48
December	13.6	0.41

* Estimate based on using coefficient for monsoon climate.

Jensen-Haise Equation: I. $E_{tp} = C_t(T - T_1)R_3$

Arid: $E_{tp} = 0.012(T - 15.5)R_1$

Monsoon: $E_{tp} = 0.011(T-19.9)R_3$

APPENDIX X

Velocity and direction of wind in Sargodha
(Based on data 1931-1960)

Month	Speed knots per hour		Direction	
	03 GMT	12 GMT	03 GMT	12 GMT
January	1.4	2.4	W	N 34 W
February	1.5	3.1	N 34 W	N 27 W
March	2.5	4.5	N 18 W	N 30 W
April	3.6	4.2	N 35 E	N 8 E
May	5.0	5.3	N 35 E	N 18 E
June	4.8	5.5	S 45 E	S 17 E
July	6.0	6.5	E	E
August	4.7	6.0	E	S 12 E
September	3.3	5.2	N 7 E	S 26 E
October	2.3	2.8	E	S 13 E
November	1.2	1.5	S 45 E	N 12 W
December	0.3	1.5	W	N 16 W

APPENDIX XI

Annual evaporation at Sargodha

Year	Evaporation in cm
1962	226.54*
1963	293.01
1964	299.49
1965	217.40
1966	212.52
1967	138.94
1968	212.85*
1969	221.62
1970	235.28
Total	2.133.85
Average	237.08

Source: Published data of Surface Water Hydrology Project WAPDA, Lahore.

* For a few days, of which the records are now missing, the average temperature was used.

APPENDIX XII

Different categories of surface salinity

Non-saline area (No symbol)

Neither soil nor crops are affected by salts. The soluble salts are less than 0.20 per cent.

Slightly saline area (S_2)

The area mapped under this category includes one-fifth of the area or crop affected by salinity. Crop growth may be uneven or patchy.

Moderately saline area (S_3)

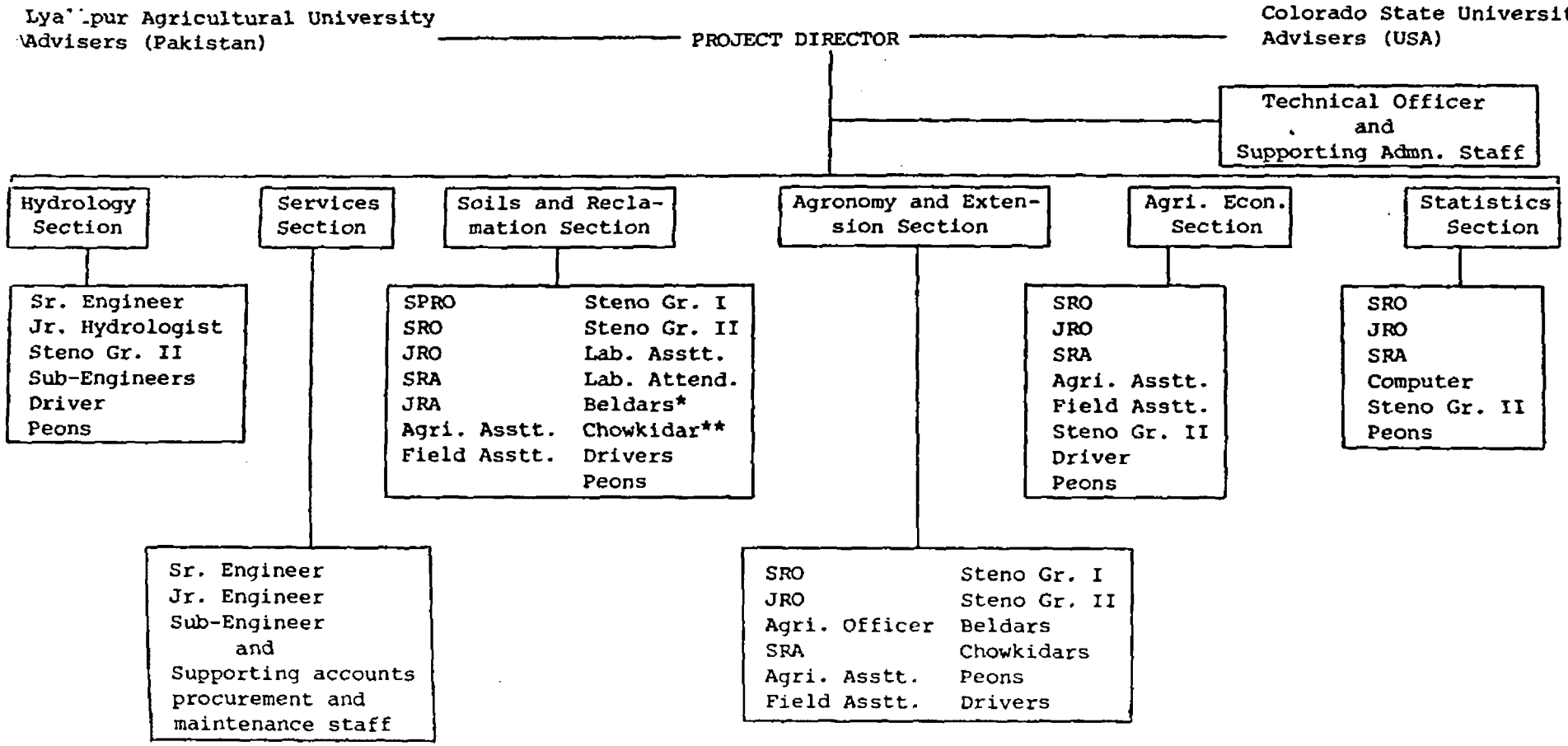
The area under this category is between one-fifth and four-fifths of the total area. The average salt content of area mapped under this class varies from 0.50 to 1 per cent.

