Environmental impacts of Chashma Right Bank Canal on the land use and agricultural resources of D.I.Khan district, Pakistan

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In The Name of Allah
The Most Beneficent
The Most Merciful

APPROVAL SHEET

This research thesis is completed under the supervision of Dr. Amir Nawaz Khan, Professor, Department of Geography, Urban and Regional Planning, University of Peshawar, Peshawar (Pakistan) for the degree of Doctor of Philosophy in Geography.

Title:

"Environmental impacts of Chashma Right Bank Canal (CRBC) on the land use and agricultural resources of D.I.Khan district, Pakistan"

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DEDICATION

This thesis is dedicated to
My parents,
Teachers
and
My wife
Who always gave me a constant moral support

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ABSTRACT

This study attempts to evaluate the environmental impacts of Chashma Right Bank Canal (CRBC) on the land use and agricultural resources of D.I.Khan district, Pakistan. Work on the Chashma Right Bank Irrigation Project (CRBIP) started in 1984 and was subsequently completed in three stages during 2003. CRBC commands 250,000 hectare of land, which spreads over the two provinces i.e. NWFP and Punjab. All of this area is situated on the left bank of CRBC. The ultimate goal of the CRBIP was to alleviate poverty through enhancement of agricultural production and employment opportunities in the CRBC command area.

This study is a sort of ex post impact evaluation of CRBIP. It attempts to answer the question that what are the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district. To achieve the mandated task five objectives were designed. Firstly, to find out the socio-economic and physical environment of D.I.Khan district; secondly, to analyse the land utilization and irrigation pattern before and after commissioning of CRBC; thirdly, to compare changes in the cropping pattern and cropping intensity pre and post CRBC; fourthly, to find out the environmental impacts of CRBC on the agricultural production, land values, mechanization, fertilizer and water-table; finally, to suggest recommendations for mitigating the adverse impacts of CRBC on the land use and agricultural resources.

To carry out this study, nine indicators were selected. These include land use, cropping pattern, cropping intensity, land value, agricultural production, irrigation, mechanization, fertilizer and ground water-table. Keeping in view the purpose and objectives of the study, data were collected both from primary and secondary sources. Data pertaining to selected variables were collected, pre and post CRBC, for all the villages in the district. However, to conduct more intensive analysis and get clear picture of the impacts of CRBC at micro-level, five sample villages were randomly selected. Amongst these villages four are from CRBC command area i.e. Jarra, Gomal, Buchari and Chera, whereas one is from off the CRBC command area i.e. Khudaka. The collected data were analysed using computer based statistical techniques and Geographical Information System (GIS). The analysed data were finally presented in the form of maps, statistical diagrams and tables.

The analysis revealed that with the advent of such large-scale intensive canal irrigation project in the arid tract of D.I.Khan district, there had been widespread anthropogenic reconstruction of the environment. These resultant changes were both positive and negative, and also vary from short to long-term on the local and regional level. The study found that after

CRBC cultivated land has gone-up in the CRBC command area. Similarly, an extensive cultivable waste has been brought under cultivation. However, no significant impact has been reported from outside the CRBC command area. The analysis also revealed that a vast tract of cultivable land has also been brought under non-agricultural uses, such as settlements, industries, construction of roads and canal etc. All this development is going on without taking care of land suitability factors.

The analysis further revealed that area under irrigation has gradually increased, since 1969-70. After comparing pre and post CRBC conditions of canal irrigated area, a net positive change of 10.77% of the total reported area was recorded. This large-scale increase in the canal-irrigated area is attributed to the inception of CRBC. Likewise, the micro level analysis found that after CRBC a positive change has occurred in the canal irrigated area of sample villages Gomal, Buchari and Chera. Contrary to this, in the sample village Khudaka, which is off the CRBC, no significant impact has been detected.

It was found that with the advent of CRBC, acreage of both Kharif and Rabi crops have improved considerably. The analysis revealed that in the CRBC command area, farmers have mostly switched over to more rewarding and water loving crops such as rice, sugarcane, vegetables and orchards etc. The analysis further revealed that after the CRBC, cropping intensity has gradually increased. It was indicated from the micro-level analysis that the rate of cropping intensity has been rapid in stage III as compared to stages I and II of the project. Furthermore, with the inception of CRBC, not only cultivated area has increased, but per hectare yield has also improved to a greater extent. Similarly, land values in the CRBC command villages has also increased at a rapid pace, whereas outside the CRBC command area impacts on the land value is insignificant. All these developments have improved the socio-economic situation of the people in the CRBC command area.

The study found that besides all these beneficial impacts, the introduction of canal irrigation has also raised the ground water-table particularly in the CRBC command area. This negative impact is mainly due to unwise irrigation practices, tendency towards water loving crops and absence of sub surface drainage.

It can also be concluded from the analysis that engulfing of prime agricultural land by built up area, lack of proper crop selection and rapid rise in water-table particularly in the canal irrigated tract have led to environmental problems in the study area. This situation if not taken care of well in time, might pose serious threats to the environment in the future. This study, however, put forward certain recommendations for not only mitigating the negative impacts of CRBC, but also provides policy guidelines for the decision-makers to avoid these problems in the future irrigation schemes as well.

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GLOSSARY

Word	*Meaning*	*Explanation if any*
Abiana	Irrigation fee or water Cess	Abiana is collected after each cropping season by the irrigation department
Hectare	Unit of area	Hectare is a unit equivalent to 2.47 acre.
Barani	Rainfed areas	Dependence of cultivated area on rainfall
Mong	Local name of Mung bean	Pulse crop
Masoor	Local name of lentil	Pulse crop
Gowara	cluster bean	Fodder crop
Mash	Urd bean similar to mung bean	Pulse crop
Titac	A kind of fodder crop	Kharif fodder crop
Rabi	Winter cropping season	
Kharif	Summer cropping season	
Distributaries	Channel taken from main canal	Channel taken-out from main canal and distribute water through minor and water courses
Minors	Channel taken from distributary	When the distance from distributary and field is high, small channel is taken from distributary is called minor.
Watercourses	Small channel, which irrigate field	Small channels excavated by the cultivators to take water from either distributary or minor
Gross Command Area	It is the gross command area of irrigation project	It include both cultivable and uncultivable land
Culturable Command Area	It is that part of Gross Command Area on which cultivation is possible	
Tehsil	Administrative sub-division of a district	
Union council	The smallest administrative unit with a population of 15,000 to 25,000	
Daman	Piedmont	Local term use for piedmont
Goara	Cluster Bean	A local name of fodder crop
Katcha	Unpaved	
Kharif	Summer cropping season	A local name for cropping season
Mouza	Village	Smallest revenue unit
Nullahs	Hill torrents channel	
Patwari	Government representative of revenue unit/ Mouza	Village level employee of the revenue or irrigation dept.
Pucca	Cemented/ paved	Made-up of cementing material
Rabi	Winter cropping season	A local name for cropping season
Rod Kohi	Hill torrent irrigation	Traditional form of irrigation in the area
Sarshaf	*Brassica Campestris*	A local name of oilseed
Titac	A kind of melon	A kind of Kharif melon
Urea	Nitrate	A type of chemical fertilizer
Usso	Brassica Napus	A local name of oilseed

ABBREVIATIONS

ADB:	Asian Development Bank
ADBP:	Agricultural Development Bank of Pakistan
AF:	Acre Feet (1 AF = 1233.48 cubic meters)
AO:	Agricultural Officer
AHD:	Aswan High Dam
BCM:	Billion Cubic Meters
CCA:	Cultivable Command Area
CCADP:	Chashma Command Area Development Project
cfs:	cubic feet per second (1 cfs = 28.320 Liters per second)
CRB:	Chashma Right Bank
CRBC:	Chashma Right Bank Canal
CRBIP:	Chashma Right Bank Irrigation Project
Cumec:	Cubic meters per second (1 Cumec = 35.310 Cusecs)
Cusec:	Cubic feet per second (cfs)
DAP:	Di Ammonium Phosphate (chemical fertilizer)
DA:	Director of Agriculture
D.I.Khan	Dera Ismail Khan
EDAO:	Executive District Agriculture Officer
FATA:	Federally Administered Tribal Areas
GCA:	Gross Command Area
GDP:	Gross Domestic Product
GIS:	Geographical Information System
GNP:	Gross National Product
GoJ:	Government of Japan
GoNWFP:	Government of North West Frontier Province
GoP:	Government of Pakistan
HKRC:	High Kabul River Canal
HBL:	Habib Bank Limited
ha:	hectare
HYV:	High Yielding Varieties
IIMI:	International Irrigation Management Institute, Lahore
JICA:	Japan International Cooperation Agency

K:	Potassium (chemical fertilizer)
km:	kilometres
MAF:	Million Acre Feet
MCM:	Million Cubic Meters
Mha:	Million hectares
N:	Nitrate (chemical fertilizer)
NBP:	National Bank of Pakistan
NESPAK:	National Engineering Services (Pakistan)
NP:	Nitro-Phosphate (chemical fertilizer)
NWFP:	North West Frontier Province
OFWM:	On Farm Water Management
P:	Phosphate (chemical fertilizer)
PARC:	Pakistan Agricultural Research Council
PE&DD:	Planning Environment and Development Department
PIDA:	Provincial Irrigation and Drainage Authority
PLL	Precision Land Levelling
ppm:	parts per million
RD:	Reduced Distance
Rs:	Pakistani Rupees
SCARP:	Salinity Control And Reclamation Project
UBL:	United Bank Limited
VECs:	Valued Ecosystem Components
WAPDA:	Water And Power Development Authority
WAA:	Water Apportionment Accord
W&SD:	Works and Services Department
WRBC:	Warsak Right Bank Canal

INTRODUCTION

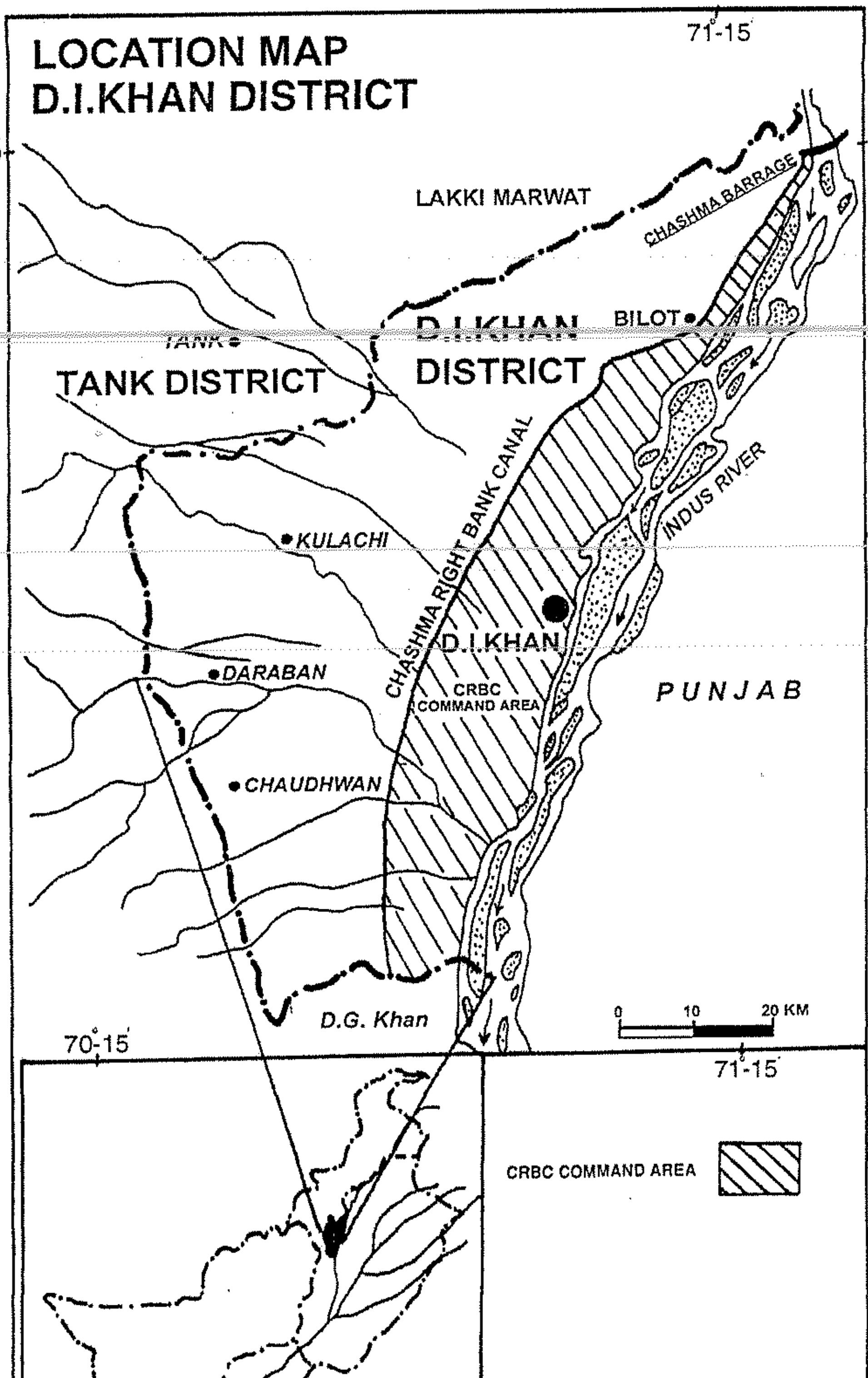
Introduction

This study attempts to evaluate the environmental impacts of Chashma Right Bank Canal (CRBC) on the land use and agricultural resources of D.I.Khan district. It is the southern most district of NWFP and stretches between 31° 15' to 32° 32' North latitude and 70° 11' to 71° 20' East longitude (Map I-1). D.I.Khan district is bounded on the north by Marwat, Bhittani and Shirani hills, while Suliman Mountain lies in its west. The Indus River and Vehowa stream form the natural boundary to the East and South, respectively. The climate of D.I.Khan is characterized by long hot summer and short cool winter.

D.I.Khan district has a total reported area of 730,575 hectare (ha), out of which 236,371 ha was cultivated, 3,908 ha under forest, 132,487 ha uncultivated and large share of about 357,809 ha was cultivable waste, during 2003-2004. Primarily, the main form of agriculture was *Barani* (rainfed) followed by *Rod Kohi* (hill torrent irrigation). Although, small areas around western tributaries such as Tank Zam, Gomal Zam, Sheikh Haider Zam, Chowdwan Zam and Daraban Zam have surface irrigation. Canal irrigation to a greater extent became possible after the inception of CRBC.

Work on the Chashma Right Bank Irrigation Project (CRBIP) has been started in 1984 and was subsequently completed in three stages during 2003. The ultimate goal of CRBIP was to enhance agricultural productivity, employment opportunities and alleviate poverty. CRBC is 272 Km long canal, spread over the two provinces i.e. 170 Km in NWFP and 102 Km in Punjab. The CRBC commands 250,000 ha, out of this 61% lies in D.I.Khan district of NWFP and remaining 39% in D.G. Khan District, Punjab Province. The CRBIP was completed in three stages i.e. stage I, II and stage III. Stage I, II and part of stage III falls in D.I.Khan district and rest of stage III in D.G. Khan District. The CRBC commands only left bank area as the slope is from west to east.

This study is a sort of ex post impact evaluation of CRBIP. To achieve this task, nine indicators which included land use, cropping pattern, cropping intensity, land value, agricultural production, irrigation, mechanization, fertilizer and ground water-table were selected. Data



LOCATION MAP
D.I.KHAN DISTRICT
71°-15'
32°-30'
32°-30'
LAKKI MARWAT
CHASHMA BARRAGE
BILOT
TANK
D.I.KHAN
DISTRICT
TANK DISTRICT
CHASHMA RIGHT BANK CANAL
INDUS RIVER
KULACHI
D.I.KHAN
DARABAN
CRBC
COMMAND AREA
PUNJAB
CHAUDHWAN
D.G. Khan
0
10
20 KM
70°-15'
71°-15'
CRBC COMMAND AREA

Map I-1

pertaining to these variables were collected both pre and post of CRBC for all the 384 villages, which covered the whole district. However, to conduct more intensive micro-level analysis, five sample villages were also randomly selected. Four from CRBC command area i.e. Jarra, Gomal, Buchari, Chera and one off the CRBC command area i.e. Khudaka, to get clear picture of CRBC impacts at micro-level.

The analysis revealed that with the advent of CRBC, there had been widespread anthropogenic reconstruction of the environment in the arid tract of D.I.Khan district. These changes are both positive and negative on the local and regional level. In D.I. Khan District, with the inception of CRBC, almost 152,000 ha were brought under canal irrigation, which greatly changed the land use pattern particularly in the CRBC command area. After commissioning of CRBC, there was constant increase in the area under cultivation and gradual decline of the cultivable waste specifically in the CRBC command area. It was mainly due to the conversion of cultivable waste into cultivated area as a result of CRBC. However, large-scale cultivable land has also been brought under non-agricultural uses, mainly because of physical development of new settlements, industries, construction of roads, canal etc. which is not according to the land suitability. This is an irreversible negative impact on the land use of this canal-irrigated region.

After inception of CRBC, the irrigated area has been gradually increased and a net positive change of 10.77% was recorded. Similarly, from 1969-70 to 2002-2003, canal irrigated area was increased more than seven fold and a positive change of 10.05% was registered. The micro level analysis indicates that prior to CRBC, rainfall and Rod Kohi were the major source of water for crops, while after CRBC canal irrigation became the major form of irrigation. As a result in the CRBC command sample villages a positive change in the canal irrigated acreage had taken place, whereas negative change in the Rod Kohi acreage was registered. Contrary to this, in sample village Khudaka no significant impact of CRBC on the irrigation pattern was detected. The analysis further revealed that this large-scale increase in the canal irrigated area occurred as a result of CRBC.

Prior to the inception of CRBC, major Kharif crops included millet, fodder, sorghum, while wheat, barley and gram were Rabi crops. After the advent of CRBC, cropped area in both Kharif and Rabi season was largely increased. The macro level analysis revealed that after CRBC, positive changes have been reported in rice, sugarcane, wheat, orchard and vegetables, while negative changes have been registered in sorghum, millet, oilseed, barley and maize. The macro and micro level analysis revealed that area under sugarcane, rice, wheat and orchard has considerably increased, whereas area under sorghum, millet, barley, oilseed and maize has reduced. The analysis further indicated that in the present cropping system new water loving crops such as rice, sugarcane and orchard have been introduced. However, the results from outside the CRBC command area was quite different than the CRBC command villages. In Khudaka both pre and post of CRBC, even a single plot was not cultivated during Kharif cropping season. The analysis further reveals that changes were found similar both at micro and macro level.

In D.I.Khan district, prior to the inception of CRBC, very low cropping intensity prevailed. Before CRBC, the annual cropping intensity was 39.4% in 1969-70. Subsequently, after CRBC, the annual cropping intensity was increased to 47% during 2004-2005. Micro-level analysis indicated that in the CRBC command villages, the annual cropping intensity was increased from minimum 88% in Gomal to maximum 169% in Buchari. However, the condition was quite different in area lies off the CRBC, where no significant impact of CRBC on the cropping intensity was identified.

The analysis revealed that there has been substantial increase in the agricultural production after the inception of CRBC. High agricultural productivity was largely confined to the CRBC command areas. In D.I.Khan district, the agricultural production of almost all the Rabi and Kharif crops was enhanced as a result of CRBC. The increase in agricultural production was recorded in rice, sugarcane, wheat, cotton, maize, pulses and orchard, whereas negative change in agricultural production occurred in millet, barley, sorghum and oilseed. Similarly, after the advent of canal irrigation in the form of CRBC the yield in kg per ha of all the crops have been improved.

In the study area, prior to the inception of CRBC, trend to use the modern agricultural implements was not very common and use of modern agricultural implements was reported from limited areas. However, after CRBC, drastic development has occurred in the use of agricultural implements. This progressive growth is attributed to the socio-economic uplift of the area as a result of CRBC. Presently, in almost all the sample villages, farmers are using modern techniques and trend towards the mechanization is positive.

In D.I.Khan district, before CRBC, the use of chemical fertilizer was not common, but after CRBC, the application of chemical fertilizer was increased considerably. The micro analysis revealed that in the CRBC command sample villages, chemical fertilizer has been widely used particularly after CRBC. It was found from the analysis that the use of fertilizer was generally high in stage I and II as compared to stage III. According to field survey, 95% farmer in the CRBC command area has used chemical fertilizer during the last cropping season and the rest didn't bear the cost of chemical fertilizer. However, outside the CRBC command area, the application of chemical fertilizer is not reported.

The analysis revealed that after inception of CRBC the land values of all the land use categories including residential, agricultural and cultivable waste have been increased several fold. It was found from the micro level analysis that in almost all the sample villages, the residential land prices were higher then rest of the land types. Per unit cultivable waste was found the lowest as compared to that of land for residential or agricultural use, which is considered as more valuable.

One of the major problems developed after large-scale surface irrigation in the CRBC command area was continuous rising of ground water-table, which was observed in several parts of the study area. This is mainly due to the unwise irrigation practices, lack of land levelling, absence of sub-surface drainage and trend towards water loving crops has inclined the water-table in the CRBC command area. Field survey together with the secondary data revealed that the water-table has been rising at an alarming pace particularly in the stage I and III.

After large scale, intensive canal irrigation in the arid tract of D.I. Khan district several changes in the land use and agricultural resources have occurred. These changes are both positive and negative on local and regional level. The present study found that engulfing of prime agricultural land by the built up area, lack of proper crop selection, absence of sub-surface drainage, unwise irrigation practices, the rapid rise in the water-table particularly in the canal irrigated tract are causing the environmental degradation. In the CRBC command area, such environmental changes are occurring and would continue to occur in the large area. This situation if not taken care of well in time might pose serious threat to the environment in the near future.This study, however, provide policy guidelines for ameliorating the negative consequences of CRBIP and avoid repeating the weaknesses of CRBIP in the proposed and future irrigation schemes. Therefore, in the present study an attempt has been made to find out the environmental impacts of CRBC on the land use and agricultural resources of D.I. Khan District and suggest policy recommendation for ensuring sustainable land use and agricultural development.

1.1. RESEARCH PROBLEM OF THE STUDY

The major research problem of the study is to find out the environmental impacts of Chashma Right Bank Canal on the land use and agricultural resources of D.I.Khan district.

1.2. PURPOSE OF THE STUDY

The purpose of the study is to evaluate the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district.

1.3. JUSTIFICATION OF THE STUDY

Water is the greatest resource of humanity (Carruthers, et al., 1997; Guerra, et al., 1998; Kume, et al., 2000). It not only helps in survival but also in making life comfortable (Gang, 1987). Besides various other uses of water, the largest use of water is made for irrigating agricultural land. Irrigation itself is a continuous and reliable supply of water to different crops in accordance with their needs (Carruthers, et al., 1997; Guerra, et al., 1998; Kume, et al., 2000). When sufficient and timely water become unavailable to the crops, it fades away, resulting in low crop yields; consequently creating famines and disasters. Irrigation can thus save us from such disasters (Gang, 1987; Amarasekara, 1993; Ahmad and Ali, 2003).

Pakistan's economy has undergone considerable changes over the years, but the agriculture sector is still the largest sector of the economy (Khalid, 2003; GoP, 2004c; Shams, 2006). Over the last one decade (1990s), agriculture grew at an average annual growth rate of 4.5%, but was quite volatile, rising as high as 11.7% and declining by as much as 5.3% (Khalid, 2003; GoP, 2004c). Pakistan total reported area is about 80 million ha. Approximately 22.2 million ha is cultivated, out of which 15.6 million ha is irrigated (GoP, 2004c). NWFP covers 8.1 million ha, out of this 1.9 million ha (24 %) is cultivated and less than 10% is irrigated.

Irrigation is an important agricultural input and Pakistan is one of the countries where dense network of irrigation exists. Since the introduction of canal irrigation, waterlogging and soil salinity have become the major problems impeding agricultural development (Ahmad, 1993; Khan, 1996; Khan, et al., 2006). The table I-1 indicates that throughout Pakistan, the intensity of irrigation is improving. The figure I-1 gives the comparative analysis of Pakistan, NWFP and D.I.Khan district, which indicates that the rate of change in irrigation intensity is quite high in D.I.Khan district as against Pakistan and NWFP. This is mainly due to the construction of CRBC in D.I.Khan district.

NWFP is not self sufficient in staple foods, but the two major projects recently completed in NWFP including Mardan SCARP and CRBIP have considerable impact on the provincial economy (GoNWFP, 2004c). The government major objectives in the water resource sector are: Protection of fertile land and infrastructure from waterlogging, salinity and floods; improvement of existing irrigation and drainage facilities; extension of irrigation and drainage through new irrigation schemes, medium size reservoir and public tube wells. CRBIP falls under one of these objectives i.e. extension. This project spreads over the two provinces including NWFP and Punjab and is therefore accorded high priority at both the federal and provincial level. The project aims to increase agricultural productivity, improve farm income and provide employment to the expanding rural labour. The CRBIP is recently completed (2003) in three stages. Stage I, II and part of stage III falls in district D.I.Khan (NWFP), whereas rest of stage III command D.G.Khan district (Punjab province). CRBC is a mega irrigation project commanding 250,000 ha.