Strongly saline area (S_4)

More than four-fifths of the area mapped under this category has been affected by salts. Such areas are usually devoid of any vegetation other than salt-tolerant plants. The average salt content of the area is more than 1 per cent. Generally, a fluffy salt layer is evidenced on the soil surface.

APPENDIX XIII

MONA RECLAMATION EXPERIMENTAL PROJECT



Notations:

Admn.	= Administrative	JRO	= Junior Research Officer
Agri.	= Agricultural	SRA	= Senior Research Assistant
Econ.	= Economics	JRA	= Junior Research Assistant
Sr.	= Senior	Agri. Asstt.	= Agricultural Assistant
Jr.	= Junior	Lab. Asstt.	= Laboratory Assistant
SPRO	= Superintending Research Officer	Lab. Attend.	= Laboratory Attendant
SRO	= Senior Research Officer	Gr.	= Grade

* Chowkidar = Watchman
** Beldars = Cooli, unskilled labour for field operatior

GLOSSARY

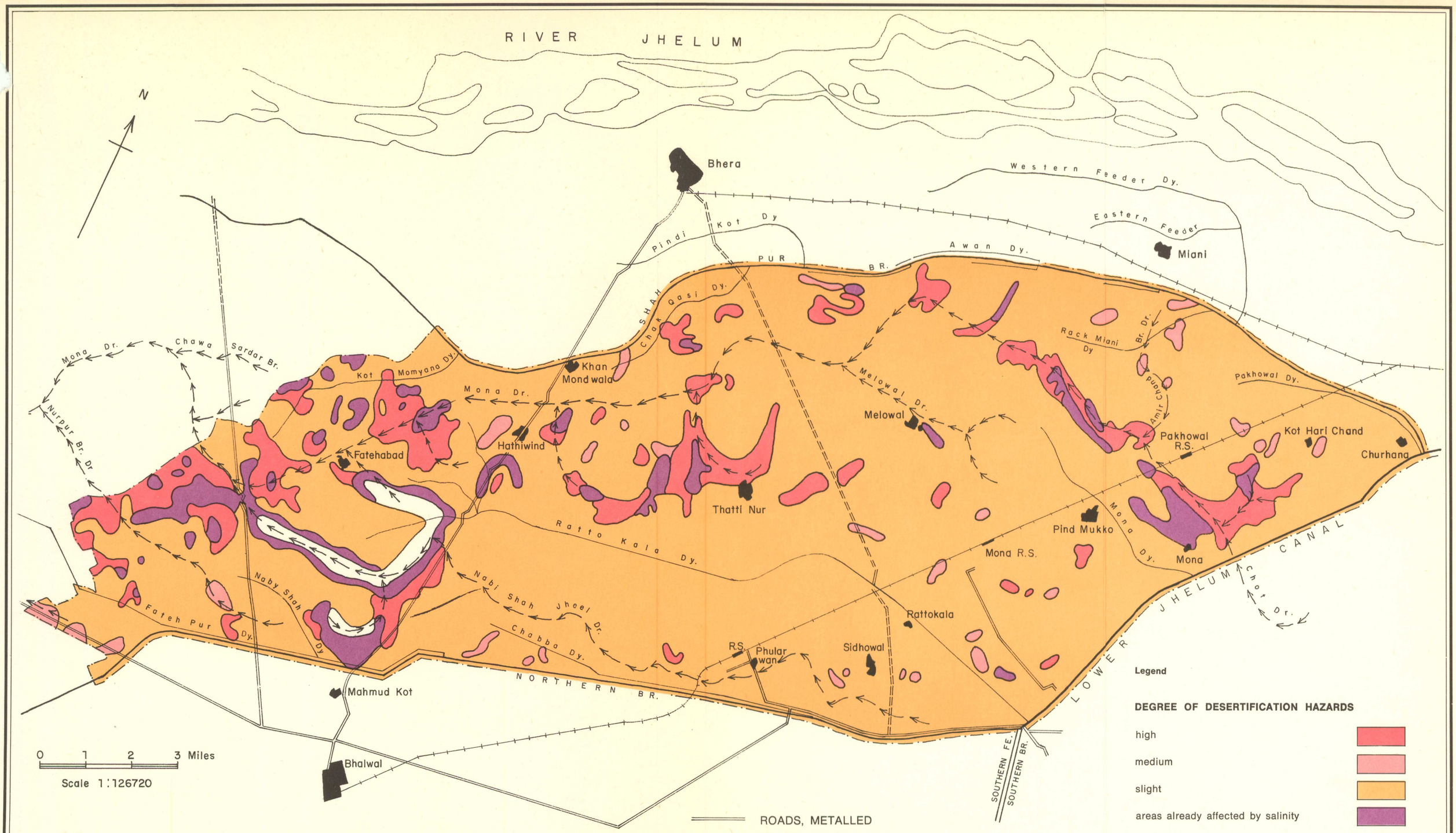
Alkali soil (nonsaline alkali soil)	A soil that contains sufficient exchangeable sodium to interfere with the growth of most crop plants. For most crops the interference is physical rather than chemical in nature. According to the US Salinity Laboratory, an alkali soil has an ESP of 15 percent or more and pH greater than 8.5
Alkaline (sodic)	A chemical term referring to a "basic" reaction, i.e. pH above 7, as distinguished from an "acid" reaction where the pH is less than 7
Area irrigated	The area on which irrigation water is applied during a cropping season. The area irrigated annually is the sum of the areas irrigated during each cropping season
Authorized full supply	The maximum flow rate authorized for an irrigation channel; commonly the design capacity in cusecs
Barani	The agricultural practice which relies upon rainfall alone for crop water requirements
Barrage	A low dam or weir equipped with a series of gates to regulate the water surface level upstream from the weir
Batai	Share cropping
Bhaiychara	The system of land holding under which common land is owned on shares either according to fixed fractions or proportionate to the revenue paid by each owner
Branch	A large irrigation channel with a capacity generally in the range of 3,000 to 6,000 cusecs offtaking from a main line canal
Bund	Embankment for retaining water. A large artificial embankment which protects agricultural land from river floods
Calcareous	Containing calcium carbonate (lime), hence alkaline in reaction
Canal (or Main Line Canal)	A channel for conveyance of water, generally in Pakistan referring to a large channel which delivers water from a river to branches or lesser channels, and having a capacity of 5,000 to 15,000 cusecs or more