Environmental Research Organizations, worldwide are under increasing pressure to undertake impact assessment of the project activities and integrate the socio-economic and environmental considerations in research, planning and implementation (Khan, et al., 2006). In the study area, water is one of the most critical and valuable natural resource. There is a great potential for water resource development in general and irrigation in particular. So far very little progress has been made in this respect. In D.I.Khan district, favourable climatic condition allows cropping throughout the year, but due to scanty and erratic rainfall, cropping is not done over an extensive part of the district. In areas where water is limited, emphasis remained on drought resistant crops. In extensive part of the district, Rod Kohi (hill torrent) and rainfed farming dominate the land use, but erratic rainfall largely results crop failure before ripening. The yields are therefore very low. Hence, in the study area, it was the man's daring effort to bring water through CRBC.

This study however attempts to evaluate the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district. In the study area, CRBC was the landmark intervention in the desert ecosystem, which brought radical changes in the command area. It has both positive and negative impacts and also varies from short to long-term on local and regional level, if judged from various angles. Despite such vulnerability, the Asian Development Bank (the funding agency) classified the project as Category B. This means the project does not require a full Environmental Impact Assessment (EIA). Hence, EIA was not carried out. This research is a sort of ex post impact evaluation and pioneering of its nature in evaluating irrigation projects in Pakistan. This study would provide policy guidelines for decision makers, planners and administrators as well as to the proposed Chashma Right Bank 1st Lift Irrigation Project (which will command 117,500 ha) and future irrigation projects to avoid repeating weaknesses of the CRBIP. Therefore, in the present study, an attempt has been made to carryout both micro and macro-level investigation, to find out the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district and suggest policy recommendations for ensuring sustainable land use and agricultural development of the area.

Table I-1

Pakistan, irrigation intensity, 1990-91 and 2003-2004

Area	*Year*	*Total cultivated area (M ha)*	*Total Irrigated (M ha)*	*Irrigation intensity (%)*
Pakistan	1990-91	21.82	16.75	77
	2003-04	22.12	18.78	85
NWFP	1990-91	1.90	0.84	44
	2003-04	1.89	0.95	50
D.I.Khan District	1990-91	0.238	0.088	37
	2003-04	0.236	0.146	62

Source: GoP, 2004c; GoNWFP, 1991 and 2004c

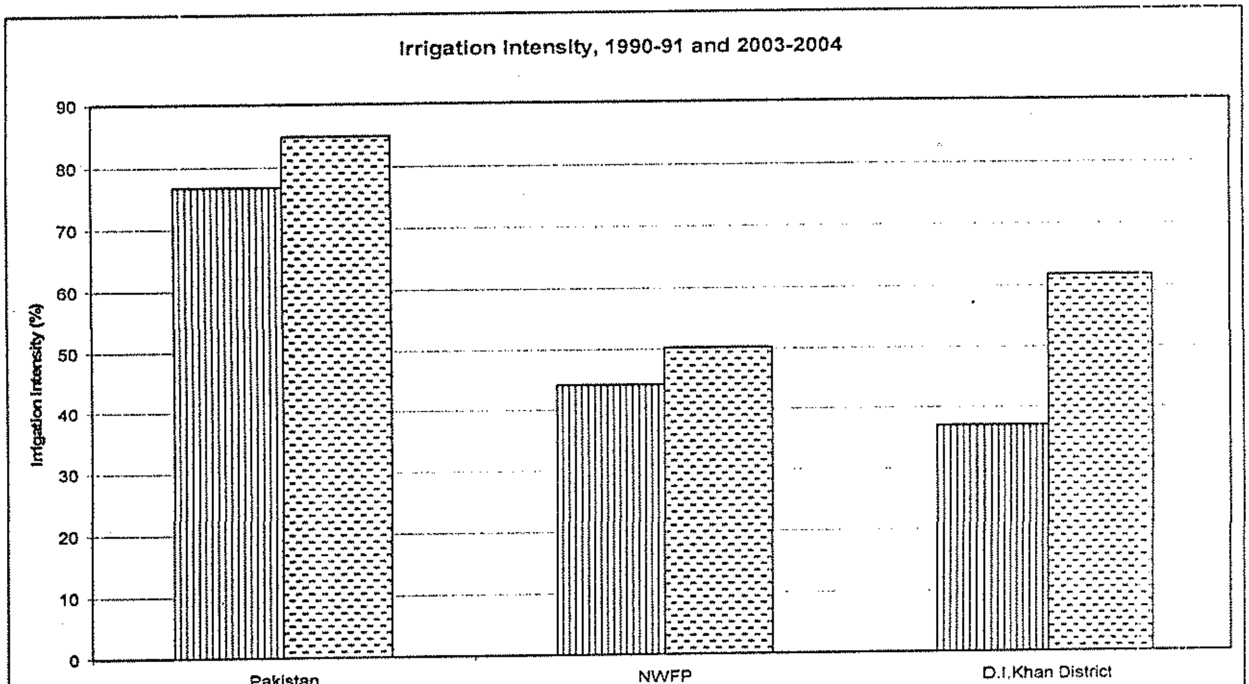


Figure I-1

1.4 RESEARCH METHODOLOGY

The following research methodology was adopted for the study to achieve the stated purpose (Figure I-2). Before research topic selection an intensive literature review was carried out to make a strong theoretical framework. As a result, the topic was selected and a framework

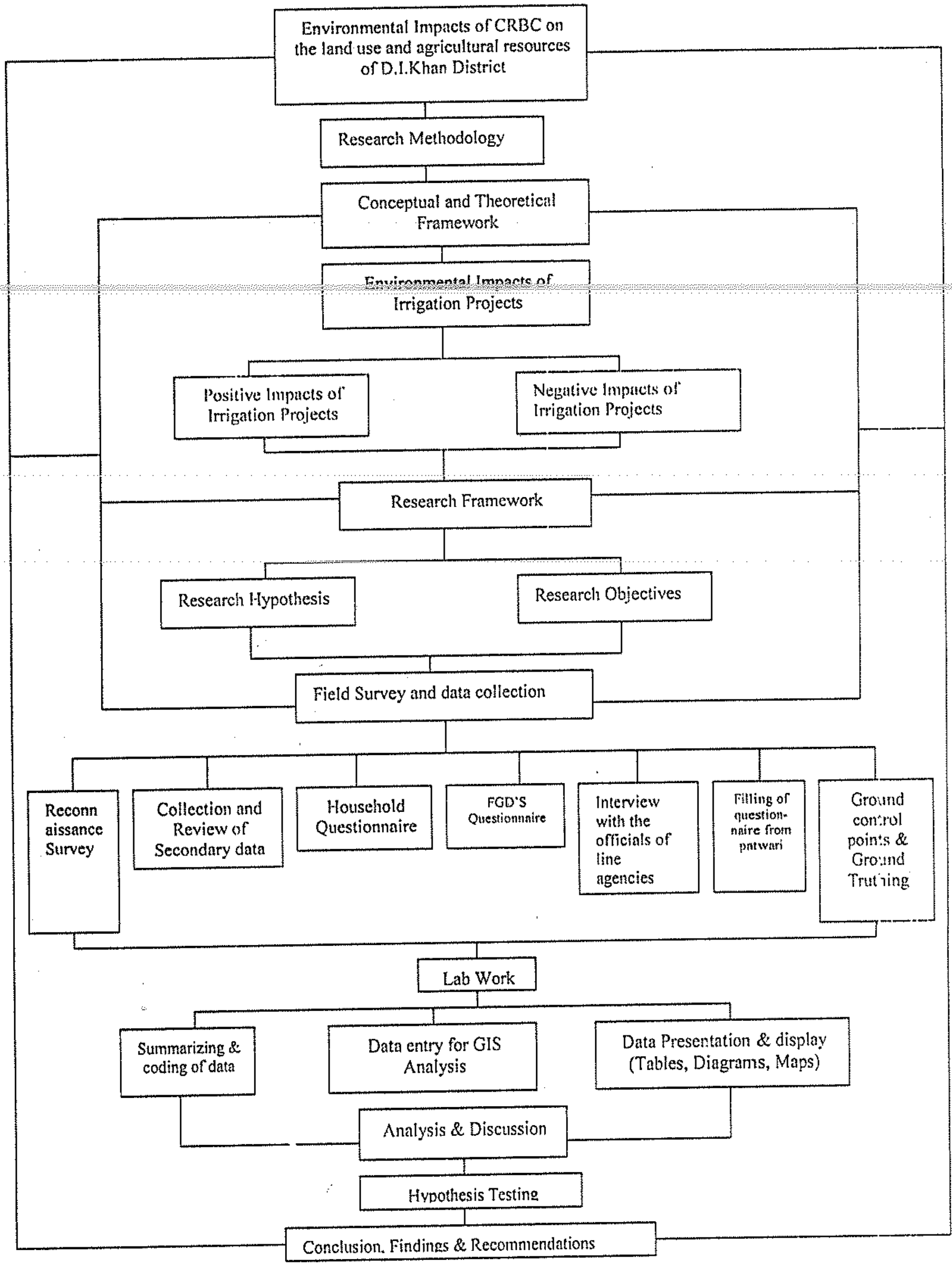


Figure I-2 Research Model of the study

was developed for necessary data collection. Both primary and secondary sources were used for the collection of data and information.

Primary data was required to find the condition of land use and agricultural pattern prior to the availability of canal irrigation (CRBC) and after the availability. Data were collected through questionnaire survey, field observation and interviews with the key stakeholders including respondents from the line agencies, landlords, farmers, officials of the CRBIP and environmentalists. However, for in depth study five sample villages were randomly selected and data were collected by adopting above mentioned techniques. Field observations were recorded in the form of photographs.

As far as secondary data is concerned, it was obtained from the related line agencies, international organizations, non-governmental organizations (NGOs), reports, journals, maps and electronic data base searches etc. Whole district was covered for the assessment of impact of CRBC on the land use and agricultural resources. The collected data were finally analysed using statistical packages, GIS software and were presented in the form of maps, tables, statistical diagrams and descriptions.

1.5 ORGANIZATION OF THE RESEARCH THESIS

The study as a whole has been divided into ten chapters. Chapter one deals with the detail introduction of the research work. Chapter two is given to environmental setting of the area. Chapter three develops theoretical framework and literature review. Chapter four presents an overview of Chashma Right Bank Irrigation Project (CRBIP). Chapter five describes the research methodology and data collection techniques adopted for the study. Chapter six analyses the environmental impacts of CRBC on the land use and irrigation pattern. Chapter seven assesses the environmental impacts of CRBC on the cropping pattern and cropping intensity. Chapter eight analyses the environmental impacts of CRBC on the agricultural production. mechanization, land value and water-table. Application of checklisting and SWOT techniques for the assessment of impacts of CRBC on the land use and agricultural resources of D.I.Khan district is given in chapter nine. Finally, chapter ten presents the summary, major findings and policy recommendations.

PART ONE

THEORITICAL FRAMEWORK

AND

LITERATURE REVIEW

CHAPTER # II

ENVIRONMENTAL SETTING OF THE STUDY AREA

Introduction

This chapter discusses the environmental background of the study area. The chapter is divided into four sections. Section one deals with the physical environment of the district, whereas section two and three discusses the human resources and cultural environment, respectively. The chapter is concluded in the final section.

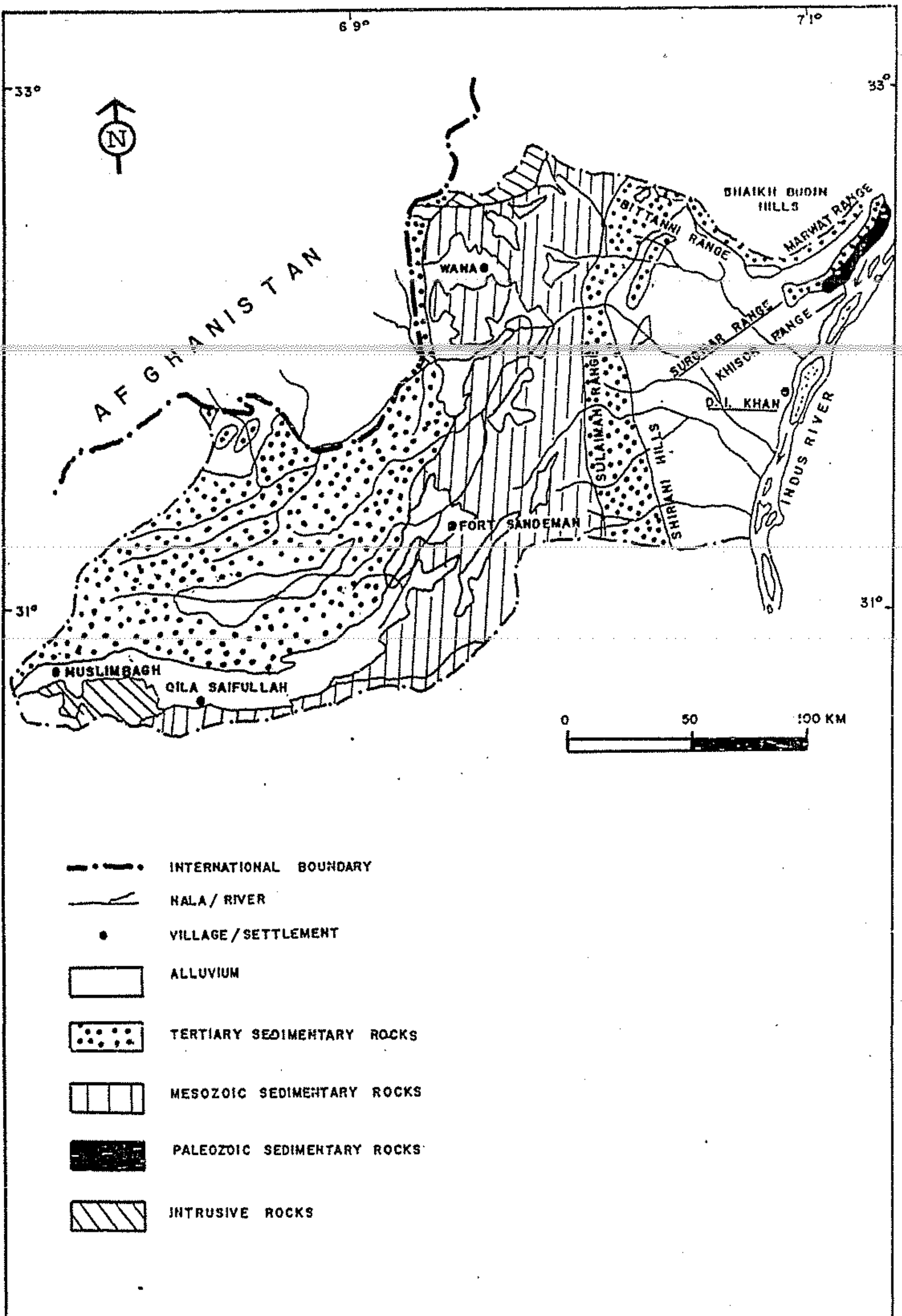
2.1 PHYSICAL ENVIRONMENT

Man's relationship with his physical environment is a complex one. Man has a role in changing the landscape, as to understand the degree, to which the physical environment has shaped the way of his life (Dubey, 1992). It becomes necessary to examine thoroughly the physical framework in spatial context to understand the limitations imposed in terms of carrying capacity of the area.

2.1.1 Geological setup

D.I.Khan is surrounded by sedimentary rocks ranging in age from Permian to recent past. A blanket of quaternary alluvium mainly composed of unconsolidated conglomerate, sand, siltstone and loess underlies the vast plain (Said, 1971). The Bhittani range is mainly comprised of Siwalik group of Suleiman range, which is further divided into Vihowa, Litra and Chaudhwan formations (GoP, 1999). These rocks are composed of sandstone, siltstone, shale and clay. Marwat and Khisor ranges are also predominantly comprised the same rocks of Siwalik group (Dichter, 1967; GoP, 1969). However, on the western extension of the Marwat range, there is a faulted block of Permian and Mesozoic sedimentary rocks (Map II-1).

The rock of the lower Permian comprises clay, sandstone and shale, and the upper Permian are consist of limestone, marble and sandstone. While the rocks of Mesozoic are comprise of Triassic marble, dolomite, limestone and Jurassic sandstone, quartzite shale, marble and shale (GoP, 1999). The area remains unexplored. However, Lucky Cement Factory is utilizing the Sheikh Budin limestone. The area is economically poor in mineral resources but some deposits of silica sand are found in the surroundings of Pezu. Limestone is also available, which is a good source of cement & building material. Limestone and gypsum are available in large quantity.



GEOLOGY OF D.I.KHAN AND SURROUNDING

Map II-1

2.1.2 Physiography

The physiographic region comprising of Dera Ismail Khan and Tank districts is known as Gomal basin (Said, 1971). It represents a rough shape of quadri-lateral narrowing towards the south. The D.I.Khan district is a vast basin rimmed by mountains on two sides (Map II-2). To the northeast is the Khisor range, which has a northeast to southwest alignment. It consists of low hills that ranges in height from 2,500 ft. to 3,000 ft. above sea level. The Marwat range runs almost parallel to the Khisor range (Dichter, 1967). Its height increases gradually from 2,460 ft. in the north to 4,516 ft. in the south. Sheikh Budin is the highest peak and marks the apex of an anticline, in which limestone rocks have been exposed. Lying between the Khisor and Marwat ranges is a depression of about 24 miles long and 4 miles wide known as Paniala basin. It is filled with recent material and recently subjected to severe gully erosion.

Physically, D.I.Khan district can be divided into the following seven broad regions (Dichter, 1967; GoP, 1969; Said, 1971; ADB, 1987; GoP, 1999).

i. ACTIVE FLOODPLAIN

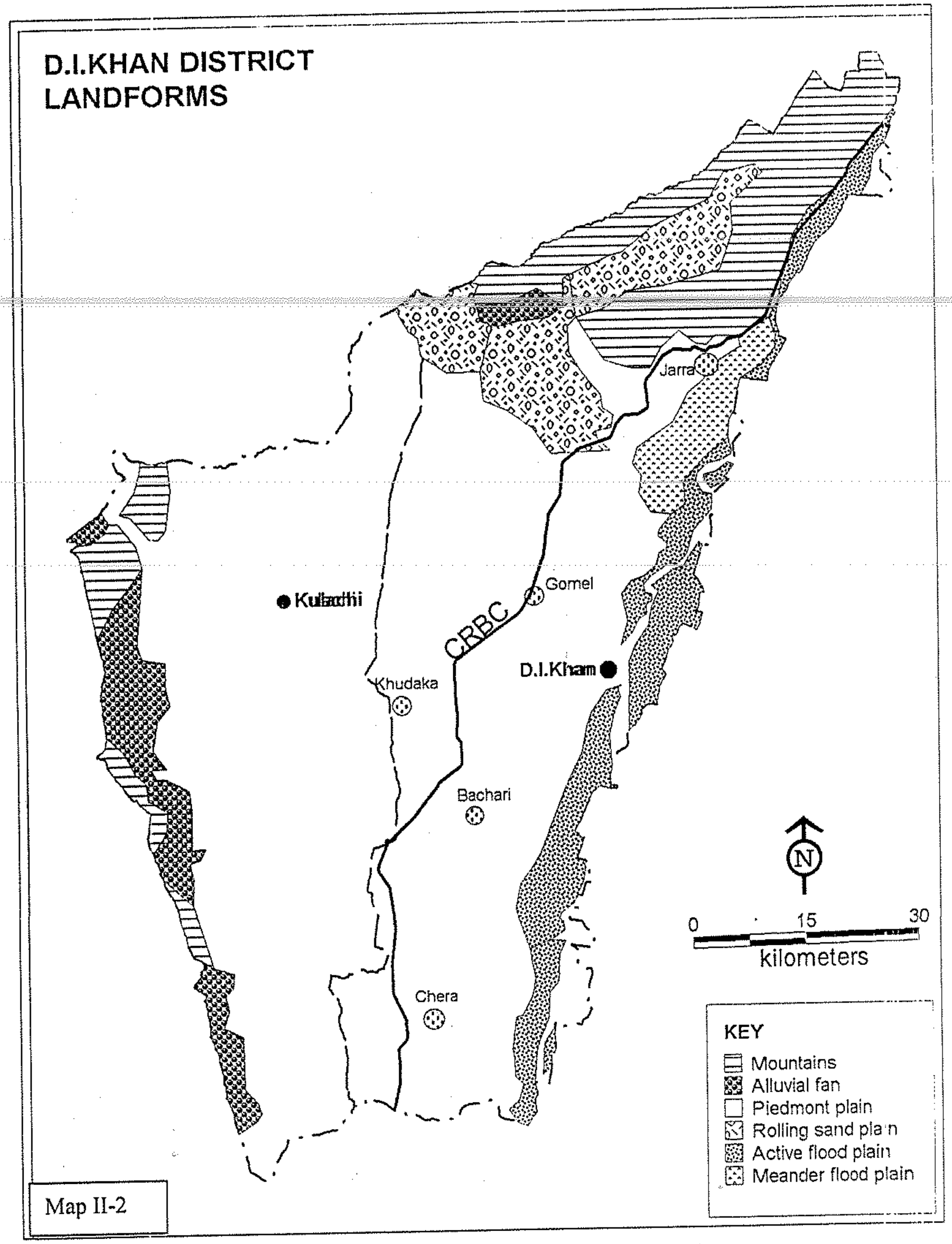
It forms a narrow strip of about 1 to 8 km wide on the right bank of river Indus. The active floodplain can be referred to as the summer Indus bed, almost all of the area is inundated during the summer season. The position of channels and river bars are continuously changing (GoP, 1969). Erosion and deposition take place on a vast scale during the flood seasons. In winter, the active floodplains show a level or slightly undulating surface, scarred by numerous active and abandoned channels.

ii. MEANDER FLOODPLAIN

Meander floodplain occupies 166 sq. km of the total area. It occurs in a compact block, 26 Km long and 10 Km wide, in the north eastern parts of the district (D.I.Khan). It covers the area from Bilot to Awan, Lang Khai, and Kalaghar, lying between the Paharpur canal and the Indus river. The gentle gradient of the river is responsible for the formation of meander floodplain (ADB, 1987). This is characterised by numerous bars, meander scars, levees and oxbow lakes. These features change continuously, as and till the river changes its course and produce a new bend. They become stable and remain so, unless the river returns and resume the process.

iii. ROLLING SAND PLAIN

Rolling sand plain occupies 663 sq. km area. It occurs in the drainage basins of the Murinwala Nala, Pezuwala Nala, Tapainala Nala, and Rud Sohaili Nala at the foot of the Marwat-Bhittinni range (Said, 1971). Much of the eolian sand was derived from the underlying Pleistocene sandstone bedrock and has been reworked by streams and wind.


D.I.KHAN DISTRICT
LANDFORMS
Jarra
Gomel
Kulachi
CRBC
D.I.Khan
Khudaka
Bachari
Chera
N
0
15
30
kilometers
KEY
Mountains
Alluvial fan
Piedmont plain
Rolling sand plain
Active flood plain
Meander flood plain

Map II-2

iv. HILLY SANDY PLAIN

Hilly sand plain occupies 103 sq. km. It occurs in the drainage basin of the Larginala at the foot of the Sur Ghar hills and is separated from the piedmont plain by the Paharpur canal (GoP, 1995b). The hilly sandy plain has a desert landscape, where sand ridges, transverse and longitudinal dunes are found over a large area. The material was originally derived from the floodplain and later on reworked by wind.

v. ALLUVIAL FANS

Alluvial fans occupy 860 sq. km. They occur at the foot of the mountains, where rivers and streams enter the plain. During the process of fans formation, the streams change, its course many times, so that the surface shows an interlacing network of braided channels (GoP, 1969). Alluvial fans may occur singly or as a band of coalesced fans, where several streams issue from the mountain in a close proximity.

vi. PIEDMONT PLAIN

When a stream is dissecting mountains, it deposits material along the front of the range; farther from the mountains, the material carried by stream form a broad flat plain. The surface of such a continuous apron is sometimes referred to as Bajada or piedmont plain. The piedmont plain of the area slopes imperceptibly away from the Waziristan Mountains, towards the Indus River (JICA, 1993). Its surface is smooth except where low sand dunes have been formed by wind action. Piedmont plain is rather a large landform unit, occupying about 5,672 sq. km. It occurs in the central parts of the district, between the alluvial fans and the active floodplain of the Indus River.

vii. THE MOUNTAINS

Exposed bedrock occupies 1,118 sq. km of the area, and consists of the Khisor, Marwat and the Bhittinni ranges.

2.1.3 Climate

Several meteorological stations have been reported to exist within and in the vicinity of D.I.Khan, some of which have been abandoned and others have data of only fragmentary nature (JICA, 1993). The only long-term data is available for D.I.Khan meteorological station. The climate of D.I.Khan is characterized by long hot and dry summer and short cold winter (Figure II-1). The hottest month is June. The mean maximum and minimum temperature recorded in June is 42°C and 27°C, respectively (Table II-1). The temperature begins to rise from April to June and then falls gradually (GoP, 1999). The two important weather elements i.e. temperature and rainfall are discussed in detail.

i. TEMPERATURE

There are extremes in temperature. During summer (April-October), the mean daily maximum temperature is usually above 33°C for seven months, while 37°C and above is recorded from May to August. June is the hottest month with mean maximum temperature above 41°C (GoP, 1999; WAPDA, 2002). During May and June the humidity remains low and the area remain under periodic dust storm. The hot wind known as sunstrock (Loo) blows across the D.I.Khan.

Winter is short and fairly cold with severe frost and temperature touching the freezing point. January is the coldest month and records a mean minimum temperature of 4°C and maximum 20°C. Due to cloudless sky, the temperature drops suddenly at night, both in summer and winter. As a result a considerable diurnal range of temperature that varies from 15°C in June to 16°C in January. The annual range of temperature is 37°C (GoP, 1969; JICA, 1995; GoP, 1999; WAPDA, 2002). The cool wave starts in October. December, January and February are the cold months. In winter, the daytime temperature is not very low. However, there is sharp decline at night.

ii. RAINFALL

The average annual rainfall is less than 300 mm. Rainfall is received in two well-marked seasons. Approximately 45% of the annual rainfall is received from summer monsoons during July and August, while the western disturbances are responsible for 30% of the annual rainfall mainly receive during winter and spring (Figure II-1). Based on the normal data (1961-2000), the annual amount of precipitation decreases south wards from about 290 mm in the north to less than 200mm in the south. In the hilly and mountainous areas, the annual rate of precipitation appears to be partly controlled by the topography i.e. the higher areas receives more precipitation than the lowland. It is estimated, that the average annual rainfall in the mountainous areas is about 20% more than that in the plain areas. It is also evident from the record that year to year precipitation varies and there may be considerable difference among stations for individual months. This clearly shows that the average annual rainfall is far below the normal requirement for the principal crops. Because of low rainfall and high evapo-transpiration, the natural vegetation is meagre.

In D.I.Khan rainfall is received in two well-marked seasons. Approximately 45% of the annual rainfall received from summer monsoon during July and August, while the western disturbances are responsible for 30% of the annual rainfall mainly received in winter. The average annual precipitation is 268 mm. The amount of rainfall is not sufficient for the agricultural production. The maximum rainfall received during July 60.8 mm.

During May and June relative humidity remains low and the area is under periodic dust storms. The hot wind known as "Loo" blows across the entire basin. The relative humidity varies from 36% in May to 64% in August. On average the humidity is high in summer, autumn and winter, whereas low in spring. The high temperature, low amount of precipitation as well as its poor seasonal distributions and low humidity that are prevalent throughout the area, provide a natural barrier in the promotion of agriculture sector.

Table II-1

Mean monthly temperature, precipitation and relative humidity, 1961-2000

Month	*Mean Temperature (°C)*		*Rainfall (mm)*	*Relative Humidity (%)*
	Maximum	*Minimum*		
January	20.3	4.2	10.0	59.2
February	22.1	7.3	17.5	55.8
March	26.9	12.9	34.8	55.6
April	33.4	18.5	21.7	45.6
May	38.7	23.1	17.2	36.8
June	41.5	26.8	14.4	41.9
July	38.5	26.9	60.8	59.7
August	37.3	26.4	57.5	64.5
September	36.7	23.8	17.6	57.6
October	33.3	17.3	4.8	53.1
November	27.7	10.5	2.1	57.9
December	21.9	5.3	10.4	61.6
Annual	31.5	16.9	268.7	54.0

Source: Pakistan Meteorological Department, Karachi.

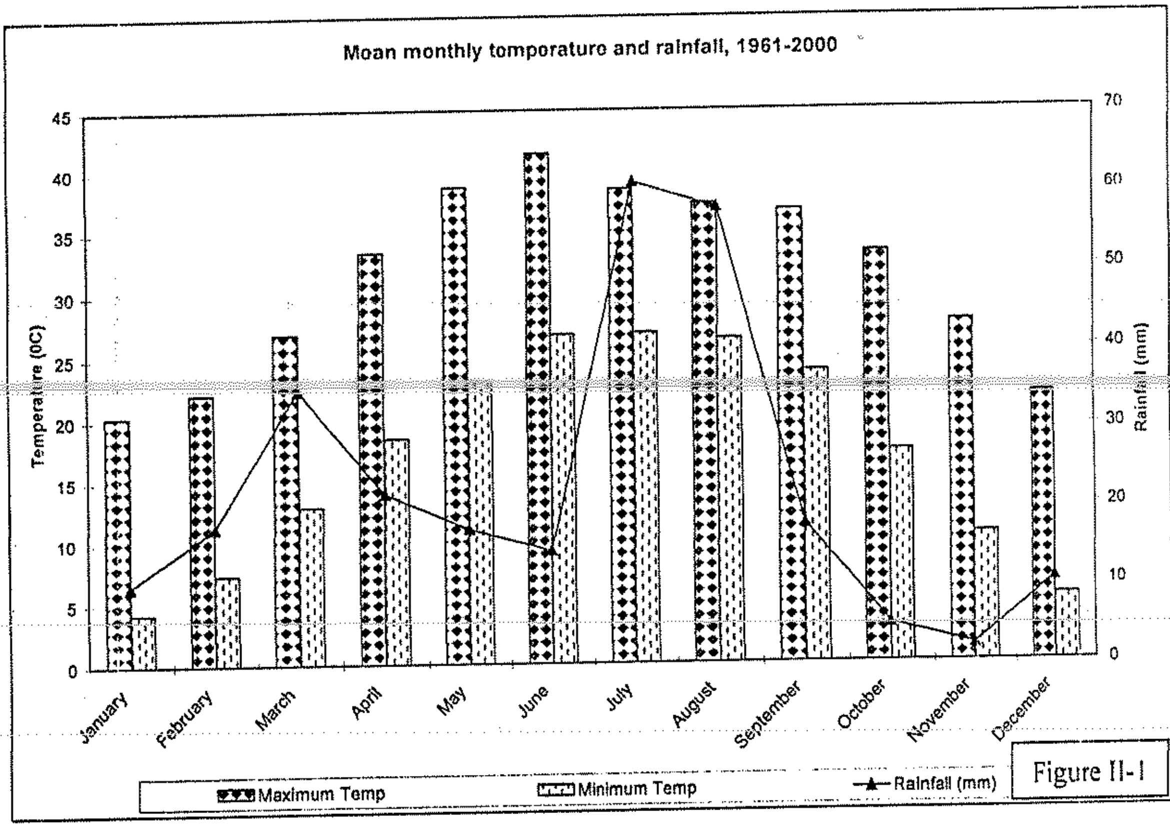


Figure II-1

2.1.4 Soil

Parent material, climate, living organisms, relief, groundwater and human activity interact with time to form soil (Khan, 1996). Depending upon the varying soil forming factors, in different parts soil has developed different characteristics.

The soils of D.I.Khan have been formed from two kinds of parent materials (i) mixed calcareous alluvium derived from the calcareous sandstones, shale and clays of the lower and middle Himalayas and the granites, schist, gneisses and slates of the Higher Himalayas; and (ii) local outwash plain derived from the sedimentary rocks of the Suleiman and Marwat ranges (GoP, 1969). Here, the soil texture ranges from sand to clay. The relief is nearly level, but locally there are depressions, convex and gently sloping. The genesis of various soil types is discussed below.

The soils occurring in active floodplains of the Indus River and the piedmont plains are the youngest and therefore the least affected by pedalogical processes. These soils have formed in recent sediments, and parts are still subject to intermittent accretion. They are calcareous and lack profile development, although, owing to high biotic activity and ploughing, the topsoil has largely been homogenized.

Mostly, the soils of D.I.Khan are alluvial with low permeability. The floods usually bring large quantities of fine silt and clay particles and deposit the same in various tracts of D.I.Khan areas. There is no specific profile formation in these plains but one can easily spot out formation of different layers (GoP, 1985). Soils of the area are mostly alkaline and cause the unavailability of phosphorous to plants because of its precipitation in soil solution by calcium. Organic matter status of D.I.Khan soils is low as the farmers mostly use crop residues and animal waste as fuel.

2.1.5 Forest

The vegetation of D.I.Khan district is composed of tree and shrubs (GoP, 1987). On account of low annual rainfall (less than 300mm) and high evapo-transpiration, the natural vegetation is very poor. Much of this has been cleared for fuel, grazing or cultivation. Today the natural vegetation survives only in scattered patches.

The mountainous area is mostly barren, with no vegetation cover, but isolated patches stands of Prosopis Spicigera (*Jhand*), Ziziphus Muratiana (*Bair*), Oliacuspodite (*Kao*) and Acacia modesta (*Phulai*) etc. are found at the high elevation of the Sheikh Budin and Marwat-Bhittinni ranges (GoP, 1969; Said, 1971). The piedmont plain is marked by Sacchum Munja (*Kana*), while on the sandy soils, Acacia arabica (Kikar). Capparis aphylla (Karir) and S.Lsol foctida (Lana) on saline soils, while Prosopis glandulose (Jhand) and Calotropis procera (Ak) found on silty and clay soils. Along the riverine tract, variety of tree vegetation found consisting of Phoenix dactylifera (Date Palm), Tamarix articulata (*Farash*), Dalbergia sisso (*Shishum*). The numerous sandy bars within the river channels have a dense cover of grasses such as Sacchum Spontanium (*Kahi*), Telia elephantiana (*Kunder*) and Sacchum Munjia (*Kanna*). The forest department reserved 75,000 acres area and along the roads has successfully planted Accasia, eucalyptus and shisham. The date palm trees are found in abundance in Paharpur and Paniala circle.

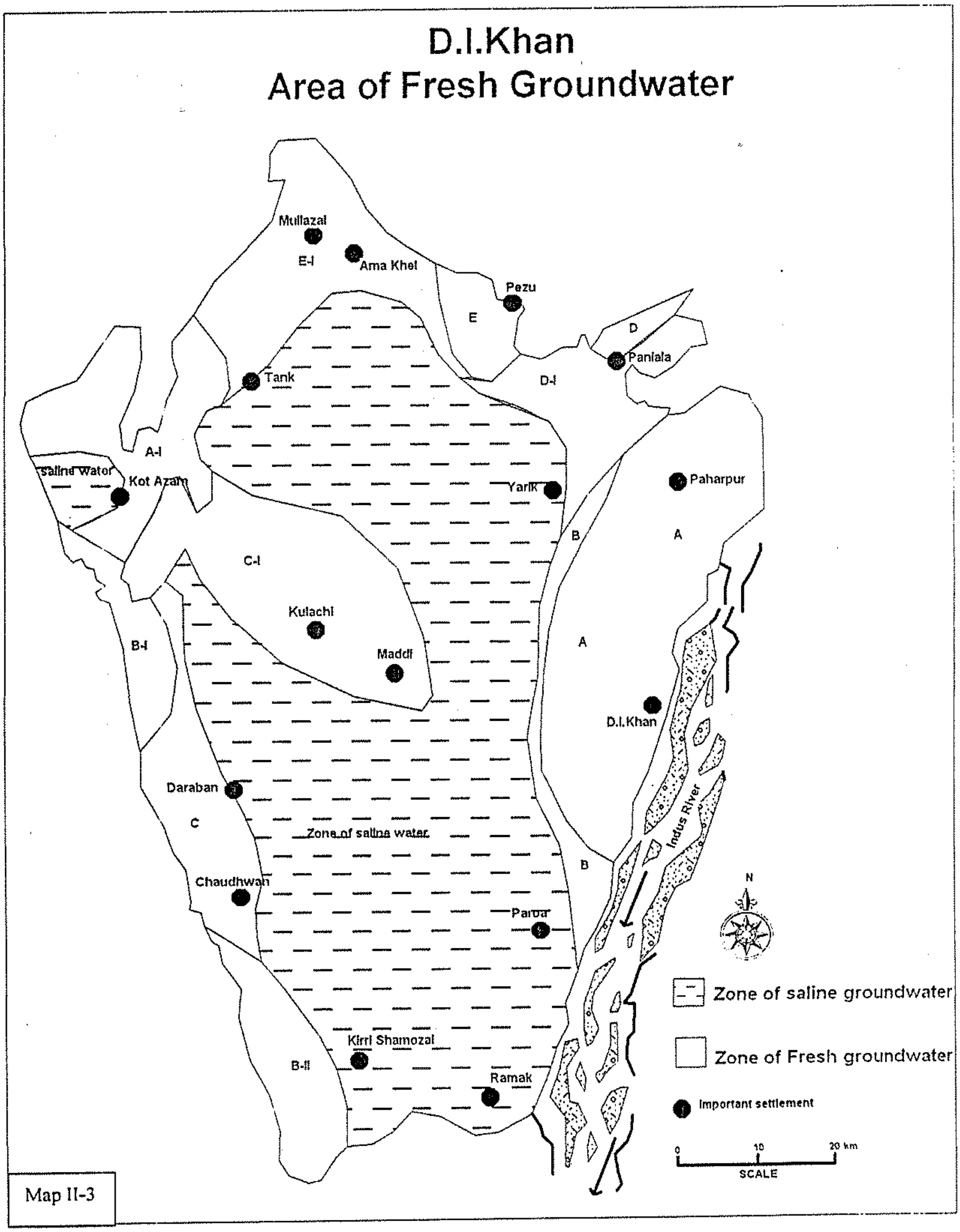
In irrigated areas, people plant tree on their farm lands yet the number of farmers making such efforts is quite few on the one hand and on the other the quality of such practices is not up to the mark. The reason for low yielding from such activities could be poor selection of species for plantation coupled with the lack of forestry extension services (Khan and Khan, 1986; GoP, 1987). However, with the introduction of modern techniques and provision of high yielding species suitable for existing physical conditions of the area can enhance the production. Keeping this in mind, the forest department proposes that people may be effectively assisted both in technical know how and provision of better species, so that optimum production level can be achieved (GoNWFP, 1995; GoNWFP, 1996a). The proposed species to be planted on agriculture lands are Robinia Pscudocasia, Ailanthus Altisima, Melia Azadirechta, Morus Alba and good quality of ziziphus etc. Plantation of such species on rainfed agriculture lands will ensure the availability of fire-wood and also fulfil the fodder requirements (JICA, 1993; JICA, 1995; WAPDA, 2002).

2.1.6 Hydro-geology

The results of the geo-physical and hydro-geological investigations indicate that the lithology of the alluvial fill along the mountain ranges generally consist of coarse sediments, like sand, gravel and boulder beds with clay layers. The coarse deposits are predominantly found in the area around Kot Azam, where the Gomal river enters the plain. In the central part of the piedmont plain, around Kulachi, the alluvial fill consists of sand layers with alternating clay deposits. The data available from test wells north of Pezu-Tank road and from the north-eastern part of piedmont plain show sub-surface lithology consisting of alternating sand and clay layers with rare gravel and boulder beds (GoP, 1985).

The floodplain deposits along the Indus river consists of thick sand formation with a maximum depth of about 425 metres. They form good aquifers. The groundwater table in most parts of the floodplain is generally less than 20 metres, whereas in the piedmont plain it ranges from 2 metres to over 100 metres. The groundwater is recharged from the mountainous streams and Indus river (Map II-3).

The flow of groundwater in the piedmont plain is from west to south-east. In the north near Ama Khel, groundwater flow is directed south eastward that gradually changes its flow direction towards south from an altitude of about 170 metres. According to GoP (1985), in D.I.Khan both saline and fresh groundwater occurs. Major part of the area has been found to contain saline water. Large quantity of fresh groundwater is also available in the area, but it is commonly overlain by saline water.


D.I.Khan
Area of Fresh Groundwater
Mullazai
E-I
Ama Khel
Pezu
E
D
Paniala
D-I
Tank
A-I
Saline Water
Kot Azam
Yarik
Paharpur
B
A
C-I
Kulachi
Maddi
B-I
A
D.I.Khan
Daraban
C
Zone of saline water
Indus River
B
N
Chaudhwan
Paroa
Zone of saline groundwater
Zone of Fresh groundwater
Kirri Shamozai
B-II
Ramak
Important settlement
0
10
20 km
SCALE
Map II-3

2.2 HUMAN RESOURCES

The study of human resource is as important as the physical environment for estimating the carrying capacity of an area. Therefore, population analysis is essential in order to understand it. The total population of D.I.Khan was 853 thousands in 1998 (GoP, 1999). It grew at an average annual rate of 3.26%, during 1981-98 (GoP, 1983; GoP, 1999). Thus, this period can be recognized as turn over period for fertility transition. However, average annual growth rate varies from tehsil to tehsil; minimum in Kulachi (2.88 percent) and maximum in D.I.Khan (3.46%). During 1951 population census, it was about 223 thousands, that increased four fold from 1951-98 (Table II-2). Since the inception of Pakistan, the population of D.I.Khan is growing faster than the national average. The map II-4 indicates mouza-wise population variation during 1981 to 1998. In 1998, the national average annual growth rate was 2.6%, compared to 2.8% for NWFP and 3.26% per annum for D.I.Khan.

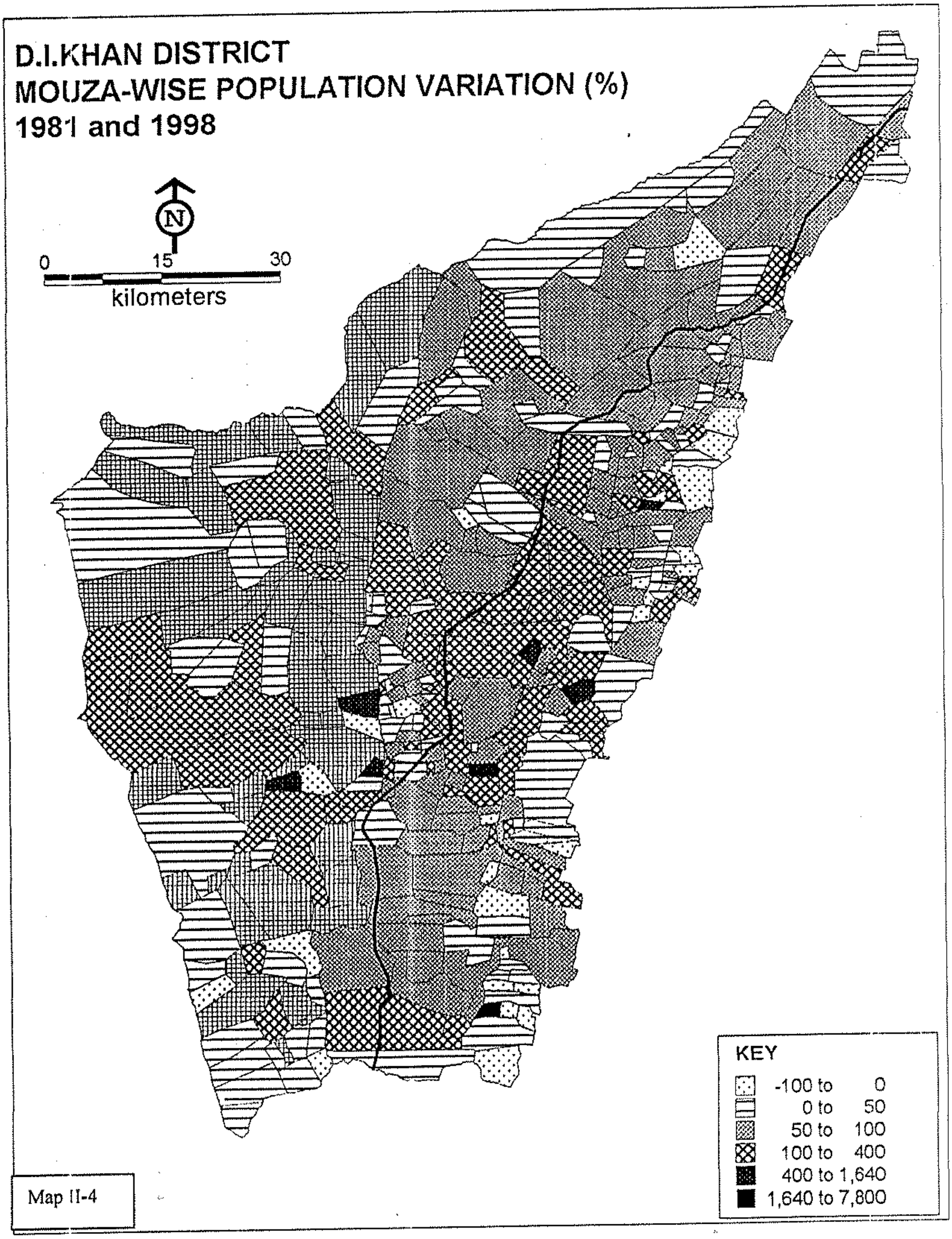
Table II-2

D.I.Khan district, Population growth rate from 1951-98.

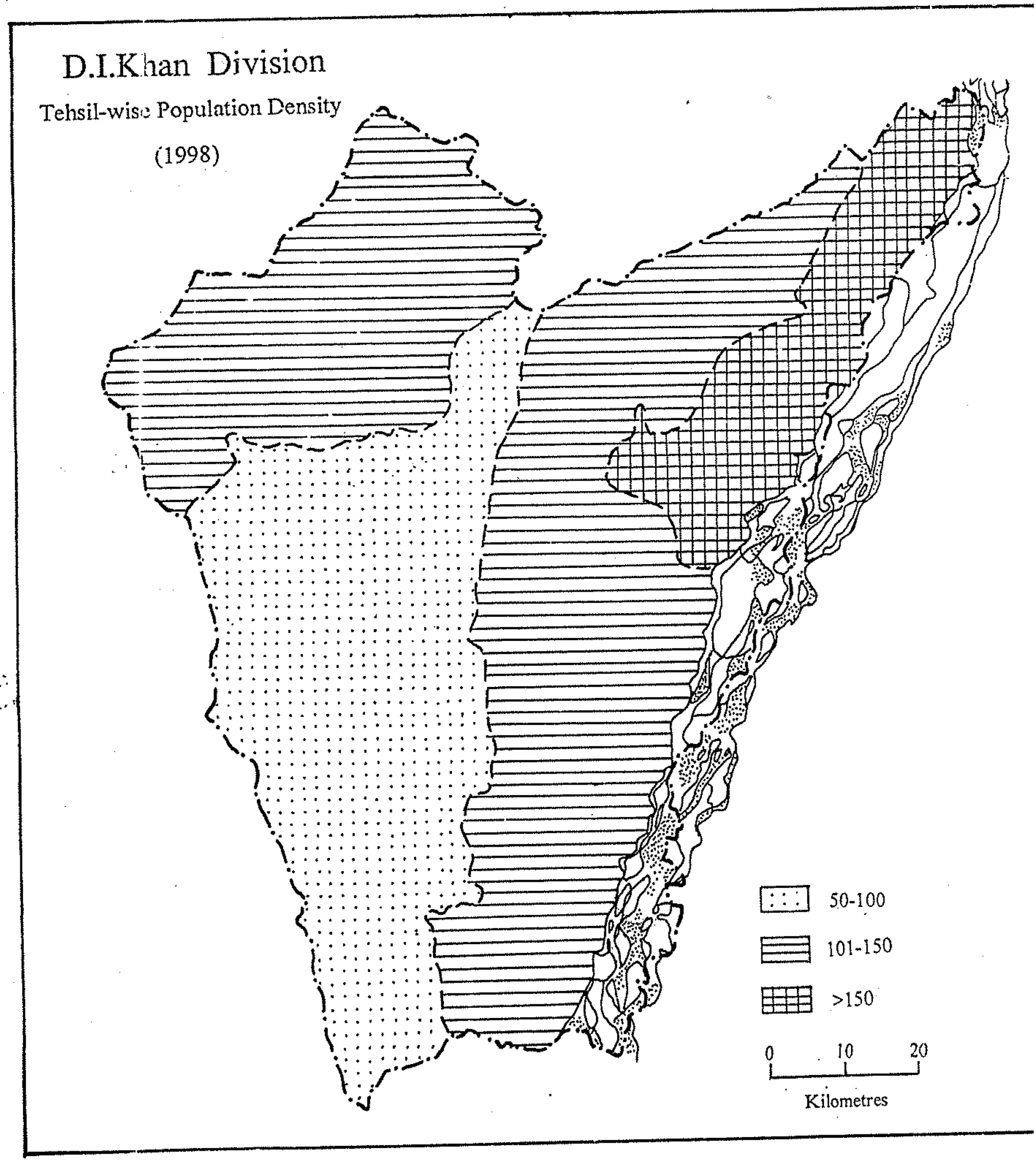
Census Year	*Population (000)*	*Intercensal increase (%)*	*Average annual growth rate*
1951	223	-	-
1961	272	21.98	2.01
1972	380	39.85	2.93
1981	494	30.03	3.23
1998	853	72.52	3.26

Source: GoP, 1951,1961,1976,1983 and 1999

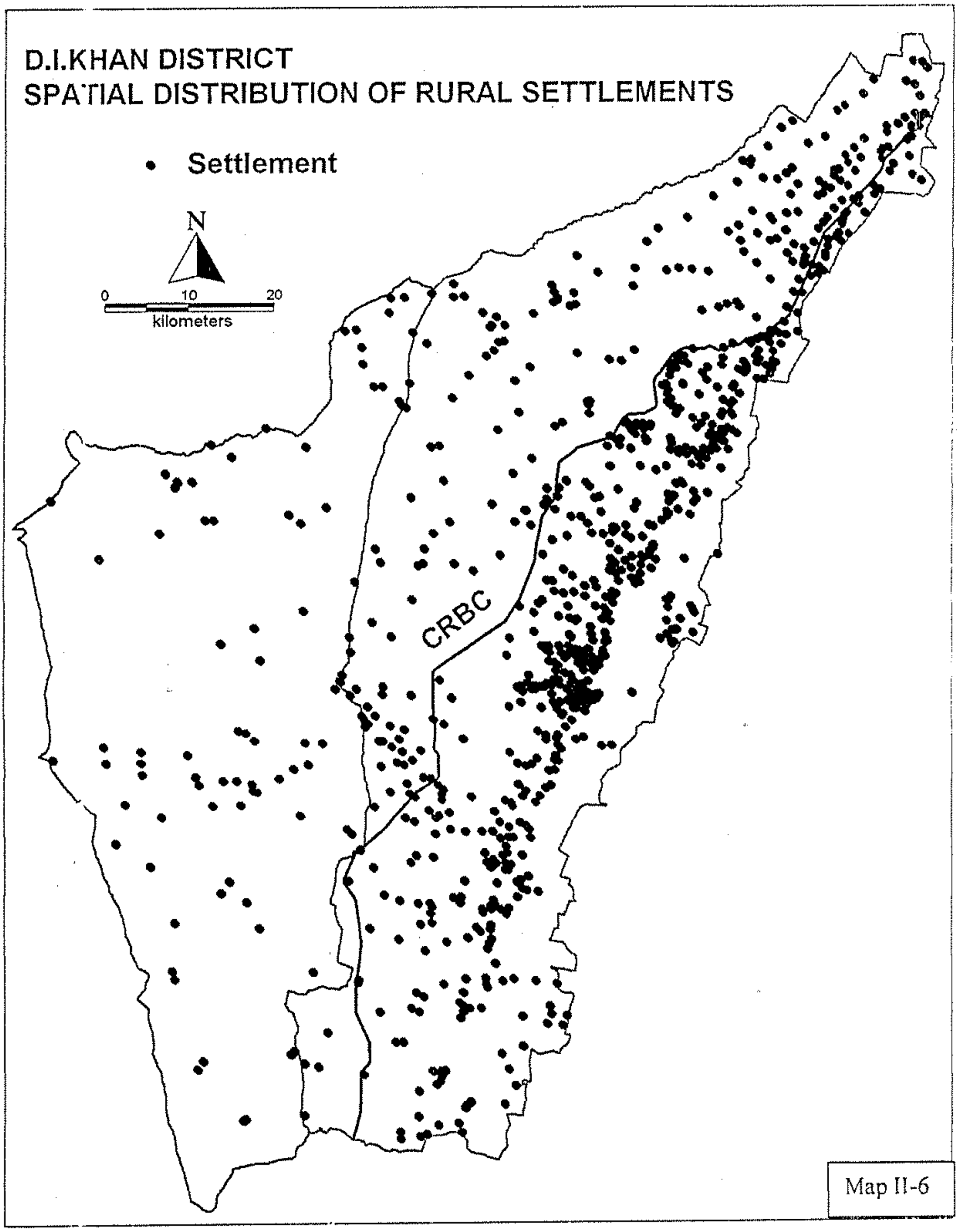
The total area of D.I.Khan district is 7,326 sq. km, which gives population density of 123 persons per sq. km in 1998, as against 70 persons per sq. km in 1981, indicating fast growth rate. Some tehsils are densely populated, while others thinly populated (Map II-5). The pressure on land is continuously increasing. In 1961, the density of population was 39%/sq km when total population was 352,247. Comparatively in 1998, tehsil-wise population density of Paharpur (164 person/sq. km) has highest followed by D.I.Khan (148), and Kulachi (57.5) (Table II-3). Spatial distribution of rural settlement can be ascertained from map II-6. In Paharpur and D.I.Khan tehsil high population is largely due to the existence of canal irrigation network. Therefore, the density is high in the irrigated areas and low in the rainfed and Rod Kohi areas (Map II-7).