Chak	Area irrigated by an outlet of an irrigation system (sometimes also designates a village)
Chakbandi	Process of delineating "chaks", or map showing area commanded by an irrigation outlet
Chaj Doab	Land between Rivers Jhelum and Chenab
Cover flood plain	A flat uniform plain composed of sediments which were carried by sheet floods and laid down by vertical accretion
Crop water requirements	The total quantity of water required by a crop for normal growth under field conditions, as measured at the crop
Cropping intensity	In the Northern Zone it is the percentage of the reclamation area (RA) that is cropped and, in the Southern Zone it is the percentage of culturable commanded area (CCA) that is cropped
Cropping pattern	The proportion of cropland devoted to each crop during the year
Culturable area (CA)	That portion of the gross area which is cultivated
Culturable commanded area (CCA)	The culturable area within a canal system which can be irrigated by gravity flow from the canal system
Dissolved solids	See "total dissolved solids"
Distributary	An irrigation channel of intermediate size, generally with a capacity in the range of 100 to 1,000 cusecs, and usually off-taking from a branch or main line canal
Doab	The land between two rivers
Fresh groundwater	Groundwater of salinity less than 1,000 ppm which can be used directly for irrigation
Gross area (GA)	The entire area within the irrigation project boundaries
Gur	Raw sugar
Inundation canal	A canal which is dependent upon the level of water in the river for its supply
Irrigation water requirement	The quantity of water required for normal crop growth and leaching minus effective precipitation. The irrigation water requirement includes losses from the point of reference to the crop

Kharif	The summer irrigation season; the six months from April 15 to October 15. Also used to denote summer crops and cropping season
Leaching requirement	The fraction of the water entering the soil that must pass through the root zone in order to prevent soil salinity from exceeding a specified value under long-term average or steady state conditions
Maund	A unit of weight equal to 82.28 pounds
Minor	A small irrigation channel, generally with a capacity of 10 to 300 cusecs, offtaking from a distributary
Monsoon	The rainy season associated with southwest monsoon
Non-perennial canal	Irrigation channel which normally flows during the summer (Kharif) period, but may carry intermittent supplies during other periods
Nonsaline-alkali soil	See "alkali soil"
Paddy	Threshed, unmilled rice; sometimes a flooded field in which rice is grown
Pattidari	The system of renting land on lease
Perennial canal	An irrigation channel which normally carries water throughout the year
Persian wheel or well	A dug well equipped with an endless chain of buckets or urns for lifting the water to the surface; usually powered by bullocks or camels
Parts per million (ppm)	Parts-per-million by weight. 1 ppm is equal to 1 milligram per kilogram, or about 2.7 pounds per acre food of water, or about 4 pounds per acre foot of soil
Rabi	The winter irrigation season; the six months from October 15 to April 15. Also used to denote winter crops and cropping seasons
Sailaba area	Lands irrigated by flood waters
Saline soil	A nonalkali soil containing soluble salts in sufficient quantity to interfere with the growth of most crop plants. The EC of the saturation extract is greater than 4 mmhos and the pH usually is less than 8.5

Saline-alkali soil	A soil containing sufficient soluble salts as well as sufficient exchangeable sodium to interfere with the growth of most crop plants. The ESP is greater than 15 and the EC of the saturation extract is greater than 4 mmhos
Square	Unit of land equivalent to 25 acres
Tehsil	Sub-division of a district
Total dissolved solids (TDS)	The concentration of dissolved minerals in ppm obtained by evaporating to dryness a filtered sample of water. Commonly referred to as "dissolved solids"
Water course	An irrigation channel offtaking from a distributary, minor or sub-minor; used to carry water to farm fields

SYNOPTIC MAP OF DESERTIFICATION HAZARDS - Mona Project (PAKISTAN)



Legend

DEGREE OF DESERTIFICATION HAZARDS

- high
- medium
- slight
- areas already affected by salinity

VULNERABILITY OF LAND TO DESERTIFICATION PROCESSES

Whole surface is subject to salinization and alkalinization.

HUMAN PRESSURE

Irrigation and drainage canals, villages and towns indicate location of human pressure.