D.I.KHAN DISTRICT
MOUZA-WISE POPULATION VARIATION (%)
1981 and 1998
N
0
15
30
kilometers
KEY
-100 to 0
0 to 50
50 to 100
100 to 400
400 to 1,640
1,640 to 7,800

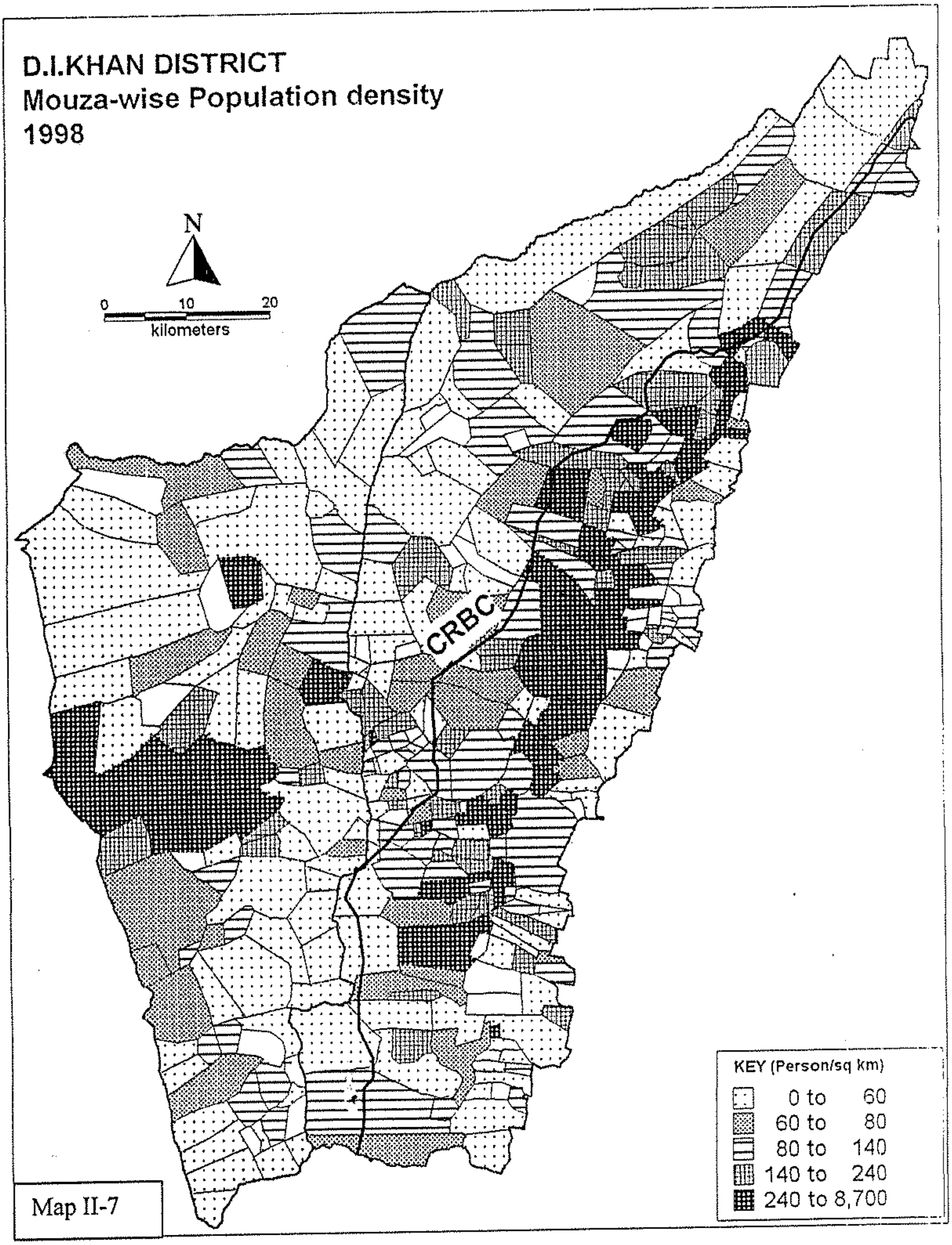
Map II-4


D.I.Khan Division
Tehsil-wise Population Density
(1998)
50-100
101-150
>150
0
10
20
Kilometres

Map II-5


D.I.KHAN DISTRICT
SPATIAL DISTRIBUTION OF RURAL SETTLEMENTS
Settlement
N
0
10
20
kilometers
CRBC

Map II-6


D.I.KHAN DISTRICT
Mouza-wise Population density
1998
N
0 10 20
kilometers
CRBC
KEY (Person/sq km)
0 to 60
60 to 80
80 to 140
140 to 240
240 to 8,700

Map II-7

Table II-3

D.I.Khan district, Tehsil-wise area, population density by rural-urban, 1998

Tehsil	*No of Mouza*	*Area Sq.Km*	*Population*	*Density (person per sq.km)*	*Urban Population*	*Rural Population*
D.I.Khan	206	3,339	493,628	148	92,114	401,514
Kulachi	87	2,769	159,094	57.5	19,113	139,981
Paharpur	91	1,218	200,273	164.4	14,580	185,693
Total	384	7,326	852,995	123	125,807	727,188

Source: GoP, 1999

In D.I.Khan district the urban population is unevenly distributed. In 1998, the urban population was 125,807, which was 14.8% of the total population (Table II-4). It grew at an average annual growth rate of 2.0% during 1981-98 (GoP, 1983; GoP, 1999). Urban proportion at tehsil level ranges from 7.85% in Paharpur (lowest) to 22.94% in D.I.Khan tehsil. In D.I.Khan district, tehsil having relatively more urban proportion are mostly lying in the fertile irrigated plain area of the district. There are total 4 urban localities out of which, Municipal Committee D.I.Khan had highest urban population of 86,969 persons in 1998. As D.I.Khan city is the district headquarter. The remaining three urban localities had less than 20,000 people. Kulachi Town Committee has 19,113 population, Paharpur Town Committee 14,580 and D.I.Khan Cantonment 5,145.

Table II-4

D.I.Khan, Urban growth rate, population and urban share, 1998

Tehsil	*Population*	*Urban growth rate (1981-98)*	*Urban Population*	*% urban population*
D.I.Khan	493,628	1.8	92,114	22.94
Kulachi	159,094	1.5	19,113	13.6
Paharpur	200,273	3.11	14,580	7.85
Total	852,995	2.04	125,807	14.8

Source: GoP, 1983 and 1999

2.2.1 Man-Land Ratio

The man-land ratio provides baseline information for the land use and agriculture planning. In D.I.Khan district, the pressure on land is continuously increasing and the rural population is unevenly distributed. This is mainly due to variation in land capability to support population. In D.I.Khan, western part is drained by a large number of streams and Chashma Right Bank Canal as well as floodplain of river Indus attract and support large population. However, eastern of D.I.Khan district is mostly drained by the hill torrents, which for greater part of the year remain dry and hence not capable to support large population.

As far as rural settlement distribution is concerned, in D.I.Khan during 1998 census. there were 384 Mouza (a smallest revenue unit) (Table II-3). Out of which 39 had population over 5,000, 81 had 2 to 5 thousands, 69 had one to two thousands and 170 had less than one thousand population, whereas 25 Mouza were uninhabited. The maximum number of Mouza is in tehsil D.I.Khan (206), followed by tehsil Paharpur (91) and Kulachi (87).

2.2.2 Socio-economic condition

Socio-economic condition is an important indicator of living standard of an area. In order to study the economic condition of the study area, following criteria are mainly used; standard of living, occupation and income level.

Living standard of the people of an area is the best indicator of the economic condition. Field survey revealed that the study area had arid type of climate. Therefore, agriculture is largely depending on rainfall. Most of the people are engaged in primary economic activity, and belong to low income group. Likewise, there is no proper transportation system and most of the villages are located far away from the district headquarter. Some villages are located in remote areas, which adversely affected the living standard of the people of the area.

The living standard of an area can also be judged by the type of occupation. The labour force was engaged in various types of occupation. Agriculture was the dominant economic activity. In D.I.Khan district, income levels vary from place to place and village to village. Field survey revealed that the income level is high in those areas where the literacy ratio is relatively high. It means that higher the literacy ratio greater the income level, lower the literacy ratio lower the income level.

i. ECONOMICALLY ACTIVE POPULATION

Economic development planning of any region can not be achieved without assigning due weight-age to volume and type of manpower. Manpower data are available from many sources, like labour force survey, manpower division, census data etc. Each one has its own merit and demerits. The economically active population is defined as the person working, most of the time during the year (Khan, 1996).

The economically active population of Dera Ismail Khan district (among the population 10 years and above) was 21.26% of the total population, out of which 98% male and only 2% female. Whereas 78.74% economically inactive and mainly consists of 33.6% children below 10 years, 32.44% domestic workers and unemployment rate 21.9%, the students share was 6.79%, while other categories constitute 5.89% in the total economically inactive population of the district (GoP, 1999). The labour force participation rate as percentage of total labour force to the population aged 10 years and above is 32.0%. There was a significant difference in the participation rate between male and female labour force as 59.25% for male and only 1.39% for females. The labour force participation rate is slightly higher in urban areas (32.78%) as compared to (31.89%) rural areas. The unemployment rate (21.9%) of the total labour force reflects a high degree of inactive population. Unemployment rate was higher among the male (22.29%) as compared to female (3.83%). The rate of unemployment in the rural areas is 22.4% as compared to 19.38% in urban areas.

In district D.I.Khan, the proportion of employed population that is 10 years and above was 25% during 1998 population census. Out of which 51.12% were self-employed, 40.6% working as employees and 7.61% are unpaid family helper. To compare rural-urban variation, the proportion of self-employed is higher in rural areas, while that of employee (Govt.) is higher in urban areas. The percentage of unpaid family helper is also higher in urban areas.

ii. OCCUPATION

Occupation for majority of the people is agriculture. These include non-cultivating owners, cultivating owners, tenants and agricultural labourers. The land is quite fertile but the main problem is shortage of water for irrigation. As tube wells have proved successful, many farmers have installed tube wells on their farms. Installation of tube wells and prospects of the Chashma Right Bank Canal has improved employment opportunities. This has given further impetus to farming, where more and more land is being brought under cultivation. Besides, significant proportion of population is not directly engaged in agriculture sector, they include blacksmiths, carpenters, potters, shoemakers, cobblers and other service groups. Dera Ismail Khan is the centre of trade. As the local handicrafts of the district are very popular throughout Pakistan, therefore, cottage industry has absorbed appreciable population in various skilled occupations.

iii. LITERACY RATIO

Human development plays a major role in optimum utilization of resources in an area. Literacy rate is an important indicator of human development. As far as D.I.Khan district is concerned, the literacy ratio was 14.2% in 1972, 19.16% in 1981, which increased to 31.28% in 1998 (Table II-5). The male literacy ratio (43.19%) is significantly higher than the female literacy (17.86%). The literacy is much higher in urban (65.17%), compared to the rural areas (24.17%).

Table II-5

D.I.Khan district, Literacy ratio by Sex and rural-urban areas, 1981-1998

Area		*1981*			*1998*		
		Both Sexes	*Male*	*Female*	*Both Sexes*	*Male*	*Female*
D.I.Khan	Total	19.16	27.63	9.18	31.28	43.19	17.86
	Rural	13.78	21.54	4.56	24.70	36.93	11.00
	Urban	41.31	53.05	27.82	65.17	75.02	53.80

Source: GoP, 1983 and 1999

Among the total educated persons, 27.70% in D.I.Khan had up to primary level education. However, level of education declines as one move from school level education to post-graduate level. Regarding sex differential male were more educated and had higher education attainment than female (GoP, 1999). Likewise, the shares in urban areas are more than the rural areas, because of availability of education institutions at door steps and trends towards education.

2.3 CULTURAL ENVIRONMENT

For livelihood man not only depends upon the physical environment but also upon the culture in which he lives (Dubey, 1992). The physical environment only provides conditions for the growth of economy, but real development can be achieved only through cultural attributes. Therefore, in D.I.Khan district cultural attributes have also played a vital role in shaping and transforming the natural landscape into cultural landscape. In the following discussion, an attempt has been made to analyse the spatial pattern of various cultural attributes.

2.3.1 Types of irrigation practised in D.I.Khan district

Traditionally, in D.I.Khan, cultivated area is irrigated by different sources including canal irrigation, inundation, lift and Rod Kohi (Said, 1971; GoP, 1985; GoP, 1999). Rod Kohi is governed over a century old system called *Kuliyat* and *Rewajat* (GoP, 1969; Khan, et al., 2005). About hundred years back the then Deputy Commissioner of D.I.Khan, Mr. Gee, planned an inundation canal from the Bilot creek to ensure regular irrigation for the area (GoP, 1985; GoP, 1999). The extension of this creek was named as Paharpur canal, which started its operation in 1902. It remained a seasonal canal and became a full-fledged perennial canal in 1970 with the completion of Chashma barrage.

In D.I.Khan, Indus is the principal source of canal irrigation and is braided through out its course. It is very wide (7-16 Km) and divided into numerous channels separated by channel bars (see Map I-1). The discharge remains low in winter, but begins to rise in April and gradually inundates most of the riverine tract from July to September. The piedmont plain is traversed by a number of hill torrents. The most important of these are Paniala, Tikwara, Hauz Khad, Khad Buds, Luni, Khaura Khad and Ramak. With the exception of Paniala, the flow is from west to east. Most of the streams that originate from the hills, braided in the alluvial fans and don't reach the main stream. For most of the year the torrents are dry and filled with water only after heavy rains. Following are various types of irrigation practiced in D.I.Khan district.

i. CANAL IRRIGATION

Canal-irrigation is available only in a narrow belt in the eastern part of district D.I.Khan (see section 6.2 and Map VI-9 & 10). The command area includes most of the Indus floodplain (*kachha*). The construction of three stages of Chashma Right Bank Canal has provided additional canal water. Presently, there is another important project under consideration known as Chashma Right Bank 1st lift Canal, which will irrigate parts of Paharpur as well as Kulachi tehsil (Daraban area).

ii. HILL TORRENTS OR ROD KOHI IRRIGATION

Hill torrent irrigation is locally known as Rod Kohi and is practised near the mountains and along large streams (see section 6.2 and Map VI- 9 & 10). It is an indigenous system of water supply for agricultural land and is designed to function under the prevailing adverse dry conditions (GoP, 1969; Said, 1971). It works in the following way: flood water rushing down the torrent is blocked by a temporary earthen dam and the flow is diverted by a number of small channels into fields already embanked to receive it. When the fields served by each dam, it is broken and the water allowed to flow down to the next dam of the series. Hill torrent cultivation accounts for more than one-third of all agricultural land in D.I.Khan and mostly occurs on upper piedmont slopes, where erratically flowing stream emerge from the mountains (Khan, et al. 2005). The main crops, which are cultivated under hill torrents, include millets and sorghum in Kharif and wheat in Rabi. The area under Rabi crops is usually more than that under Kharif crops.

iii. ZAM IRRIGATION

The perennial streams are known as Zam, which are restricted to the western and north-western parts of the district (see Map VI- 9 & 10). They take their rise in the Waziristan and Suleiman mountains, where precipitation is relatively higher. The most important perennial streams are the Gomal and Tank Zam, while Zarkani, Daraban and Chaudhwan are of lesser importance. Although classed as perennials, but little, water from these streams actually reach the Indus river, except at the times of severe flood.

This type of irrigation is potentially better than Rod Kohi because of more reliable and systematic distribution of water. Small areas near Daraban and Chaudhwan are zam irrigated. The water is distributed systematically as in canal-irrigated areas. The intensity of cropping is quite high in the upper reaches of the diversion channels, but areas farther below are cultivated in large blocks of adjoining fields, while other blocks are left fallow. The next year most of the fallow blocks are cultivated while most of the formerly cropped blocks are in turn usually left fallow. Cereals such as wheat and millet are the major crops grown over zam irrigated areas. A small acreage is also devoted to vegetables and fodders.

iv. INUNDATION IRRIGATION

Summer floods in the Indus are the principal means of irrigation in the active floodplain of the Indus river (see Map VI- 9 & 10). This area is mostly under flood during summer, but in winter as the floods recede, wheat and *sarson* (Brassica campestris) are sown, which mature on the residual moisture left from the previous summer flood. The volume, time and duration of floods are uncertain and vary from year to year and from place to place. No summer crop is raised on lands which are most subject to destructive floods. However, higher areas, lying farther inland, may produce a small summer crop mostly millets and sorghum in addition to a major winter crop wheat.

v. LIFT IRRIGATION

Narrow eastern fringes of the *daman* and most of the active floodplain have good quality of groundwater that is suitable for lift irrigation (see Map VI- 9 & 10). In areas close to the Indus, Persian wheel are used to lift underground water (Said, 1971). In other areas, increasing number of power-driven tube-well is used for irrigation. In spite of an assured water-supply, cropping patterns on well-irrigated areas have no marked differences from those under dry-farming. This is attributed more to tradition rather than to any other factor. Wheat is the predominant Rabi crop. Millet and sorghum constitute the major Kharif crops, but due to extension of CRBC system, the importance of lift irrigation is greatly reduced.

During 1999-2000, there were total, 47 government tube-wells, out of which 27 were run by electric power and 20 by diesel. Likewise, privately owned tube-wells are also equally contributing in irrigating the vast desert area of D.I.Khan. During 1999-2000, total 413 private tube-wells were reported from D.I.Khan district (GoNWFP, 2000c).

vi. RAINFED CULTIVATION

Due to scanty and erratic precipitation, rainfed cultivation is not practicable in most parts of D.I.Khan district. It is, however, attempted in the northern parts, where the rainfall is relatively higher and more evenly distributed throughout the year (see section 2.1.3). The rainfall water is collected and stored in the ditches and then used to irrigate few fields for cropping. However, in the sandy plain near Pezu, the rain is used directly and is not collected.

Patches of coarse and medium-textured soil lying near the foot of the Marwat, Khisor and Bhittanni ranges are farmed and not irrigated by canals, wells, torrent-water or river spills. Low rainfall is the only source of moisture. Therefore, cropping intensities are comparatively very low. The extent of the area sown in this section and the proportion of the crop matured varies according to the amount of rainfall received in a certain cropping season (Said, 1971; JICA, 1995). Winter crops include gram, wheat and oil-seeds. In summer, mostly millet is grown.

2.3.2 Settlement

The history of human settlements goes back to thousands of years, when people used to live in caves. After settled life, it took long time to build proper villages. Archaeological investigations further confirm these settlements in Gomal basin, particularly from the excavation of Rehman Dheri (Dani, 1971). However, the recent history goes back to 1,500 years. In D.I.Khan, there are several historical villages, like Paniala, Takwara, Kirri Shamozai, Choudhwan, Zarkani and Gurwali etc. In the following discussion, it has attempted to bring out the settlement location, distribution and settlement pattern.

a. Settlement Location and Distribution

People have always kept in mind particularly the location of their dwelling unit, giving preference to the site and situation of their houses. In the rural areas agriculture is the major economic activity of the people, land productivity, accessibility to water sources, streams and specifically roads are the major contributing factors for settlement location and distribution. In D.I.Khan district, a number of factors played their role in the establishment of settlements, they include soil fertility, irrigation and utilization of water from river Indus, and its distributaries, Indus highway and water bodies in the highlands have played their major role in the establishment of settlements. With the passage of time, settlements were distributed in the whole basin in the form of villages. Presently, there are 384 villages, in D.I.Khan district.

b. Settlement Pattern

Settlement pattern is concerned with the character and shape of the settlement that whether the settlement is nucleated or dispersed. In the study area, both nucleated and dispersed settlement pattern were found. In D.I.Khan district, nucleated settlement pattern is the most prevalent one, like village Kotla Saidan, Gomal Bazar and Moriali etc. whereas the disperse settlement pattern were found seldom. Disperse settlement pattern is new trend mainly because of high population growth and filtering up of the new dwelling units. Settlements are built in the open fields or along the road side. Such practice changed the nucleated pattern into dispersed settlement pattern such as Ratta Kulachi, Ramak etc.

2.3.3 Sources of drinking water

The easy access to potable and safe drinking water is one of the basic human needs. Historically speaking, water bodies always attracted human settlements. In D.I.Khan district, bulk of water supplies for domestic purposes are obtained from open wells, ponds, store run-off, Indus river, and from the western tributaries and streams. Large number of tubewells has already been installed by the Public Health & Engineering Department (PHED) and other government departments. Other agencies are also supplying water in the main towns and villages of the district. However, in certain areas of D.I.Khan and Kulachi tehsil, the groundwater is highly mineralized and is not fit for domestic purpose. However, after inception of CRBC, canal remained the major sources drinking supply particularly in the saline belt of CRBC command area. The supply from existing PHED tube wells to the settlements located in far-off areas is also difficult because of damages to water supply lines during the period of occasional high floods. The most common way to obtain water for domestic and other uses is generally to prepare open ponds, where rain water and run-off is collected for their use.

According to 1998, housing census, the facility of drinking water in-side the housing units were available to only 63.3%, while 36.7% of the housing units used outside sources as drinking water in D.I.Khan district (Table II-6). The facility of inside the house was high in the urban areas as compared to the rural areas. Pipe, hand pump, well, ponds and are other sources of drinking water. The table shows that more than 20% people still use pond as a source of drinking water (GoP, 1999). In urban areas, the drinking water supply system was comparatively better than the rural areas.

Table II-6
Source of drinking water in rural/urban areas (%), 1998

Source	*D.I.Khan*		
	All areas	*Rural*	*Urban*
Inside	63.3	58.08	95.14
Pipe	13.74	11.00	30.41
Hand pump	49.17	46.70	64.21
Well	0.40	0.38	0.52
Outside	36.70	41.92	4.86
Pipe	4.93	5.39	2.10
Hand pump	2.56	2.88	0.60
Well	1.33	1.55	0.01
Pond	20.71	23.96	0.86
Other sources	7.18	8.14	1.29

Source: GoP, 1999

2.3.4 Source of lighting and fuel

Majority of housing units were using electricity as source of light representing 92.4 percent of the housing units both in urban and rural areas of D.I.Khan district (Table II-7). Kerosene oil was being used by approximately 6.88 percent of the housing units while other sources of light like patromax, mustard oil etc, are hardly being used by 0.8 percent of the housing units. The table II-7 provides detail, percentage of housing units by source of light with urban and rural areas in 1998.

Table II-7

Housing units percentage by source of lighting by rural/urban areas, 1998

Source	*All Areas*	*Rural*	*Urban*
Electricity	92.4	91.4	98.4
Kerosene Oil	6.8	7.7	1.1
Others	0.8	0.9	0.5

Source: GoP, 1999

Almost 95 percent of housing units were using wood as cooking fuel in their houses while nearly 1 percent was using kerosene oil for this purpose. Hardly 0.3 percent are using gas and 4.1 percent other sources of cooking fuel in their houses. Regarding urban and rural variation wood was mainly used, representing 94.7 percent, in rural areas and 94.8 percent, in urban housing units. The table II- 8 indicates percentage of housing units by source of cooking fuel with urban rural break up in 1998.

Table II-8

Housing units percentage by source of cooking fuel used by rural/urban areas, 1998

Cooking Fuel Used	*All Areas*	*Rural*	*Urban*
Wood	94.7	94.7	94.8
Kerosene Oil	0.9	0.8	1.4
Gas	0.3	0.2	1.3
Others	4.1	4.3	2.5

Source: GoP, 1999

2.3.5 Manufacturing

In D.I.Khan, the industrial growth is satisfactory, keeping in view small industrial base, with which it has started. The industrial activity has been found predominantly in private sector. The economy is primarily agriculture. Hence, it offers potentials for the development of agro-based industries. The important crops for these industries are sugarcane, sugar beet, vegetables. fruits and other by-products like wood and wood products. Investment in the agro-based industries may boost the economic prosperity of the region.

2.4 CONCLUSION

This chapter finally concludes the environmental settings of the study area. Geographically, the area is bounded by mountains from the north and west. They have mineral resources of low economic importance. Extensive area of the district is piedmont and is drained by the numerous hill torrents. Large proportion of underground water is saline and not fit both for drinking and irrigation. The climate is arid to subtropical continental. Due to low rainfall and high evapo-transpiration the vegetation cover is very poor.

Population of the district is increasing at an alarming rate, higher than both the national and provincial average. Natural increase is the dominant factor contributing to population increase. The population density vary from 57 to 160 persons per sq. Km. The population density is high in the area, where maximum facilities were available including water supply and infrastructure. The urban population is very small, only 15% of the total population lived in urban areas. The sex ratio indicates that male dominate over female i.e. 110 male per 100 female. The income level varies from place to place and village to village. However, the income level is high in areas, where the literacy ratio is comparatively high. In D.I.Khan district, the literacy ratio is 31%, lower than both the national and provincial average. Settlements were largely created, where several factors support human life. Variation in the building material indicates difference in the economic condition. Mostly the sources of drinking water are inside the houses. Majority of the household had access to electricity and were using wood as a fuel.

LITERATURE REVIEW AND THEORITICAL FRAMEWORK

Introduction

The previous chapter was given to the environmental setting of the study area, while this chapter provides strong theoretical framework for the entire study. This chapter is divided into seven sections. Section one deals with water as a resource. Section two assesses the global status of irrigated agriculture. Section three deals with an overview of the land use study, while section four discusses the environmental impacts of irrigation projects. Section five highlights the concepts, types and methodologies of impact evaluation for irrigation projects. Section six discusses the irrigation related issues and documents in Pakistan. The chapter is finally concluded in section seven.

3.1 WATER AS A RESOURCE

The world's thirst for water is going to become one of the most pressing resource issues of the 21st century (Carruthers, et al., 1997; Guerra, et al., 1998; Kume, et al., 2000). It is very important to note that water is abundant on the earth. However, only 1% of it is available for human use. Whereas the rest of water is distributed as 97% lies in the ocean and seas and 2% of all water is in glacial/ice (Stockle, 2001). Besides this, another aspect of the water picture is the uneven geographical distribution of its availability around the globe. Chronic scarcity of water is experienced in large parts of Africa and the Middle East. Similarly, there is inadequacy of water in the northern part of China, parts of India, and Mexico, the western part of the USA, north-east Brazil, Russia and greater part of the Central Asian republics (Cantor, 1967; Sadhukhan, 1990). Scarcity of water led to cross-border conflicts e.g. in the Indus basin, in the Nile basin and in the Middle East. There are problems of water disputes even among various communities with in the countries and Pakistan is no exception to it (Khan and Atta-ur-Rahman, 2004).

It has been estimated that since 1970, global demand of water for domestic, industrial and agricultural purposes have risen at the rate of 2.4 % per annum (Carruthers, et al., 1997). The main reasons are increase in the human population and subsequently increasing water consumption. However, despite the rising demand of water per capita availability of water resources declined by 40-60% in many Asian countries from 1955 to 1990, and is expected to decline further by 15-54% over the next 35 years (Carruthers, et al., 1997). To keep pace with the population growth and income-induced demand for basic resources such as water in most low-income countries, waste and non-productive uses of water must be carefully scrutinized for the purpose of sustainability (Carruthers, et al., 1997; Kume, et al., 2000).

Agriculture is the major user of freshwater, with a world's average of 71% of the water use. There are large regional variations in the use of water for agriculture, from 88% in Africa to less than 50% in Europe (Stockle, 2001). It is estimated that meeting the projected crop demands for 2025 could require an additional 192 cubic miles of water, a volume nearly equivalent to the 10 times annual flow of the Nile (Hussain, 2004; Khan, et al., 2006). No one yet knows how to supply that additional water in a way that protects supplies for future use and minimizes environmental impact. Severe water scarcity presents the single biggest threat to future food production. Even now, many freshwater sources (underground aquifers and rivers) are stressed beyond their limits (Stockle, 2001). As much as 8 percent of foods crops grow on farms that use groundwater faster than the aquifers are replenished, and many large rivers are so heavily diverted that they don't reach the sea for much of the year.

3.2 GLOBAL STATUS OF IRRIGATED AGRICULTURE

Irrigation is the artificial application of water to overcome the deficiencies of rainfall for the growing of crops (Sadhukhan, 1990; Khalid, 2003). Its practice occurs in three main conditions. First, in arid and semi-arid regions, its use is most extensive and is being practiced from thousands of years such as Nile basin, Indus basin and Mesopotamia etc. Second, in areas, which have marked seasonal shortage of rain, like monsoon Asia and land with Mediterranean climate. Third, generally in humid areas, where the rainfall is normally sufficient to promote plant growth and where irrigation is used as a safeguard against drought and promotes high yields (Cantor, 1967).

In practice, there are four general sources of water available to man that is surface water, groundwater, atmospheric water and the marine water (Cantor, 1967). By far the most important of these is surface water in the form of rivers, streams and lake and the same is utilized for irrigation. Amongst other three sources, the importance of groundwater is increasing, rapidly, particularly in those areas, which lack surface drainage (Cantor, 1967).

3.2.1 Past trend of irrigated agriculture

Historically speaking, irrigation has been important for agricultural production in Mesopotamia (parts of present day Iraq and Iran) for 6,000 years. The region has low rainfall and is supplied with surface water by two major rivers, the Tigris and the Euphrates. The plains of Mesopotamia have always had problems with poor drainage of soils, drought, catastrophic flooding, silting, and soil salinity (Khan, et al., 2006). Although Mesopotamia is very flat, the bed of the Euphrates is higher than that of the Tigris; in fact, floods of the Euphrates sometimes found their way across country into the Tigris.

The Egyptian irrigation history as described by the Greek historian Herodotus around 450 BC, Egypt as the gift of the Nile (Cantor, 1967). Almost two and half thousand years later, Egypt is still the gift of the Nile, but the Nile has been reshaped due to interventions of several generations of Egyptians in their continuous attempt to harness the river flow. Farmers used to divide an agricultural year into three main seasons; inundation, coming forth and lack of water (Ahmed, 2000). The typical farming practice was to bury seeds in dry soils before the land was inundated by the following flood. The main crops that characterised the one-crop-per-year regime at ancient times were wheat and barely. Other non-flooded crops e.g. vine and olives were further introduced in the Egyptian agricultural system and by using lifting water devices, such as the *shadouf*.

China has also a long history of irrigation. Two thousand years ago, the world-famous Dujiangyan irrigation district in Sichuan Province was built and remains in use after many periods of rehabilitation and modification (Khan, et al., 2006). With a current irrigated area of 670,000 ha, it is a highly developed economic centre of great importance to China's food production. In 1949, the irrigated area of the whole country was 16 M ha accounting for only 16% of the country's farmland and the per-capita food consumption was 209 kg. Development in the last half century has resulted in the irrigated area growing to 53 M ha, accounting for 40% of the farmland, and the per-capita food consumption was 400 kg at the end of 1998 (Khan, et al., 2006). The total water use for irrigation gradually increased from approximately 100 BCM in 1949 to 358 BCM in 1980, after which it stabilised.

The main engineering problems for earlier civilisations were water storage, flood control and maintenance of canals (Cantor, 1967). The salinity problem was low, not fully appreciated, and could not be overcome by the engineering measures available at the time. It was difficult to drain water from fields and there was always a tendency for salt to accumulate in the soil (Khan, et al., 2006). The problems of irrigated agriculture in Mesopotamia were silting of canals; soil salinity; water politics arising from tension between upstream and downstream users; over exploitation of resources and Institutional failure (Khan, et al., 2006).

During the last century, the technological advances have brought about a great expansion in irrigated agriculture. The first large scale, modern irrigation system, which usually consists of a simple diversion dam linked to headwork's and canals developed in the second half of the nineteen century in Egypt (Cantor, 1967). The greater part of these modern projects is based on the year round use of surface water, frequently associated with large-scale multi-purpose schemes.

3.2.2 Present trend of irrigated agriculture

Presently, irrigated lands contribute significantly to the world agriculture output and food supply (Sadhukhan, 1990; Stockle, 2001; Hussain, 2004; Khan, et al., 2006). In 1996, it was estimated that developed countries, on average, irrigated 10% of their agricultural area, and developing countries 23%, and combined they irrigated 18% of the total agricultural area (Stockle, 2001; Hussain, 2004). The successful expansion of irrigation farming has been one of the most striking features of the growth of world agriculture, during last century (Cantor, 1967; Sadhukhan, 1990; Hussain, 2004; Khan, et al., 2006).

Currently, irrigated agriculture provides about 40% of the world's food, from only 20 percent of its cultivated area (FAO, 2003). It has been instrumental in the success of the 'Green Revolution' in meeting food needs over the past 40 years, particularly for staple grains. However, these successes have come at significant environmental costs. For example, irrigation typically consumes over 70 percent of the diverted water resources in Asia. Guerra, et al., (1998) found that more than 80% of the developed freshwater resources in Asia are used for irrigation purposes and more than 90% of the total irrigation water is used for rice production. The available amount of water for irrigation, however, is increasingly getting scarce worldwide. During the crop growth period, the amount of water usually applied to the field is much more than the actual field requirement (Guerra, et al., 1998). When water supply within the irrigation system is unreliable, farmers try to store much more water in the field than needed as insurance against a possible shortage in the future. The actual amount of water used by farmers for land preparation is often several times higher than the typical requirement (Guerra, et al., 1998). To accurately calculate water requirement for the system, information is needed not only on cropping pattern, but also on the actual water requirements of different crops under different soil conditions.

Irrigated agriculture also poses some adverse consequences. The unwise utilization of irrigation has generated off-farm impacts including waterlogging, salinization and pollution of rivers and lakes (Wichelns, et al., 2002). Reducing those off-farm impacts is quite challenging in most irrigated regions due to non-point source nature of agricultural drainage water, the difficulty of measuring water delivery to individual farmers and cultural or political constrains regarding the imposition of water prices and effluent charges.

In many regions of the world, farmers and agricultural scientist are being asked to increase productivity to satisfy increasing demand for food and fibre at reasonable cost. At the same time, public agencies and consumers are calling upon farmers to enhance environmental quality by reducing the negative off farm impact of agricultural practices (Carruthers, et al., 1997). Both goals have merits, given the substantial gains in food production required to support a growing world population.

It is recognized worldwide that the performance of most irrigation systems, especially in developing countries, is far below its potential (Garg, 1987; Hussain, 2004, Khan, et al., 2006). Yet improved performance of irrigation systems is crucial for sustained agricultural growth (Stockle, 2001). In order to address this problem, practical procedures for the assessment of the performance of irrigation systems in every dimension, such as productivity, efficiency, equity of life, sustainability and environmental soundness, need to be developed (Abu-Zeid, et al., 2000). Consequently, the need arises to develop an analytical systems approach, including management modelling for examining the consequence of specific efforts to improve irrigation system.

Irrigation has already played a major role in increasing food production over the past fifty years. The world's irrigated land was 8 miilion hectares in 1800, 48 million hectares in 1900, 94 million hectares in 1950 198 million hectares in 1970, and about 220 million hectares in 1990 (Jensen, et al., 1990). Presently, about three-quarter of the irrigated land is in the developing countries. In these countries, almost 60 percent of the production of major cereals (primarily rice and wheat) is derived from irrigation. Irrigated land presently accounts for 15 percent of the cultivated land but produces 36 percent of the world's food (FAO, 1988).

Table III- 1

Irrigated land expansion by region of the developing world, 1961-2000

Region	*1961-63 (M ha)*	*1979-81 (M ha)*	*2000 (M ha)*	*Annual growth rate (%)*	*Irrigated land as a % of potential*
All developing countries	118	173	234	1.9	30
Sub Saharan Africa	4	5	7	2	14
Near East and North Africa	13	18	21	1.7	62
South Asia	37	56	82	2.3	57
India	25	37	58	2.6	65
East Asia and pacific	40	59	75	1.6	64
China	30	45	55	1.4	70
Latin America and Caribbean	8	13	19	2	27
Europe and central Asia	16	22	30	23	N.A.
World	142	210	277	1.8	N.A.

Source: Stockle, 2001

3.3 CONCEPT AND DEFINITIONS OF LAND USE AND AGRICULTURAL RESOURCES

Land resources has played strategic role in determination of man's economic, social and cultural progress (Pawar, 1989; Marsh and Grossa, 2005). An assessment of the land resources, their extent, distribution and utilization are of prime importance for rational exploitation and sustainable development (Pawar, 1989; Swami, et al., 2004). In order to increase food production, a proper utilization of land resources is very essential and to put the wasteland under the beneficial uses is the most important task (Singh, 1991). According to Chouhan (1991) land use and proper assessment of land resources is very essential for understanding the agricultural potential and planning of a region. Physical and cultural factors directly affect the land use pattern and playing their role in variety of land use pattern.

The uses of land are as old as the agriculture and settled life. Although, land is used for many purposes, but agricultural is the dominant use. Therefore, land use studies are traditionally associated with agriculture. In sub-continent for the first time, a detailed record of land and its uses was prepared during the reign of well-known ruler *Allauddin Khilji* (Ahmad and Chaudhry, 1988; Khan, 1996). He also established an organized revenue department very much similar to the existing revenue department in Pakistan. However, for the first time the scientific land use survey was started in Great Britain by Stamp, during 1930-1943 (Stamp, 1962) and was completed in 12 years. The objective of the survey was to study every inch of land that how people utilize it for different purposes. In 1941, the International Geographic Congress (IGC) recognized the land use survey as an important part of Geography discipline. A number of committees were formed in order to start land use survey in their respective countries.

In Pakistan, land use survey was first introduced in East Pakistan under the supervision of Geographical society of Dhaka University. Later on, it was introduced in the Department of Geography, University of Sindh. In 1969-70 faculty members and students of Geography Department, University of Peshawar, conducted land use survey of different districts of N.W.F.P (Said, 1971). The general topographic sheets were used as a base map. Verification was done during the field survey.

In Pakistan, during 1953-54, a reconnaissance soil and salinity survey was carried out under Colombo plan. The mapping of landforms, soil and present land use was carried out by interpretation of aerial photographs supported by ground truthing (World Commission on land use survey, 1958). Most of the photographs were taken during the winter months, when salinity is more obvious and can be efficiently recorded. The salinity-affected areas were divided into two groups, those severely saline and where saline patches were common. Waterlogged and poorly drained soils were also mapped. The study found that seven percent land was severely saline and 16% salt affected. Similarly, 17 percent area was waterlogged or poorly drained. The main categories recommended by the World Commission on land use survey includes perennially canal irrigated, non-perennially canal irrigated with well irrigated, non-perennially canal irrigated with dry farming, watered by hill torrents, dry farmed, well or tube well or Persian wheal irrigated, grazing land with sparse shrub/ arid/ sandy/ semi desert, reserved forest, unreserved forest, swamp/ marsh land and presently unproductive land (World Commission on land use survey, 1958).

The soil survey of Pakistan classified some 74 million acres of Pakistan for agricultural potential (GoP, 1972). This area includes, the Indus plain, Potwar upland, Peshawar plain and adjoining areas. This organization placed the lands into seven capability classes as very good agricultural land, good agricultural land, moderate agricultural land, poor agricultural land, good grazing land, poor grazing land, agriculturally non-productive land and miscellaneous (GoP, 1972). However, recently GoP (2004c) classified land use into two broad categories i.e. farm and non-farm area.

Land use means the classification of geographical area in accordance with its use (GoP, 2000c; GoP, 2004c). Land use can be classified into cultivated land, cultivable waste and uncultivated land. Moreover, cultivated area can be defined as that farm area, which was sown at least once during the year or year before (GoNWFP, 2000a; GoP, 2004c). Cultivated area was further classified into net sown and current fallow (GoP, 2004c). Net sown is that farm area, which was actually cropped during the year regardless of the number of crops raised. Whereas current fallow is that farm area, which was vacant during the year under reference but was sown at least once during the previous year (GoNWFP, 2000a; GoP, 2000c; GoP, 2004c). Whereas uncultivated is that area, which is not available for cultivation including settlements, rivers, roads etc. Likewise, cultivable waste can be defined as that area which is fit for cultivation but left uncultivated due to unfavourable physical or cultural conditions (Singh, 1991; GoP, 2004c).

Cropping pattern means the proportion of area under various crops at a point of time (Hussain, 1979; Pawar, 1989), whereas changes in the cropping pattern refer to change in proportion of area under different crops at two different times (Pawar, 1989). The cropping pattern is in fact, the interplay of complex physical, social and economic factors. These factors include availability of water, fertility of soil, topography, climatic conditions, input-output prices, agricultural technology, agricultural infrastructure, farm location, farm size, economic condition, socio and political situation (Swami, et al., 2004). The cropping pattern is a dynamic phenomenon, because all the above-mentioned factors on which it depends themselves keep on changing.

Cropping intensity refers to the number of crops grown on the same area in any one year (Gajja, 1991; GoP, 2004c). Cropping intensity indicates the extent to which cultivated area was used for cropping. Intensity of cropping refers to the number of crops grown on the same area in any one year (Gajja, 1991; GoP, 2004c). It can be expressed statistically by showing the cropped land as a percentage of the total cultivated land (GoP, 2004c). For example, a land holding on which half fields are sown to Rabi will have a cropping intensity of 50 percent. If all fields are sown in Kharif, the cropping intensity will be 100 percent, while the annual cropping intensity (Rabi+ Kharif = 50+100) will be 150%. Thus, higher the intensity of cropping higher is the land use efficiency and lower the intensity of cropping the lower is the land use efficiency (Gajja, 1991; GoP, 2004c).

3.4 ENVIRONMENTAL IMPACTS OF IRRIGATION PROJECTS

The world's population continues to grow. Therefore, dams and irrigation projects will have to be built, particularly in the developing countries (Stockle, 2001). Nevertheless, such projects must be built to higher standards and with more accountability to local people and their environment than in the past (Stockle, 2001). New approaches to meet water needs will not be easy to implement, which will have less destruction to ecosystems (Government of India, 2002).

Irrigation projects are mainly classified into two types i.e. flow and lift (Garg, 1987; Dalua, 1993). Qamar (1993) found that dominant delivery method is flow irrigation, in which water is distributed by gravity flow. The other system of irrigation is sprinkle and drip. Although, they are relatively new and hence, requiring high investment. However, sprinkle and drip methods show great potential for maximizing the water efficiency and reduces irrigation related problems (Qamar, 1993). Depending on capacity, flow irrigation project is again classified into three types i.e. major, medium and minor (Garg, 1987; Dalua, 1993). A major irrigation project is capable of irrigating more than 10,000 hectares of land. A medium irrigation project is that one, which can irrigate more than 2,000 to 10,000 hectares, while minor irrigation project irrigates less than 2,000 hectares. It is important to mention here that; the lift irrigation project has no such categorization (Dalua, 1993).

Increasing expansion in the irrigated area is mainly due to large-scale irrigation projects involving enormous capital expenditure, which aims to develop the resources of whole river system (Cantor, 1967). Every irrigation project is designed, keeping in view its economic expenditure to be incurred and the benefit is likely to occur (Garg, 1987). There is a capital investment on the project and the future maintenance charges. The project is generally sanctioned, when benefit are higher. Although irrigation projects are usually associated with its positive impacts on human life, unwise irrigation practices may be associated with adverse impacts on environmental conditions, which may eventually curtail the sustainability of irrigation projects (Dalua, 1993). Almost all irrigation projects have both positive and adverse impacts as discussed in the following lines.

In a number of countries, irrigated agriculture has resulted in major environmental disturbances such as waterlogging and salinization, depletion and pollution of water supplies, especially groundwater, and increased health risks. The recreational, aesthetic and habitat values of many water systems and agricultural landscapes have also been degraded by improper irrigation development and practices. Most of the problems of waterlogging and secondary salinization prevalent in irrigated lands and of associated water pollution have resulted from the excessive use of water for irrigation as a consequence of inefficient irrigation distribution systems and poor on-farm management practices and inappropriate drainage management.

3.4.1 Beneficial Environmental impacts of irrigation projects

Some of the positive impacts of irrigation projects are as follow:

i. WATER SUPPLY

All small and large-scale irrigation projects help in supplying water to the agricultural land, towns and industries, where water is deficient (Cantor, 1967; Garg, 1987; Chouhan, 1991; Ahmad, 1993; Abu-Zeid, et al., 2000; Atta-ur-Rahman, 2003a). It also provides water for swimming, bathing, navigation, cattle drinking etc. (Sadhukhan, 1990; Anwar, 1997).

ii. CONVERSION OF CULTIVABLE WASTE INTO CULTIVATED LAND

The introduction of irrigation has brought about an almost total transformation of the landscape from cultivable waste to cultivated land particularly in the arid and semi-arid regions. Though the scale of transformation vary from a few acres in Sahara oasis to million of acres in the Imperial-Coachella valleys of south California (Cantor, 1967). The study on Nile river irrigation system indicates that due to the introduction of canal irrigation, millions of acre cultivable waste was brought under cultivation (Ahmed, 2000).

In Pakistan, the Indus irrigation system is presently one of the largest contiguous irrigation systems throughout the world. It provides irrigation water to about 14 M ha of Cultivable Command Area (CCA) (Hussain, 2004). In NWFP, High Kabul River Canal (HKRC) both on left and right banks of Kabul River was planned in 1960. This project has brought extensive cultivable waste under cultivation. The left bank irrigates 4,450 ha, whereas right bank irrigates 42,990 ha of Peshawar district (Ahmad, 1993). After Warsak Right Bank Canal (WRBC) construction, the land use in the command area has greatly changed. Tit was found that the cultivated land was rapidly improved and cultivable waste was reduced (Khan and Ali, 1998). Osman (2003) found that major irrigation systems lead to more effective land use by bringing more land under cultivation, which finally result improvement in household income.

China has a large irrigated area. In 1949, the irrigated area of the whole country was 16 M ha accounting for only 16% of the country's farmland. Development in the last half century has resulted in the irrigated area growing to 53 M ha, accounting for 40% of the farmland at the end of 1998 (Khan, et al., 2006). Wang and Otsubo (2001) found that annual variation of land use pattern in China shows that the areas of total cultivable waste and dry fields have decreased year after year.

The study on Indira Gandhi Nahar Irrigation Project, India indicates that after the introduction of canal irrigation, the agricultural landscape has been changed. More than 99 percent of cultivable land of the sample villages was under command and about 91 percent of the cultivable land was levelled. Before inception of canal irrigation, the total cultivable land was 328,980 ha, which increased to 357,192 ha, after canal irrigation (Ali, and Singhvi, 2001). Hirashima and Gooneratne (1990) found that with the application of irrigation, expansion in the cultivated land has been noted.

iii. CROPPING PATTERN

Khan and Ali (1998) found that in the WRBC area, significant changes in the cropping pattern have been occurred with two crops in a year including fruits and vegetables. Likewise, after WRBC construction, use of agricultural inputs including chemical fertilizers, improved seeds, insecticides, pesticides and agriculture machinery have become much popular (Khan and Ali, 1998). Mishra (1991) found that with the availability of water, cropping pattern totally has always changed. The crops diversification exceeded from 2 and 3 to 5 and 6 crops. The study on role of Aswan high dam in promoting irrigation indicates that one million acres seasonally irrigated land was replaced by perennial irrigation and hence changed the cropping system from one crop per year to two and three crops per year. Likewise, the farmer also switched to water intensive crops like rice and sugarcane (Ahmed, 2000). The cropping pattern in Indira Gandhi Nahar Irrigation Project, India was analysed that main Kharif crops were millet, oilseed, fodder etc. and the main Rabi crops were barley and gram. After development of irrigation facilities, increase in area under crops was noted (Ali and Singhvi, 2001).

In the state of Indian Punjab during last three decades, there has been a shift in the cropping pattern due to management of irrigated agriculture (Khepar, 1993). The total area under principal crops increased from 3,837,000 to 6,481,000. The area under rice increased almost five fold and an appreciable increase in the area under wheat was also noted. The shift in cropping pattern has replaced the less water consuming crops by more water intensive crops (Khepar, 1993). Hirashima and Gooneratne (1990) found that application of irrigation has changed the cropping pattern and a shift towards the more remunerative and labour intensive crops were made. Cantor (1967) found that advantage of irrigation is that it frequently enables a much greater variety of crops to be grown than is possible under natural condition. Likewise, Sadhukhan (1990) found that crops are not damage due to water in the irrigated regions. Mishra (1991) concluded that it is not the soil type, but water availability has determined the cropping pattern.

iv. IMPROVEMENT IN CROPPING INTENSITY

Various studies on the irrigation projects indicate that with the availability of assured canal irrigation the cropping intensity has improved. The study on Fertility Impact of the Rahad Irrigation Project, Sudan found that irrigation project has influenced the income level, labour force participation and economic productivity due to higher cropping intensity (Osman, 2003). The study on role of Aswan high dam in promoting irrigation indicates that cropping intensity greatly enhanced after commissioning of canal irrigation (Ahmed, 2000). After inception of WRBC, the cropping intensity increased from average 20% to 110%. The cropping intensity is comparatively high at head reaches than the tail one (Khan and Ali, 1998). The study on the irrigation and water management in Asia indicates that application of irrigation has increased the cropping intensity and is one of the positive impacts of irrigation projects (Hirashima and Gooneratne, 1990).

v. REVENUE GENERATION

Revenue generation is considered to be the most important positive economic impact of irrigation project (Ahmad, 1968; Puri, 1992). Irrigation projects generate revenue, which helps in Operation and Maintenance of irrigation projects (Garg, 1987). Some time, revenue return is quite high and helps in the prosperity of the country and economic development.

vi. INCREASE IN AGRICULTURAL PRODUCTION AND FOOD SECURITY

Irrigation helps in increasing crop yield and hence, to attain self-sufficiency in food (Garg, 1987). Irrigation farming gives much greater crop yields than dry land farming and in many countries double cropping pattern are applied (Cantor, 1967; Sadhukhan, 1990). In developing countries, irrigation improves economic returns and can boost production by up to 400%. In 1949, the per-capita food consumption was 209 kg, but due to the technological advancement during last half century has resulted an increase in the per-capita food consumption (400 kg) at the end of 1998 (Khan, et al., 2006). The study on WRBC found that areas close to the head or middle reach of the main canal have high agricultural production, whereas areas located at the tail of the canal, lag behind in yield (Khan and Ali, 1998). In China, areas under paddy fields and irrigated land have increased largely. As a result, grain production has rapidly improved, especially since 1980 (Wang and Otsubo, 2001).

Likewise, the study on Baranggay Tapayan, Philippine was focused on irrigable area of about 400 hectares (Dumagay, 1984). Here, improved irrigation is recognized as an important factor in achieving maximum food production. After the establishment of irrigation system, the farmers' produce has increased from 9-10 tonnes per hectare. Subsequently, it has enhanced the farmer incomes. The irrigation project also helped Tapayan farmers to get higher yields during the wet season (Dumagay, 1984; World Bank, 1997). Osman (2003) found that irrigation projects largely influenced the economic productivity by improving farm production, which has finally enhanced the living standard.

vii. AGRICULTURAL INPUTS

Water is an essential agricultural input for high crop yield (Sadhukhan, 1990). It has been observed that the best use of available water is necessary for high production (Cantor, 1967; Chaudry, 1993). Irrigation as an important agricultural input for increasing agricultural production in areas, where climatic conditions are unfavourable and water resources are limited (Chaudry, 1993; Atta-ur-Rahman, 2003a). Egypt is an example of traditional peasant irrigation farming. The traditional features were small primitive techniques of cultivation, and low yield. but with the provision of canal irrigation, which permits cultivation the year round, over most of the area (Cantor, 1967).

After inception of WRBC, use of agricultural inputs including irrigation, chemical fertilizers, improved seeds, insecticides, pesticides and agriculture machinery have become much popular (Khan and Ali, 1998). A study on management of irrigation supply indicates that the yield of maize crop increased with the application of number of irrigation. Yield were 29, 58 and 63 mounds per acre for 4, 6 and 8 irrigation, respectively. It means that more the number of irrigation more will be the yield (Chaudry, 1993). In China, annual variation of land use pattern shows that the area of total cultivated land and dry fields around big urban centres have decreased year after year and grain production has increased rapidly, especially since 1980. However, agricultural inputs such as investment, fertilizer utilization and mechanization have substantially increased after availability of assured canal irrigation (Wang and Otsubo, 2001).

viii. INCREASE IN LAND VALUES

On of the important positive impact of irrigation project is increase in the land value as against areas without irrigation. Hirashima and Gooneratne, 1990 found that the value of land with an assured water supply has increased at a rate faster than that of land without irrigation. Various studies (Gajja, 1991; Puri, 1992; Azhar, 2001) also indicate that the value of irrigated land is comparatively higher than the cultivable waste.

ix. IMPROVEMENT IN THE SOCIO-ECONOMIC CONDITION

One of the positive impacts of irrigation project on the command area is the creation of employment opportunities. It generate both on-farm and off-farm employment. Dumagay (1984) conducted a study on Tapayan Communal Irrigation System, Baranggay Tapayan, Philippine indicates that with the establishment of the irrigation system, the farmers' produce has increased and lived even better than ordinary government employees or public school teachers. Likewise, on-farm employment analysis shows that high-irrigated farms employed more labourer than the low-irrigated farm (Dumagay, 1984).

The inception of Third Andhra Pradesh Irrigation Project, India has increased the production and generated farm jobs, transport, marketing and processing of farm produce (World Bank, 1997). Osman (2003) conducted a study on the Fertility Impact of the Rahad Irrigation Project, Sudan found that irrigation projects positively influence the income and labour force participation. In addition, irrigated agriculture affects the labour utilization within the household and opening opportunities even for female to participate in the farm activity.

Irrigation channel is usually provided with embankments and inspection road. It also enhances accessibility of the people to the market (Garg, 1987). The study on WRBC found that substantial socio-economic changes have taken place after the inception of canal irrigation. It also revealed that infrastructure facilities and services such as roads, transport and communication, education, health, drinking water, electricity and market facilities improved, which was previously not available or inaccessible. Likewise, several improvements in the field of socio-economic have taken place including enhanced living standard, replacement of mud houses by cemented one and availability of modern domestic gadget. (Khan and Ali, 1998). Osman (2003) found that irrigation project has boost-up economic condition of the farmers. In turn, this economic prosperity leads to investment outside the field of agriculture and encourages modernization.

x. SOCIAL ORGANIZATION

Irrigation does not only affect crops and crop yields, but it also determines, to a greater extent, the social organization of the farming unit (Cantor, 1967; Chambers, 1992). In an area of indigenous peasant irrigation farming, the distribution of water is often regulated by the irrigation societies, which promotes social organization and awareness amongst the community (World Bank, 1997).

xi. SOIL FERTILITY

Irrigation projects helps in improving the soil fertility by siltation (Shams, 2006). Soil of the irrigated dry regions is rich in inorganic matter and irrigation facilitates easy absorption of these nutritious matters by plants (Gupta, 1985; Ahmad, 1993). Silting through irrigation add fertility to the soil (Sadhukhan, 1990; Khan, 1996; Shams, 2006)

xii. AFFORESTATION

With the application of irrigation project, trees are generally grown along the banks of channel, which increases the timber wealth of a country in general and command area in particular. It also helps in reducing soil erosion (Champion, et al., 1965; Garg, 1987; Khan, 1996; Shams, 2006).

3.4.2 Adverse Environmental impacts of irrigation projects

The primary aim of irrigation is to secure the required amount of water in due time for plants (Singh, 1991). Nevertheless, irrigation projects may have unwanted environmental consequences as well. About one-third of the world's irrigated lands have reduced productivity because of poorly managed irrigation that has caused waterlogging and salinity (Sadhukhan, 1990; Khan and Ali, 1998; Hussain, 2004; Khan, et al., 2006). Most of the researches in irrigation sector have already focussed attention on socio-economic aspects, but impacts on the physical environment have not yet been considered (Amarasekara, 1993). Some of the adverse environmental impacts are as follows:

i. LOSS TO ARCHAEOLOGICAL, HISTORICAL AND CULTURAL RESOURCES

Irrigation projects occupy large area, whatever comes in their way is levelled and subsequently vanished (Dani, 1971). The constructions of reservoirs usually drown the archaeological and historical monuments. Qamar (1993) found that construction of irrigation facilities usually damage the archaeological, historical and cultural resources. Stockle (2001) found that irrigation projects causes great threat to the archaeological sites, which preserve the age-old history of a region.

ii. RESETTLEMENT TO ACCOMMODATE IRRIGATION PROJECTS

Large-scale irrigation projects have one of the negative impacts on the local population is in the form of resettlement or relocation of inhabitants to accommodate new irrigation projects (Stockle, 2001). Usually, weir, barrages, reservoirs and canal system construction occupy extensive area, which needs settlement displacement (Qamar, 1993).

iii. WATER POLLUTION

Polluted water is a major cause of human disease (Stockle, 2001). Pollution is affecting the quality and supply of irrigation water (Cantor, 1967). The problem of downstream degradation of water quality by salts, agrochemicals and toxic lactates is a serious threat to the water pollution. The use of untreated human wastewater for irrigation purposes contributes to contamination of food chain. The study on Chambal irrigation project, India revealed that intensive use of herbicides and pesticides, entered into the food chain (Chourasia, 2003). In many developing countries, there is little or no treatment of municipal sewage, yet urban wastewater is increasingly being used for irrigation. The most common diseases associated with contaminated irrigation waters are cholera, typhoid, ascariasis (*intestinal infection*), amoebiasis (*intestinal parasitic illness*), giardiasis (*major diarrhoeal disease*), and enter invasive E. Coli (*dysentery*). Crops that are most implicated with spread of these diseases are ground crops that are eaten raw such as cabbage, lettuce, strawberries, etc (Stockle, 2001).

iv. WATERLOGGING

Waterlogging is a problem most commonly associated with a rise in the water-table (Bhatt, 1991). An agricultural land is said to be waterlogged, when its productivity is adversely affected by high water-table (Garg, 1987; Yaseen and Rao, 1993). Waterlogging is caused by the over and uncontrolled irrigation, seepage and percolation from field and channels, impervious obstruction, inadequate natural and surface drainage, excessive rain, irregular and flat

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topography (Garg, 1987; Sadhukhan, 1990; Sing, 1991; Yaseen and Rao, 1993; Shams, 2006). The percolated irrigation water raises the underground water-table and causes waterlogging.

Worldwide, about 10% of all irrigated land suffers from waterlogging. As a result, productivity of this area has fallen about 20% and in many cases (Stockle, 2001). In Punjab and Sindh (Pakistan), the agricultural land is facing with acute problems of waterlogging. This is the outcome of perennial canal irrigation, which was introduced to combat aridity (Ahmad, 1993; Khan, 1996; Khalid, 2003). The study on Warsak Right Bank Canal (WRBC) found that despite its many fold advantages, it has also been a source of negative effects; the chief adverse impacts include the emergence of waterlogging in some areas (Khan and Ali, 1998; Javaid and Niamatullah, 1992). Ahmed (2000) found that one of the adverse impacts of Aswan dam irrigation system was the problem of waterlogging, which was emerged due to the over-irrigation, increasing cropping intensity and expansion of rice and sugarcane cultivation.

World Bank (1997) found that the principal adverse impact after introduction of canal irrigation includes waterlogging. Karunasena (1993) found that in Ellegala Irrigation System, Seri Lanka agricultural land is severely affected by waterlogging. This condition can be worsened, if sufficient drainage facility not provided. Likewise, in Chambal irrigation command area, India has resulted severe problem of waterlogging (Chourasia, 2003). Khepar, (1993) found that due to excessive seepage from canal networks, blockage of runoff and less withdrawal of groundwater the state of Indian Punjab is also facing a serious problem of waterlogging. In Haryana state, India, after inception of canal irrigation almost 60% state area has been waterlogged and salinized. The conveyance losses and irrigation inefficiency is the major cause responsible for this situation (Singh, 1993). Bhatt (1991) found that major causes of waterlogging include over irrigation, excessive rainfall, induced seepage, sub-soil flow and poor outflow. Whereas, adverse effects of waterlogging included soil infertility, salinity and yield reduction. Yaseen and Rao (1993) found that waterlogging has reduced the potential of agricultural land causing poor yield.

v. SOIL SALINITY

Salinity is often linked with the rise of water-tables resulting from excessive irrigation and poor drainage in perennial irrigation systems. The resulting shallow water-tables bring salts to the upper layers of the soil profile. The ascent of dissolved minerals associated with the irrigation water through capillary action increases the soil alkalinity and damages the soil fertility (Sadhukhan, 1990; Ahmad, 1993; Khan, 1996; Khalid, 2003). The technical problems that have led to irrigation-induced salinity include poor on-farm water use efficiency; poor construction, operation and maintenance of irrigation canals causing excessive seepage losses, and inadequate or lack of drainage infrastructure or, if drainage facilities are present, their poor quality of construction, operation, and maintenance.

Globally, about 10 M ha of agricultural land is lost annually due to salinisation, of which about 1.5 M ha is in irrigated areas (Yaseen, and Rao, 1993). Stockle (2001) found that in 1982, salinization affected about 196,550 square km (0.7 percent) of the agricultural soils in Central America and Mexico, and 1,291,630 (7.6 percent) in South America. Argentina and Chile have about 35 percent of their irrigated lands affected by salinity whereas 30 percent or 250,000 ha. of the coastal region of Peru under irrigation are impacted by this problem. Estimates indicate that roughly one-third of the irrigated land in the major irrigation countries is already badly affected by salinity or is expected to become so in the near future. Present estimates for India range from 27% to 60% of the irrigated land, Pakistan 14%, Israel 13%, Australia 20%, China 15%, Iraq 50%, Egypt 30%. Irrigation-induced salinity occurs in large and small irrigation systems alike

Khan, et al., (2006) found that in Australia, the rice crop is mainly grown on the riverine plain in New South Wales by utilising surface-water supply from the Murray and Murrumbidgee rivers. Here, soil salinisation due to rising water-tables, is a major threat to the rice-based farming systems. Likewise, in Rechna Doab, a significant amount of ground and surface water is used for irrigation that caused a problem of soil salinity (Khan, et al., 2006). Research on Nile irrigation project indicates that wide expansion of rice and sugarcane cultivation has caused soil salinity hazard (Ahmed, 2000). The research on Ellegala Irrigation System, Seri Lanka indicates that agricultural land is severely affected by soil salinity hazard (Karunasena, 1993). Chourasia (2003) found that the surface water irrigation has increased the problem of soil salinity and alkalinity.

World Commission on land use survey (1958) found that in the Indus basin seven percent land was severely saline and 16% were salt affected due to unwise utilization of irrigation water. The study on WRBC indicates that irrigation has resulted problem of soil salinity (Khan and Ali, 1998). In Pakistan, water-table started rising and created problem of salinity. In some places it became so high that certain crops couldn't be grown there (Sarwar and Khan, 2001). A study on Environmental Impacts of Warsak dam indicates that after implementation of irrigation project, it has severely affected the fertile land unproductive due to severe problem of soil salinity (Javaid and Niamatullah, 1992). In Seri Lanka and China same problem of salinization affected large irrigated track and considered as an important environmental issue (Amarasekara, 1993; Kume, et al., 2002).

vi. DISTURBANCE OF NATURAL HYDROLOGY

Withdrawing surface water implies changes to the natural hydrology of river and sometimes deeply affecting the aquatic ecosystems associated with these water bodies (Stockle, 2001). An excessive withdrawal from river system, is clearly affecting the environment in some areas. For example, the Colorado river often contains essentially no water by the time it crosses the border into Mexico, owing to both urban and agricultural withdrawals. In fact, in most years, the Colorado River doesn't make it to the ocean. This has consequences for the river and its riparian ecosystems, as well as for the delta and estuary system at its mouth, which no longer receives the recharge of fresh water and nutrients that it normally did. The same is true for the Yellow River in China (Kume, et al., 2000). The San Joaquin River in California is so permanently dewatered that trees are growing in its bed and developers have suggested building housing over there. In the last 33 years, the Aral Sea has lost 50% of its surface area and 75% of its volume, with a concomitant tripling in its salinity, owing largely to diversion of water from its feeding rivers for irrigating cotton (Hirashima and Gooneratne, 1990). Stockle (2001) found that in USA, about 20% of the irrigated agricultural area is watered by pumping in excess of recharge. Likewise, Texas has lost 14% of its irrigated acreage since 1980 as a result of aquifer depletion. In India's Punjab, pumping exceeds recharge by 1/3, causing water-tables to drop by 1 m/yr or more.

vii. OTHER ADVERSE IMPACTS

Other adverse impact of irrigation projects is the emergence and breeding of mosquitoes (Khan, et al., 2006). Research on Nile river system indicates that due to over-use of irrigation water, ponding and waterlogging has propagated Schistosomiasis (*bilharzias* a parasitic disease) (Ahmed, 2000). Likewise, Cantor (1967) found that in Gezira, Sudan, the inception of canal irrigation brought about the spread of Schistosomiasis. World Bank (1997) found that after inception of canal irrigation, the principal environmental impacts were increase in malaria and waterborne diseases. Amarasekara (1993) found that irrigation has generated unprecedented increase in water born diseases such as malaria, typhoid and encephalitis (Mosquito-borne, inflammation of the brain). Chourasia (2003) found that public health hazard is one of the negative impacts of surface water irrigation. Qamar (1993) found that irrigation projects have increased the incidence of water-born diseases.

The intensive irrigation in a part of Chambal project command area has degraded the chemical quality of groundwater for drinking purpose (Chourasia, 2003). Qamar (1993) found that irrigation project has deteriorated the quality of water and was found unfit for drinking purpose. This is mainly attributed to the intensive use of agro-chemicals. Singh (1991) found that irrigating the fields by water containing much salt, especially sodium salt may result in secondary soil alkalinity, which means a great danger to land resources.

3.5 AN OVERVIEW OF EVALUATION

3.5.1. Concept and definition of evaluation

The concept of impact evaluation has been variously defined, because it conveys different meaning to different people (Havens, 1981; Baker, 2000; Maredia, et al., 2000). The evaluation may be described as a systematic process of collecting and analysing progress data pertaining to the development projects. In order to measure their pre-determined objectives and targets to be achieved with in a specified time (Hussain, 1991). The concept of evaluation may broadly be defined as any information obtained through intervention or social change programme. A more specified definition is put forward by Rutman (1982) that evaluation deals with the use of scientific method to measure the implementation and out-come of the project for decision-making. The project evaluation is a process to analyse the achievements and results of the completed projects (Hussain, 1991). Evaluation actually measures the effects of the outcome against the specified goal of a project. Hence, evaluation pinpoints all the weaknesses of the project.

The main purpose of evaluation is improvement in the inherent policies and programmes. The process of evaluation helps in what is planned for the future is better than what went before by pinpointing where the problems exist. Therefore, it shows the gap between the target set and the out-come. This mechanism also brings to focus the policy weaknesses and other external factors. Evaluation of completed projects also suggest for the possible measure to correct the various shortfalls and inadequacies as well as provide guidelines for the future projects (Maredia, et al., 2000). The evaluation process should not only focus on the negative checks but also positive and constructive factors as well.

3.5.2 Basic issues of evaluation

Evaluation of the project is incomplete unless it addresses the three basic issues of relevance, efficiency and effectiveness.

i. *Relevance*: When assessing the relevance of a project, it is intended to determine, whether the particular solution proposed in the project is pertinent to the development need and is likely to produce output of immediate use to solve the identified problem.

ii. *Efficiency*: Efficiency of a project is defined as the cost in resources of attaining goal. It can be expressed as the relationship of cost and outcome. The most widely used measure of efficiency is cost effectiveness and target group satisfaction.

iii. *Effectiveness*: The assessment of effectiveness is a major part of evaluation exercise. It entails an in-depth analysis of the intended results of a project from variety of angles. The nature and extent of the effects generated is quantified.

3.5.3 Types of evaluation

Evaluation is a distinct process and there are three types of evaluation (Hussain, 1991; ADB, 1993; Baker, 2000; World Bank, 2000).

i. *Built-in or self-evaluation:* This type of evaluation is conducted internally by those directly involved in the execution of the project or by outside the implementing agency.

ii. *On-going evaluation*: It is an essential part of the management information system and takes place at interval during the implementation of the project. It may be undertaken with or without an input from external evaluators.

iii. *Ex post evaluation*: Ex post evaluation takes place after completion of the project. It is more in depth then on-going evaluation.

Ex-post evaluation is an applied science activity. However, there is no single field that deals with ex post evaluation, as it is interdisciplinary approach (Baker, 2000; Maredia, et al., 2000). In fact, ex post evaluation is characterised by a diverse array of methods and approaches, which differ considerably according to the scale, scope and type of analysis (ADB, 1993). Ex post evaluation is a type of evaluation that is intended to determine the consequences of an intervention. This analysis can be either ex ante or ex post, which measures outcomes that have actually resulted from the intervention to date (Baker, 2000; Maredia, et al., 2000). Ex post evaluation provides feed back for future irrigation projects in terms of policies, design, implementation strategy etc. Ex post evaluation should make use of the data produced through monitoring as well as the findings of the on-going evaluation. However, the need may arise for the collection of new data and information, especially regarding the impacts on beneficiaries.

It can be concluded that ex post evaluation research has two common objectives:

i. Accountability: It provides empirical information about the effectiveness of past investment for deriving outcomes. It also indicates the relevance of overall strategies pursued.

ii. Feedback: After providing in-depth analysis it helps in comparing effectiveness of various investment options that could enhance the implementation of ongoing and future projects.

Although there are extensive literature on quantitative versus qualitative methods in evaluation and a growing acceptance for integrating the two approaches (Hussain, 1991; Baker, 2000). Ex post evaluations using quantitative data from statistically representative samples are better suited for reaching generalize conclusion. However, qualitative methods allow the in-depth study of selected issues/cases and can provide critical insights into beneficiaries' perspectives, the dynamics of a particular reform, or the reasons behind certain results observed in a quantitative analysis (Baker, 2000; Maredia, et al., 2000; World Bank, 2000). Integrating quantitative and qualitative evaluations can often be the best vehicle for meeting the project's information needs. There are several benefits of using integrated approaches in research that also apply to ex post evaluations (World Bank, 2000).

3.5.4 Ex post evaluation methodologies

Ex post evaluation methodologies are widely used (ADB, 1993). These methodologies are also used before project implementation as well as after. Today, these evaluation methodologies have been categorised into major groups by various authors (Leopold, et al., 1971; UN, 1985; World Bank, 1991; ADB, 1993; Wood, 1995; Barrow, 1997; Azhar, 2001). In fact, the accuracy and scope of each technique varies according to the intended purpose as well as the targeted user. A fundamental objective of any method remains; however, to determine all potential positive and negative impacts in a manner that facilitates the comparison between available project alternatives. Some of the authors have listed ex post evaluation methodologies as fallow:

i. ADHOC

This methodology is one of the oldest and crudest methods. The adhoc methodology is good, where detailed investigation is not required. It is valuable for initial and rapid examination (UN, 1985). The drawback of this methodology is the superficial examination of the environmental components.

ii. CHECKLISTS

The term checklists cover a variety of characteristics and degree of complexity (UN, 1985; Azhar, 2001). Checklists are known to be the simplest method for the evaluation of any project impacts on the different components of the environment (Leopold, et al., 1971). Many authors have divided the checklists into different forms of simple checklists, descriptive checklists, questionnaire checklists, scaling checklists and scaling weighting checklists (Leopold, et al., 1971; UN, 1985; Azhar, 2001). This checklist provides a list of all environmental factors, affected the project. It ensures that no relevant impact is neglected. With respect to irrigation projects, the two most widely acclaimed checklists are those prepared by the World Bank (1991) and the International Commission for Irrigation and Drainage (ICID). However, in the present study simple checklist is used.

iii. MATRICES

Matrices, unlike checklists, adopt an objective procedure for environmental impact assessment that enables rating, weighing, and consequently can assist in decision-making. Leopold matrix is the most well known example of an interaction matrix (Leopold, et al., 1971). The matrix is a more complex and time-consuming technique than a checklist (Westman, 1985).

iv. NETWORKS

The network could be called as an extension of the matrices incorporating the long term impacts of the project activities. As the name of the methodology shows that here the environmental components are connected in the form a web or network (Petry, 1998; Smith, 1993).

v. OVERLAY MAPPING

The overlay mapping method is simply the superimposition of a set of transparent maps representing each environmental attribute on a base map of the area. The boundaries and the density of the colour indicate the extent and value of impact. This spatial distribution of the project effects provides a powerful visual representation of the potential impacts that can be easily displayed and comprehended by audience (Smith, 1993).

vi. COST-BENEFIT ANALYSIS

Cost-benefit analysis attempts to measure the economic efficiency of program costs versus program benefits, in monetary terms. For many projects, especially in the social sectors, it is not possible to measure all the benefits in monetary terms. This would require cost-effectiveness analysis. The concepts for both types of analysis are the same (World Bank, 2000).

vi. SIMULATION MODELLING

Simulation modelling is a powerful interactive tool that can demonstrate and predict the response of the environmental components to the project activities. They are normally based on mathematical formulations that can be quickly processed using computer capabilities. The simulation results can guide impact assessment studies including environmental, social and economic aspects even in cases of few available data or considerable uncertainty of the dynamic relationships (Abu-Zeid, 1994).

vii. EX POST EVALUATION USING SWOT ANALYSIS

SWOT is one of the techniques applied for the evaluation of impacts of projects. SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. Strengths and weaknesses are internal factors. Opportunities and threats are external factors. SWOT analysis is a framework for analyzing the study area Strengths and Weaknesses and the Opportunities and Threats that the area faces (Hussain, 2004). SWOT analysis is a tool for auditing a project and its environment. It helps decision maker to focus on key issues (Paliwal, 2006). This technique help planners and decision-makers to focus on the project strengths, minimize weaknesses, and take the greatest possible advantage of available opportunities. What makes SWOT particularly powerful is that with a little thought, it can help uncover opportunities to take advantage by understanding project area weaknesses, can manage and eliminate threats that would otherwise catch the implementer unaware. More than this, by looking the SWOT framework, one can devise a strategy that could help to distinguish already focused project from others and could achieve the task sustainable.

3.6 IRRIGATION IN PAKISTAN

In Pakistan, history of irrigation goes back to the Indus civilization (4,500 BC). The history tells us that the inhabitants of the fertile valleys of Mohenjodaro and Harrrapa used to irrigate their lands through river spills during the floods in the rivers (Ahmad, 1993). Feroz Shah Tughlaq constructed the earliest canal during 1351, which was taken from Jamna river to irrigate Hissar. In the year 1633, Ali Mardan Khan (engineer) also constructed canal, which originated Madhopur on river Ravi and irrigating Shalimar Garden and part of Bari Doab (Ahmad and Chaudhry, 1988). Later on, between 8th and 19th century AD, various emperors built a large number of inundation canals. The Mughal emperors also constructed a number of canals. During the 1870s, the British initiated the canal construction program. They developed the irrigation system on a massive scale and converted the inundation canals to the properly regulated perennial canals by constructing the barrages on the rivers.

Historically speaking, in Peshawar vale first irrigation system was introduced during the British period. Initially, an irrigation canal was taken out from river Swat at Munda during 1890 called as lower Swat canal and during the same year, another canal was taken out from Kabul river down stream Warsak (Ahmad, 1993). Although, there was no concept of EIA, however to protect the land from the menace of waterlogging and salinity, the access water was drained to the dry channels. Unfortunately, this system is no more functioning. After inception of Pakistan no lesson was learnt from the British period irrigation planning. Likewise, in 1902, Paharpur canal was taken out from Indus to irrigate D.I.Khan area. This canal is now remodelled and shifted to Chashma barrage, after the construction of Indus Basin Works. Similarly, in 1915, a canal was taken out from river Swat at Amandara called as upper Swat canal. This canal after power generation at two points, irrigate Dargai plain and part of Mardan district. After advent of Pakistan, in 1960 high Kabul river canal both on left and right banks of Kabul river were constructed. The left bank carries 45 cusecs and irrigates 10,993 acres. However, the right bank bifurcated into gravity and lift canal. They jointly irrigate 106,187 acres of Peshawar district (Ahmad, 1993).

During the 1960s, a number of projects were started with the signing of the Indus Basin Water Treaty. Mangla dam with a storage capacity of 5.34 MAF was constructed on river Jhelum in 1967 fallowed by Tarbela dam with a storage capacity of 9.4 MAF on Indus river in 1975 (Khan, 1996). Other works include barrages at Balloki, Trimmu, Mailsi siphon, Sidhnai, Qadirabad, Marala, Rasul and Chashma. New major link canals were Sidhnai-Mailsi-Bahawal, Trimmu-Sidhnai Link, Balluki-Sulemanki Link, Qadirabad-Balloki Link, Rasul-Qadirabad Link, Taunsa–Panjnad Link, and Chashma-Jhelum Link. In 1949, total canal water withdrawals were 67 MAF, which increased to 108 MAF after the construction of this irrigation network (Shams, 2006). Presently, the Indus irrigation system is the largest contiguous irrigation system in the world, which provides irrigation water to about 14 M ha of Cultivable Command Area (CCA) in Pakistan (Hussain, 2004). The system is comprised of the Indus river and its major tributaries, 3 major storage reservoirs, 19 barrages/ head-works, 12 link canals and 43 canal commands (Khan, 1996; Khan, et al., 2006; Shams, 2006). The total length of the canal system is about 58,500 km, while the watercourses, from channel and field ditches, are running another 1.6 million km in length. This network of irrigation infrastructure helped to reduce rural poverty by increasing the productivity of agricultural lands and providing employment opportunities to the rural non-farm households. With the passage of time, the development of irrigation has significantly changed the status of agriculture. Although historical data beyond Pakistan's history are not available, farm-gate supply of irrigation water has increased from 58.74 million acre-feet in 1960–61 to 133.28 million acre-feet in 1999–2000. This, in other words, implies that the total increase over the 39-year period was nearly 27 percent, which would correspond to an annual growth rate of 2.04 percent in irrigation water resources.

The cultivated area in Pakistan is about 20 M ha, of which more than 16 M ha are irrigated (Shams, 2006). The Indus basin irrigation system in Pakistan is the largest integrated irrigation system in the world. This irrigation system diverts approximately 123 BCM of annual river flow and spreads it over 13.5 M ha of cultivable land, of which nearly 9 M ha can be irrigated throughout the year (Khan, et al., 2006). This controlled distribution is accomplished by means of 17 barrages and canal diversion works, 42 major canals, 6,000 km of minor canals, 600 km of link canals, and 78,000 watercourses. The total capacity is nearly 7,000 m3/s. This flow is supplemented with over 150,000 tube wells, which pump 24.5 BCM/year from groundwater.

Pakistan has a huge potential to increase agricultural production due to its relatively level terrain, heavy soils, sunny days, appropriate climatic conditions and abundant supply of farm labour (Khan, et al., 2006). Unfortunately, inadequate supply of irrigation water at critical times of growth, lack of drainage, saline and sodic soils, low-quality seeds, antiquated farm implements, imbalances in farm inputs, unsatisfactory agriculture and irrigation practices are major constraints limiting crop production in Pakistan. Since the introduction of canal irrigation, waterlogging and soil salinity have become the major problems impeding agricultural growth and development (Khan, 1996).

Table No. III-2

Pakistan, Types of Irrigated area, 1950-51 to 1997-98

Year	Irrigated area (Million hectare)	Percentage of area irrigated by			
		Canals	Tube wells	Wells	Others
1950-51	9.25	81.4	-	11.7	6.9
1960-61	10.41	82.5	2.4	8.3	6.8
1970-71	10.51	63.2	21.2	12.2	3.4
1980-81	14.84	82.2	12.3	1.4	4.1
1990-91	16.75	82.6	15.3	0.8	1.3
1997-98	18.0	81.4	16.7	0.9	1.0

Source: Agricultural statistics of Pakistan, 1997-98 and other years

3.6.1 Irrigation related line agencies

There are several agencies involved in managing the irrigation supplies and drainage in the irrigated areas of Pakistan. These include: Water and Power Development Authority (WAPDA); Provincial Irrigation and Drainage Authority (PIDA); On-Farm Water Management

Directorate (OFWMD); Salinity Control and Reclamation Projects (SCARP) staff; Private Sector Ground Water Project (PSGWP); Agricultural Development Bank (ADBP) etc.

3.7 CONCLUSION

The chapter discussed the role of water as a resource. Water is a precious resource and it is unevenly distributed over the globe. In practice, there are four general sources of water available to mankind that is surface water, groundwater, atmospheric water and the marine water. By far the most important of these is surface water in the form of rivers, streams and lake and the same is utilized for irrigation.

The chapter further explained the global status of irrigated agriculture. Historically, irrigation has been important for agricultural production for thousands of years. Presently, irrigated lands contribute significantly to the world agriculture output and food supply. The successful expansion of irrigation farming has been one of the most striking features of the growth of world agriculture, during the last century. Recently, the technological advances have brought about a great expansion in irrigated agriculture. Traditionally, the problems of irrigated agriculture were silting of canals, soil salinity, water politics arising from tension between upstream and downstream users, over exploitation of resources and Institutional failure.

The chapter also focused on various environmental impacts of irrigation projects. The irrigation project poses both positive and adverse impacts on the environment. However, the positive impacts of irrigation project do not need any emphasis particularly during the times of acute food shortages and growing population. The spread of irrigation has been a key factor behind the near tripling of global grain production, since 1950. At the same time, several irrigation projects failed due to inefficiency in water management. Some of the key challenges faced by present day irrigation projects include changes in land use, declining cropping intensity and production, health hazards from use of polluted water, loss of water through seepage and percolation and due to rising water-table the emerging twin problem of waterlogging and salinity.

The chapter explained in detailed the concepts of ex post evaluation and irrigation projects. Evaluation is the process to find and determine the consequences of an intervention. It can also be explained as to find the effectiveness of implemented projects. It has two uses i.e. accountability and feedback. Both qualitative and quantitative techniques are applied individually or jointly. In the last section, the chapter discussed irrigation in Pakistan. The focus remained on the history of irrigation systems, various water management organizations, water user's association, new national water policy and institutional reform in irrigation and drainage sector.

CHASHMA RIGHT BANK IRRIGATION PROJECT (CRBIP)

Introduction

This chapter is designed to provide an overview of the Chashma Right Bank Irrigation Project. The chapter is divided into seven sections. Section one gives the project background in detail. Section two discusses the aims and objectives of the project. Section three assesses the major benefits of the project. Section four discusses the project components. Project implementation process is described in section five, whereas section six gives the Operation & Maintenance of the project. The chapter is concluded in the final section.

4.1 AN OVERVIEW OF THE PROJECT

The Water and Power Development Authority (WAPDA) prepared a feasibility report on the Chashma Right Bank Irrigation Project (CRBIP), in 1970 (ADB, 1987). The Asian Development Bank (ADB) approved the loan in December 1977. Moreover, the Asian Development Bank classified the project as Category B. This means the project does not require a full Environmental Impact Assessment (EIA). After starting physical works on the project, it was found that the CRBIP would cost substantially more than the originally estimated (JICA, 1993). Pending resolution of the cost over run issue, bank action and disbursement for further contracting and procurement activities were withheld from mid 1980.

Following virtual termination of construction, Government of Pakistan (GoP) and WAPDA, the main executing agency for the project made various studies on the CRBIP, which involved sub-division of the project into three stages. It has been implemented through segmenting 272 km main canal into increments of 84 km, 38 km and 150 km, respectively (ADB, 1987). In early 1984, all pending issues on the revised CRBIP were formally resolved and the bank reactivated the loan stage-wise, starting application on stage I. During construction phase, little amendments were made in the alignment of the main canal to bring maximum area under the command of CRBC (Plate IV-1 and 2).

The CRBIP is a large irrigation system spread over the two provinces NWFP & Punjab. It is fed by the Indus river through the Chashma barrage. It covers a gross extent of about 250,000 ha. Out of this area, 61% lies in NWFP and 39% in Punjab, mainly on the right bank of Indus river south of Chashma barrage (WAPDA, 2002b). Actually the water has been diverted into the right bank via canal, formerly known as Paharpur canal. Prior to this project, Paharpur canal was irrigating some parts of the project area in the north of D.I.Khan district. Paharpur

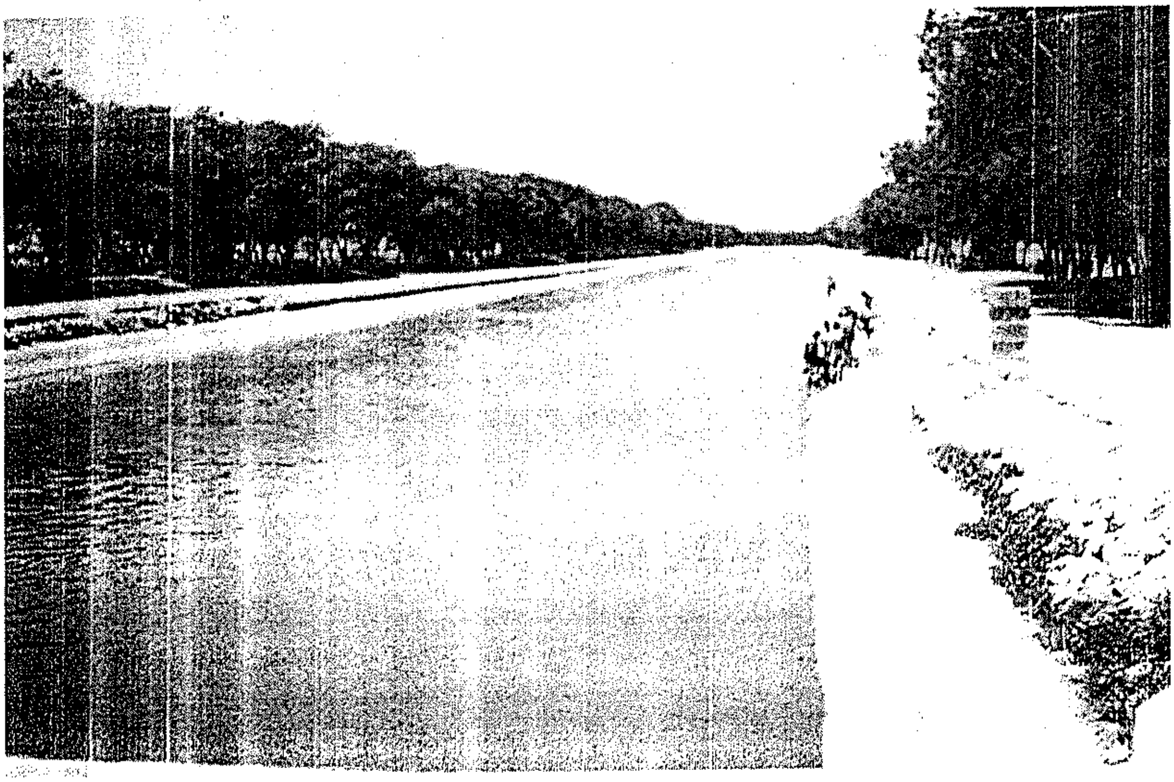


Plate IV-1. Chashma Right Bank Canal

Plate IV-2. Chashma Right Bank Canal

canal was originally an inundation canal built in 1902 and upgraded to become perennial in the 1930s (GoP, 1985; Ahmad and Chaudhry, 1988; Ahmad, 1993). Discharge into the Paharpur canal was significantly increased following headwork's improvement in 1980. Another old seasonal canal, the Massu wah, exists in stage III area, commanding some 6,000 ha, but irrigating only a small part from July to September (WAPDA, 2002a). There is also small Gishkori lift scheme in the north of stage III operating from 1951. It commands 940 ha, however here the cropping intensity was less than 50%.

4.1.1 Rationale for undertaking the project

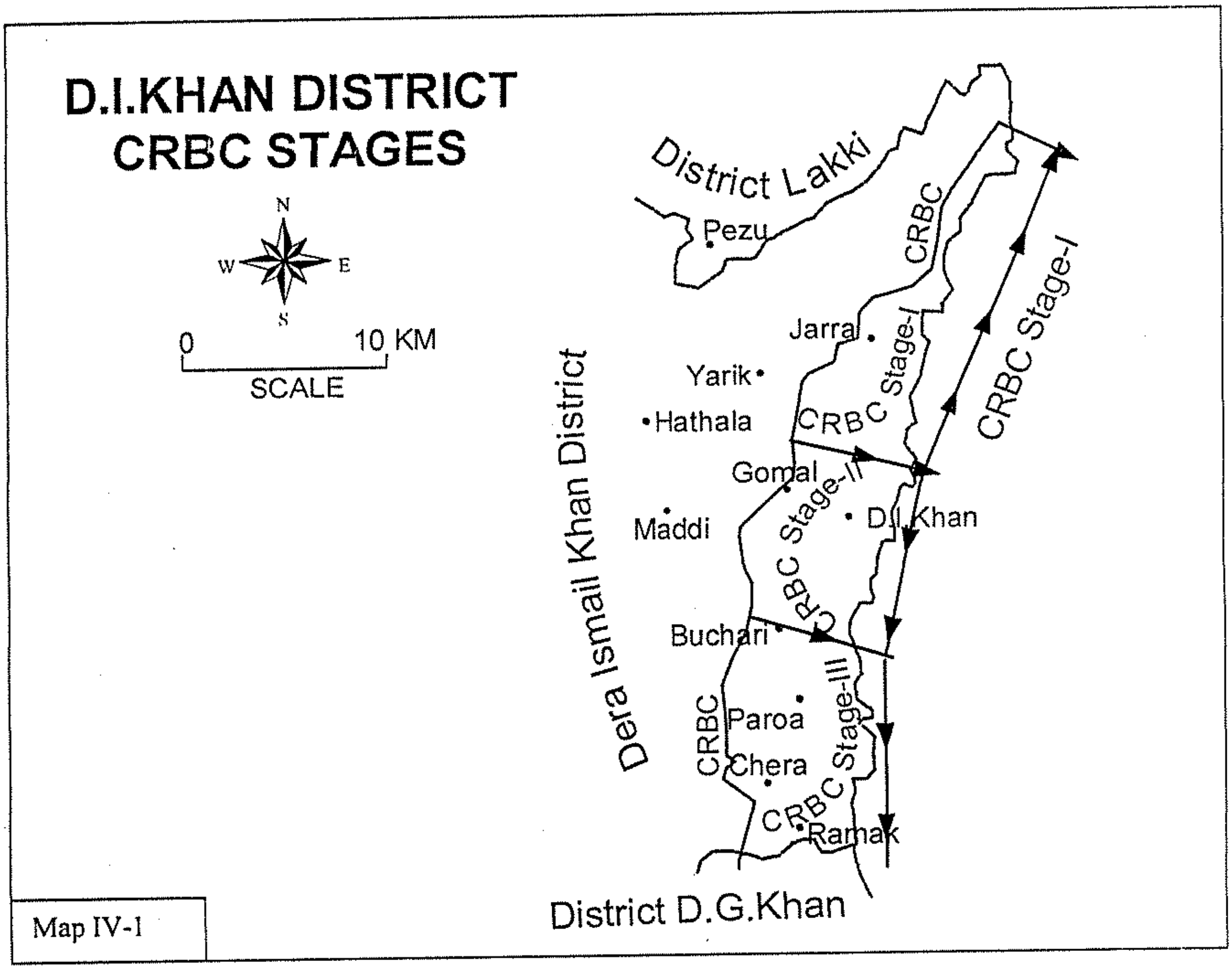
After completion of Chashma Barrage in 1971, a major diversion was made on the left bank and the feasibility for a diversion on the right bank was under preparation by WAPDA (WAPDA, 2002a). Once the barrage was completed, the rationale for implementing the CRBIP was justified, on the basis that it supported three development goals of the government as expressed in the fifth, sixth and seventh five-year plans. These goals are:

- To increase agricultural production
- To improve social and economic condition of rural population
- To promote priority development of less developed areas

4.1.2 Stages of the project

The Chashma Right Bank Irrigation Project has been completed in the following three stages (Map IV-1):

- Stage I, initiated in 1978, but major construction efforts on stage I, covering 84 km main canal, was started in 1984. Stage I consisted of rehabilitation of old Paharpur canal and construction of new main canal, in order to serve 61,000 ha of cultivable land (Table IV-1). The main canal was commissioned in February 1987.
- Stage II construction was started in 1988 and was completed in 1995. It provides 38 km main canal and serves about 39,000 ha.
- Stage III consisted of 150 km main canal. It has a total command area of about 150,000 ha. An additional area of 14,575 ha was added to the originally planned command area because of realignment of the main canal (Table IV-1). Construction on stage III was started in 1999 and was subsequently completed in 2003.



Map IV-1

Table IV-1
Stage and province-wise summary of the design parameters

Design Parameter	*Stage*			*Total*	*Province*	
	I	*II*	*III*		*NWFP*	*Punjab*
CCA (ha)	61,000	39,000	150,000	250,000	61%	39%
Percent of total CCA	24.8%	15.5%	59.7%	100%	-	-
Canal length (km)	84	38	150	272	170	102
WA Accord (cfs)	1,226	800	2,853	4,879	3,079	1,800
No. of cross regulators	2	3	16	21	8	13
No. of Direct outlet	0	0	11	12	4	8
No. of distributaries	12	16	43	71	41	30

Source: Modified after, CRBC, PC-I, 1996 and 1999.

4.2 PURPOSE OF THE CHASHMA RIGHT BANK IRRIGATION PROJECT

The main purpose of the project was the country's socio-economic development, sustained growth and equitable income distribution (JICA, 1993; JICA, 1995; WAPDA, 2002a). To achieve this purpose the agricultural sector strategy recognized the need to improve the availability, use and management of irrigation water supplies, which was the main thrust of this particular project. The ultimate goal of the Chashma Right Bank Irrigation Project (CRBIP) was to increase agricultural productivity and increase employment opportunities in the rural areas as well as strengthening institutional support in the agriculture sector (ADB, 1987; JICA, 1993; JICA, 1995; WAPDA, 1995; WAPDA, 2002a; WAPDA, 2002b). All these goals were aimed at poverty alleviation among the people of the area. The overall objectives of CRBIP as appraised by the Government of Pakistan, 1977 were:

- To improve the living condition of the people by providing irrigation to achieve poverty alleviation.
- To facilitate the provision of water for domestic uses in forsaken areas, where even drinking water is not available.
- To increase cropping intensity from 28% to 143%.
- To protect fertile land, roads and communication and infrastructure from floods and hill torrents.
- To create job opportunities for the local people during and after project implementation.

4.3 ENVISAGED BENEFIT OF THE PROJECT

As mentioned earlier, the CRBIP was aimed to enhance the agricultural productivity of both land and water resources. The principal quantifiable benefit of the project was to increase production of crops (WAPDA, 2002b). The annual incremental production of crops like wheat, rice, sugarcane, oilseeds etc. will further enhance and this would be achieved by increasing cropping intensity (ADB, 1987). With the project, yield per hectare will also increase.

4.3.1 Employment enhancement

With the project, the local labour demand would not keep pace with the increasing work force and under employment will develop (ADB, 1987; WAPDA, 2002b). However, the project will generate an additional farm labour equivalent to nearly five times the demand without project (ADB, 1987). The project construction activities will also generate substantial employment, indirectly.

4.3.2 Cropping intensity enhancement

Prior to the inception of CRBC, the annual cropping intensity was 28%. One of the objectives of CRBIP was to enhance cropping intensity from 28% to 143%.

4.3.3 Agricultural economy

The annual gross foreign exchange value of the tradable product generated by the project particularly of rice, wheat, cotton, sugar and oil are particularly important for agricultural economy (WAPDA, 2002a). The farm value added from the agricultural output in the D.I.Khan district is expected to improve. Furthermore, processing particularly in terms of the incremental volume of rice and oilseeds will add significantly to the regional and national Gross Domestic Product (GDP).

4.4 PROJECT COMPONENTS

Following are the major components of the project:

4.4.1 Design of main canal conveyance and distribution system

The Chashma Right Bank Canal has its off take at the barrage on the Indus river and flow almost parallel to the Indus for 272 km (ADB, 1987; JICA, 1995; WAPDA, 2002a). The canal maintains high elevation, in order to irrigate the commanded area by gravity. Out of total 272 km main canal, the first 39 km is unlined and has a slope of 1:8,000, while the remainder of the canal lined with a slope of 1:14,000 has been provided in the next reach of 198 km. The final 35 km lined canal has a steeper slope of 1:8,000.

An important physical feature of the CRBC is the provision of structures to carry rainwater by numerous hill torrents across the canal. Siphons were made in stage I and II. Latter on, the design was changed to super passages at the end of stage II and all of stage III, because of maintenance problems mainly due to sediments deposition in the siphons. The flow, crossing the canal is conveyed to the Indus river by flood carrier channels (WAPDA, 2002a). At the main canal level, cross regulators, escapes and gated-off-takes have been constructed, to achieve and maintain the required water elevations at variable supply. Twenty-one cross regulators have been provided in the main canal, 8 in stage I & II and 13 in stage III. Seven escape structures have also been provided to manage the extra flow during emergency.

The distributaries off-take only from the left bank of main canal and flow towards the Indus river. Distributaries in stage I and II are unlined and partially lined in stage III. The design criteria for distributaries head regulators of stage I and II consider the full supply operations as the target. The project has also provided roads along the distributaries and associated minors (WAPDA, 2002b). To ensure maximum supply of water to CCA on the left side of the main canal, the project also included lift pumps on the main canal, for supplying water to just high level distributary canal.

4.4.2 Canal communication system

The project recognizes the difficulty of communication with long canal system during the construction, operation, routine and emergency operation and maintenance activities. A high power (125 watt) high frequency radio communication has been provided with five base stations. Besides this, 10 mobile vehicle units also monitor the performance of canal.

4.4.3 On Farm Water Management

The main objective of the On Farm Water Management (OFWM) is to bring benefit to the farmers of all stages of CRBIP through construction of watercourses, formation of Water User's Associations (WUA), land levelling, training of farmers and related work (WAPDA, 2002a). Some of the first watercourses along the old Paharpur canal system, which are now in the CRBC command area, were constructed in the early 1980s. Under CRBIP up to December 2002, some 2,917 new watercourses have been constructed mainly in stage II and III (WAPDA, 2002b). OFWM record shows that about 2,930 WUA's were made in all the three stages.

4.4.4 System Operation

In CRBC command area, it has been decided in the planning stage to adopt crop-based irrigation. A crop calendar in line with the existent patterns of the area was assumed with relatively small increase of water for crops. Due to climatic condition of the region, the daily potential evapo-transpiration varies from 3 mm/day to 100 mm/day (WAPDA, 1995). Therefore, the computed water demand of the proposed crop varies from 30% to 100%, for the lowest to highest demand period. The critical influence of the crop-based planning is 10 daily variable water allocations for the system.

The Water Apportionment Accord (WAA) of March 1991 authorised 10 daily allocations for the CRBC based on the evapo-transpiration estimates. This accord has fixed the share of Punjab province and NWFP in 1981, 1991 and 1996 (WAPDA, 2002a). The net seasonal volume allocated by the WAA is given in table IV-1. Although, CRBC is designed as crop-based irrigation system, but it is operated on a demand based system. After more than fifteen years operation of stage I and nearly eleven years of stage II, water is still being delivered on continuous fixed supply basis (WAPDA, 2002a).

4.5 PROJECT IMPLEMENTATION

4.5.1 Project executing agencies

The project was executed by WAPDA and provincial Planning, Environment and Development Departments (PE&DD). WAPDA was made responsible for:

i. Investigation, design and construction supervision of all the engineering works associated with the main canal, distribution system, canal cross drainage structure and canal communication system;

ii. Land acquisition for these works;

iii. Procurement of equipment and vehicles;

iv. Recruitment of consultants associated with these works;

v. Monitoring and evaluation of the physical parameters and implementation of the works under WAPDA control.

WAPDA was assisted by Provincial Irrigation and Drainage Authority (PIDA's) for planning and development aspects. The provincial subject was coordinated by the PE&DD, the executing agencies for subcomponents are: PIDA's, Executive District Agricultural Officer (EDAO) and Works and Services Department (W&SD). PIDA's was made responsible for:

i. Investigation, design and construction supervision of drainage works including open collector and flood carrier drains;

ii. Works for gravel surfacing of all the main canal and distributary canal

The OFWM was made responsible for the command area development sub components, which included watercourse construction and demonstration for Precision Land Levelling (PLL) as well as the upgradation, teaching and demonstration facilities at the OFWM training centre, D.I.Khan.

4.5.2 Project Coordination

Project coordination arrangements were placed at the disposals of Command Area Development Project. This involved project supervision and coordination committee at the federal level, while provincial coordination committee is chaired by the additional chief secretary of the PE&DD. At the district level, the District Project Coordination Committee included district level representatives.

4.5.3 Project Management

The chief engineer CRBIP was made responsible for overall implementation of the project. Six superintendent engineers had worked under the chief engineer and were responsible for various aspects of planning, design and implementation. The major responsibilities of Chief Engineer included:

i. Overall planning of the project implementation;

ii. Liaison and coordination between investigation, design and construction aspects;

iii. Preparation of designs, specifications, tender documents, contracts and procurements;

iv. Quality control;

v. Command Area Planning to ensure orderly progression of works;

vi. Staff training; and

vii. Accounts.

The major portion of design work was carried out from the design cell headquarters in Lahore with a sub-cell of design staff located on site at D.I.Khan.

4.5.4 Land acquisition

Land acquisition was under taken through Land Acquisition Act, 1894 (ADB, 1987). After general alignment notification has been gazetted under section 4, which allows right of entry and subsequently detail description of individual land parcels to be acquired by the gazette. The price paid is estimated on comparative land sales one year prior to section 4, notification. The price reflects the market value plus compensation for standing crops, trees, built-up property, severance, injurious acquisition and incidental charges. A further provision of 15% of the land value was made for compulsory acquisition and compound interest from the data of possession to settlement at 8%.

4.6 OPERATION AND MAINTENANCE

Chashma Right Bank Canal is of inter provincial nature. Its operation and maintenance has been suitably coordinated between the relevant agencies to avoid any conflict. In March 1999, WAPDA and two provincial governments agreed to the following formula for the Operation & Maintenance (O & M) of the CRBIP system:

i. O & M of the feeder canal from the barrage to the control regulator and all of CRBC from origin to the end of the canal including all structures and facilities will be the responsibility of WAPDA.

ii. Maintenance of the flood carrier channels beyond 1,000 feet east of the main canal will be the responsibility of the respective Provincial Irrigation and Drainage Authority (PIDA's).

iii. O & M of all the distributaries and minors below their off takes from their main canal including structures and other facilities will be the responsibility of the respective PIDA's.

iv. All O & M activities below Mogha out let will be the responsibility of the farmers. Water Users Association will be encouraged to eventually take-over the O & M of distributary and minors.

v. Provinces will provide adequate working capital to WAPDA for O & M of the canal.

vi. Provinces will reimburse actual O & M expenditure to the WAPDA after receipt of an audited statement of the expenditure.

vii. Each province will share O & M costs according to the quantities of water actually received.

viii. WAPDA will consult the provinces for the preparation of annual O & M plan and scheduling of major maintenance work.

There has been little or no maintenance of the main canal by WAPDA in recent years due to lack of financial resources. As a result, there have been some incidents of disruptions to flow in stage I and II, when emergency canal repairs were needed. These could have been avoided if an adequate O & M budget had been available (WAPDA, 2002a).

The maintenance responsibility of the distributaries lies with the respective Provincial Irrigation and Drainage Authorities (PIDA's). The constraints that the Provincial Irrigation and Drainage Authorities faced were mainly lack of funds to do maintenance. The studies confirmed that the irrigation department, NWFP for stage I and II, a budget of less than Rs.2/acre was received for annual maintenance (WAPDA, 2002b). While the estimated annual budget required was in the order of Rs.111/acre of command. Therefore, the budget short fall needs to be addressed seriously. It is felt that the annual requirement of Rs.111/acre is well within the water tax (*abiana*) level currently being charged.

Water cess *(Abiana)* was charged on the basis of per crop, but fallow and other uncultivated land generated no *abiana.* Whereas an acre cropped both in Kharif and Rabi would generate two charges. Sugarcane is an annual crop and the rate indicated covers entire period. The irrigation charge for orchards is on annual basis. Current *abiana* rates are effective since July 2001 is presented in table IV-2 (WAPDA, 2002a).

Table IV-2
Abiana rates (Irrigation services fees)

Crops	*NWFP (Rs/Acre)*	*Punjab (Rs/Acre)*
Kharif crops		
Rice	185.60	708.24
Sorghum	109.60	301.20
Millet	142.40	354.40
Maize	109.60	425.12
Mung Bean	142.40	513.84
Cotton	142.40	744.16
Vegetables	324.00	868.16
Tobacco	185.60	744.16
Melon	185.60	620.00
Spices	185.60	620.00
Barley	142.40	301.20
Rabi crops		
Wheat	142.40	372.08
Gram	142.40	124.08
Trifolium (Fodder)	109.60	301.20
Vegetable Rabi	324.0	354.40
Oil seed	148.00	301.20
Annual crop		
Sugarcane	410.40	903.20
Orchards	324.00	1116.00
Trees/Forest	185.60	496.16
Fish Farm	2332.80	DNA

Source: PIDA, NWFP and Punjab

4.7 CONCLUSION

The Chashma Right Bank Irrigation Project (CRBIP) has accorded high priority at both the federal and provincial level. It was need of the day to execute such a mega project in one of the desert ecosystem of Pakistan. The CRBIP was funded by the ADB. Actual project implementation was started in 1984 and completed in three stages during 2003. The project was initiated to increase agricultural productivity, help, improve farm incomes and provide employment to the expanding rural labour force. Presently, high productive crops including wheat, sugarcane, cotton, oilseeds etc is cultivated in the CRBC command area. Likewise, with the project the proposed cropping intensity of 150% will be achieved. The project will also generate more than five times labour demand as was without project. This will directly benefit the local population in terms of socio-economic uplift. The inhabitants of the CRBC command area not only full fill their water requirements for domestic but will also supply water for irrigation.

The CRBC flow almost parallel to the Indus for 272 Km and maintain high elevation, in order to irrigate command area through gravity. Numerous structures also constructed to ease the flow of water. For maintaining emergency O & M, a high frequency Radio communication has established. The task for the formation of WUA's, land levelling and farmers training was assigned to OFWM wing of agriculture department. This was project was executed by WAPDA and Provincial Irrigation and Drainage Authority (PIDA's). Project coordination was the responsibility of Command Area Development Project. The O & M of CRBC system was distributed amongst the related departments of the two provinces. WAPDA was made responsible for major O & M, while provinces will provide capital.

PART TWO

RESEARCH METHODOLOGY, ANALYSIS AND DISCUSSION

RESEARCH METHODOLOGY AND DATA COLLECTION

Introduction

This chapter presents the methodology adopted for carrying out research as well as techniques of data collection and analysis. This chapter is divided into ten sections. Section one deals with the research question. Section two and three discusses the research hypothesis and research objectives respectively. Section four explains various research variables used in the study. Data needed for the study is given in section five, while section six and seven presents the techniques of data collections and important characteristics of the sample villages. Section eight discusses data limitation. Section nine gives the methodology adopted for data analysis and presentation. The chapter is concluded in the final section.

5.1 RESEARCH QUESTION

The research question is "What are the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district?

5.2 RESEARCH HYPOTHESIS

Following indicators have been used for testing:

i. There has been considerable enhancement in the cultivable land as a result of CRBC.
ii. Canal irrigated area has been increasing in the study area after commissioning of CRBC.
iii. New water loving crops have been introduced in the study area with the launching of CRBC.
iv. There has been significant increase in the cropping intensity after the advent of CRBC.
v. There has been substantial increase in the agricultural production after the inception of CRBC.
vi. Land value has been increased considerably after commissioning of CRBC.
vii. The water-table in the command area has been raised as a result of CRBC.

5.3 RESEARCH OBJECTIVES

To achieve purpose of the study, the following objectives were formulated:

i. To find out the existing socio-economic and physical environment of D.I.Khan district.
ii. To analyse the land utilization and irrigation pattern before and after commissioning of CRBC.

iii. To compare changes in the cropping pattern and cropping intensity before and after launching of CRBC.

iv. To find out the environmental impacts of CRBC on the agricultural production, land values, mechanization, fertilizer and water-table.

v. To suggest recommendations for mitigating the adverse impacts of CRBC on the land use and agricultural resources.

5.4 RESEARCH VARIABLES

i. Independent Variable

a. Irrigation
b. Mechanization
c. Fertilizer

ii. Dependent Variable

a. Land use
b. Cropping pattern
c. Cropping intensity
d. Land values
e. Agricultural production
f. Water table

5.5 DATA NEEDED FOR THE STUDY

The data regarding the project background, components, implementation etc. were obtained from the office of CRBIP D.I.Khan; Water & Power Development Authority (WAPDA) house, Lahore; Environmental Protection Agency, Peshawar; Provincial Irrigation and Drainage Authority (PIDA) Peshawar; Paharpur and CRBC irrigation circle D.I.Khan. The water cess (*abiana*) information was obtained from both the PIDA Peshawar and revenue office, D.I.Khan. Data pertaining to irrigation, waterlogging and tube wells were obtained from the Paharpur irrigation circle and CRBC irrigation circle, D.I.Khan. The pre and post CRBC land utilization and crops statistics were obtained from the office of Director General, Agriculture, statistics wing, Peshawar and Executive District Agriculture Office, D.I.Khan.

Pre and post CRBC, land use and cropping pattern data of all the mouza of district D.I.Khan were collected through Revenue and Estate officer, D.I.Khan. For detailed and intensive study, pre and post CRBC data regarding each and every plot of the sample villages were obtained from the concerned patwari. It includes information about the plot area, ownership, land use, type of irrigation, cropping pattern, size of holding, land tenure and fragmentation etc. The Executive District Agricultural Office, D.I.Khan provided data pertaining to Agricultural Engineering, Agricultural Extension as well as On Farm Water Management (OFWM), Livestock and soil conservation. Data dealing with the agricultural research, inputs, guidelines for the use of chemical fertilizers and other literature were gathered from the Agricultural Research Institute, Ratta Kulachi, D.I.Khan.

Primary information about the beneficial and adverse impacts of CRBC on the land utilization and agricultural resources were collected through questionnaires administered directly to the stakeholders such as local inhabitants, functionaries and affectees. There were several national, provincial and local organizations responsible for coordination, implementation and monitoring of CRBIP. Almost all the relevant agencies were visited and the officials were interviewed using standard questionnaires and information was assembled accordingly. CRBIP has improved the over all socio-economic condition of the inhabitants in the CRBC command area.

5.6 DATA COLLECTION TECHNIQUES

As mentioned above, to achieve the mandated task extensive primary and secondary data sources were used. Data were obtained from both inside and outside the CRBC command area. Initially, a series of reconnaissance visits were made to grasp an idea of positive and adverse environmental impact of CRBC on the land utilization, cropping pattern, agricultural inputs and other selected variables. For collection of primary data, four different types of questionnaires were designed i.e. questionnaire for individual household, questionnaire for the whole village (Focus Group Discussions), questionnaire for the line agencies and questionnaire for the mouza patwari. Questionnaire for the individual households were administered to the general public. Similarly, for every sample village two to three questionnaires for the whole village were administered during Focused Group Discussions (FGD's) with the community leaders and elderly people (Plate V-1). Questionnaire for the line agencies were filled-up by interviewing officials of the concerned line agencies. Likewise, questionnaire for the mouza patwari was designed to collect land use and crops data both pre and post CRBC for each and every mouza of D.I.Khan district, to grasp the environmental impacts of CRBC on the land use and agricultural resources (Plate V-2).

In D.I.Khan district, there were a total of 384 mouza (smallest revenue unit) in 1998 (Map V-1; GoP, 1999). Data about land use and cropping pattern before and after CRBC of all these mouza were collected, to get clear picture of CRBC impacts on land use and agricultural

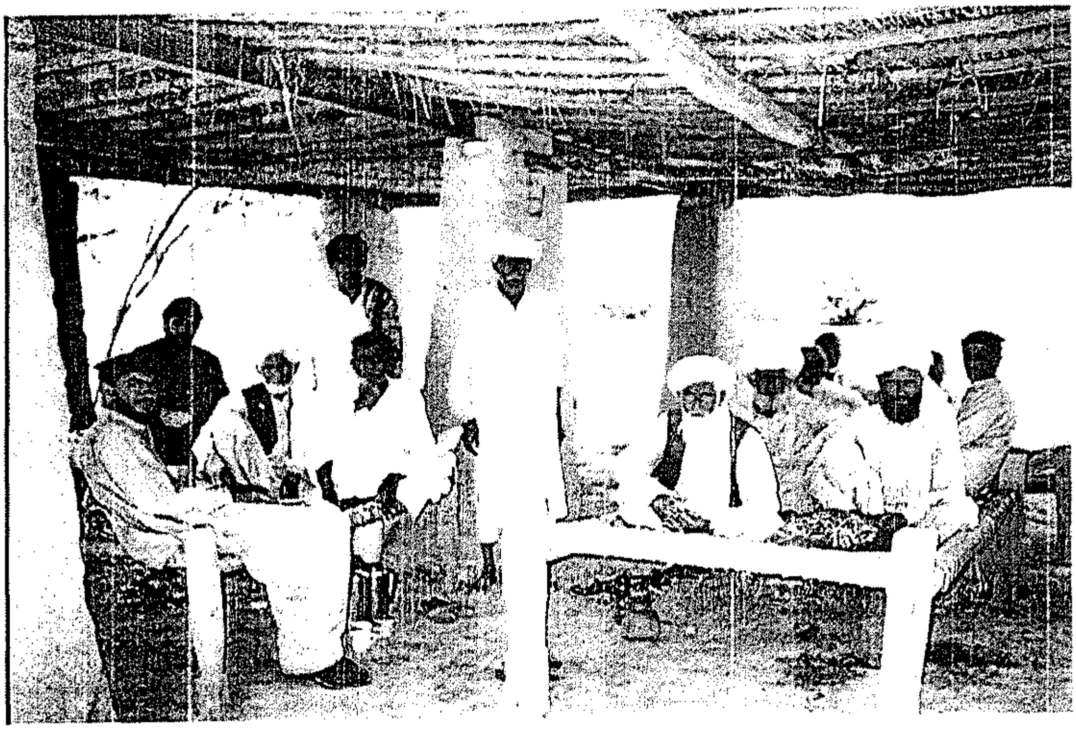


Plate V-1. Focused Group Discussion (FGD's) with the residents of Buchari

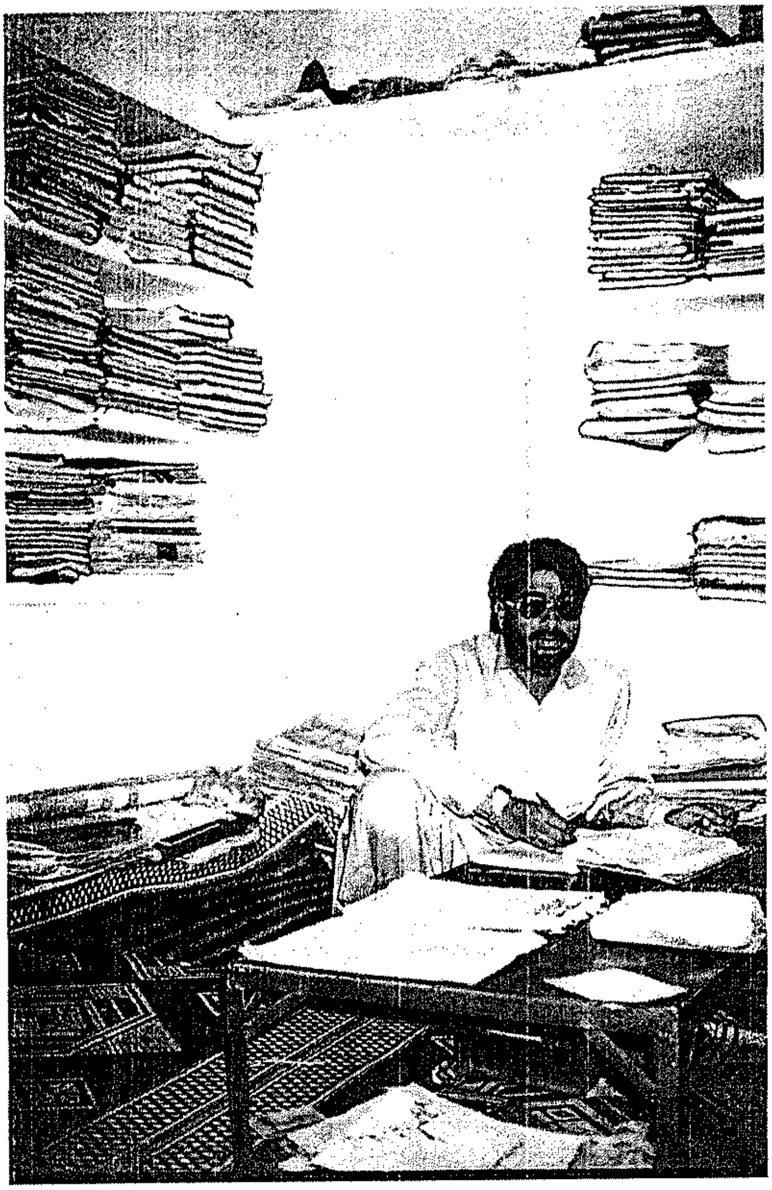
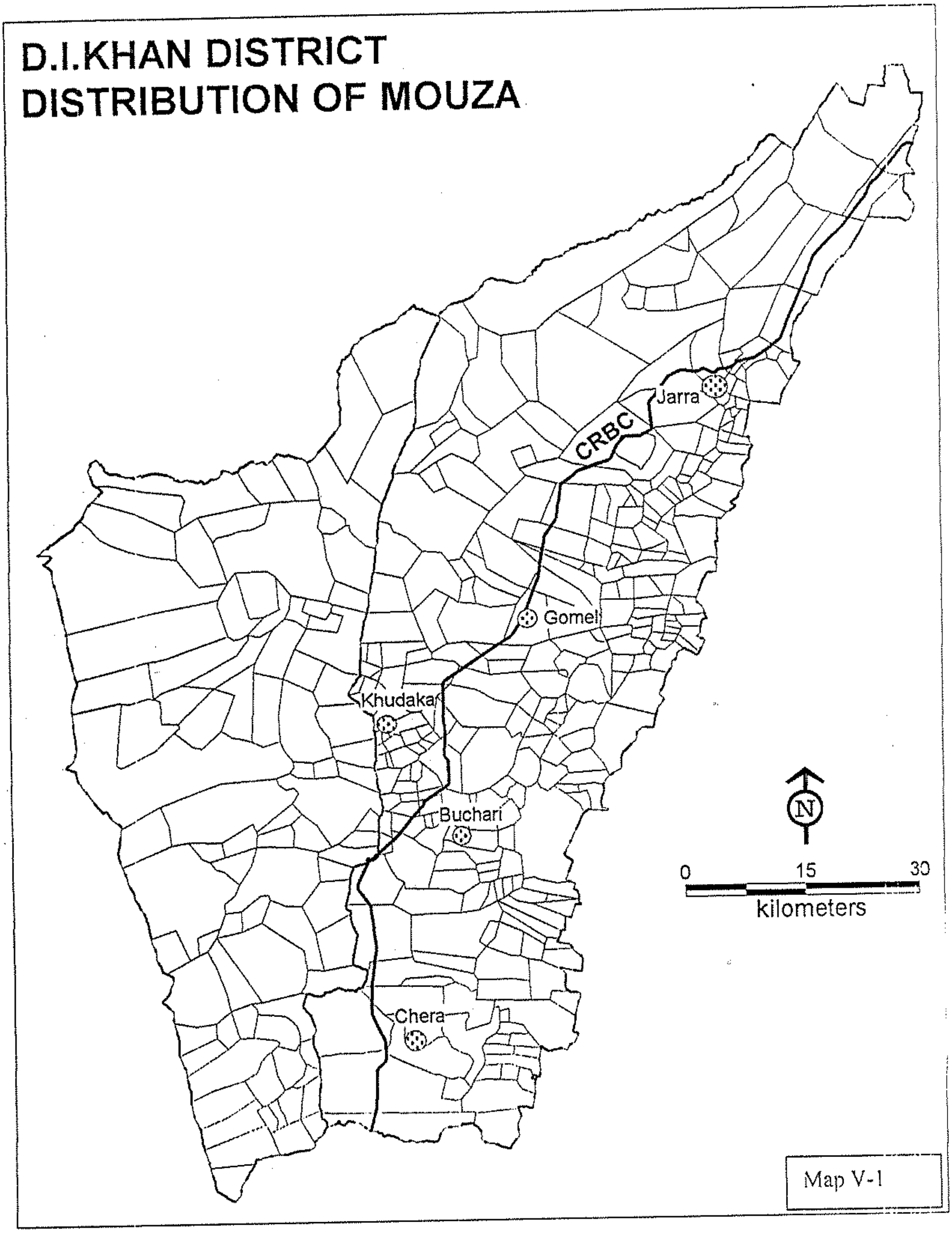


Plate V-2. Patwari of village Chera: Government official of village revenue record resources of D.I.Khan district. Ideally, the entire mouza should have been surveyed for in-depth study. However, due to time and resource constraint, sampling technique was applied. Hence, for detailed and intensive study, out of a total of 194 CRBC command mouza, four were randomly selected for micro-level study namely: Jarra, Gomal, Buchari and Chera, which make 2.4% of the CRBC command mouza (Map V-2). Likewise, one mouza that is Khudaka was also randomly selected outside the CRBC command area. The sample sites were selected from all the three stages of CRBC .i.e. from stage I, Jarra (middle reach), stage II Gomal (head reach) and stage III Buchari and Chera (tail reach). In the sampled villages, there were a total of 1,102 households, making a household size of 7.8 people. Out of total households, 300 were surveyed, which makes a sample of 27.22 % of the total household.

Likewise, for each and every sampled village, two to four questionnaires were filled during Focused Group Discussions (see Plate V-1). Group discussion with the community leaders, local organizations and farmers etc. were the landmark feature for cross checking the individual data. Questionnaire for the line agencies were designed and filled in by interviewing thirty officials of different line agencies. General observations were also recorded in the form of photographs and field notes.

The secondary data was obtained from the offices of: Chashma Right Bank Irrigation Project, D.I.Khan; Ministry of Water and Power, Islamabad; Directorate of Hydrology, Lahore; WAPDA, WAPDA house, Lahore; Provincial Irrigation and Drainage Authority, Peshawar; Planning Commission of Pakistan, Islamabad; Federal Bureau of Statistics, Islamabad; Soil Survey of Pakistan, Peshawar; Soil conservation wing, Agriculture Department, Peshawar; Salinity Control And Reclamation Project (SCARP), D.I.Khan; Survey of Pakistan, Rawalpindi; SUPARCO, Regional office, Peshawar; Revenue and estate Department, D.I.Khan; Pakistan Meteorology Department, Karachi; Population Census Organization of Pakistan, Islamabad; Bureau of Statistics, Peshawar; Director General Agriculture, Peshawar; Department of Revenue and Estate, Peshawar; Agricultural Research Institute, D.I.Khan; Arid zone wing, D.I.Khan; Executive District Agriculture Officer, D.I.Khan; Environmental Protection Agency, Peshawar etc.


D.I.KHAN DISTRICT
DISTRIBUTION OF MOUZA
CRBC
Jarra
Gomel
Khudaka
Buchari
Chera
N
0
15
30
kilometers
Map V-1

5.7 IMPORTANT CHARACTERISTICS OF THE SAMPLE VILLAGES

Mouza Jarra is one of the CRBC command villages. Prior to CRBC, this mouza was irrigated by 100 years old Paharpur canal. Currently, Jarra is under the command of CRBC and is famous for the desert fruit such as dates and other orchards. Jarra lies in the CRBC stage-I. As far as mouza Gomal is concerned, it is famous for lift irrigation. Prior to CRBC, large area was irrigated through Rod Kohi but some area was also irrigated through tube wells. Gomal partly lies off the CRBC and largely under the command of CRBC. Mouza Gomal falls in the CRBC stage II. Mouza Buchari and Chera are the two sample villages, which fall in the CRBC stage three. Prior to CRBC, these villages were entirely dependent on the Rod Kohi and rainfall. During dry spells, the inhabitants used to leave the villages and migrate towards the river Indus. In the Buchari and Chera underground water is saline and unfit for drinking. The main reliance was on the water of hill torrent and pond. Mouza Khudaka is the fifth sampled village. It is selected from outside the CRBC command area. Traditionally, this village is irrigated through Rod Kohi system and the underground water is deep and saline.

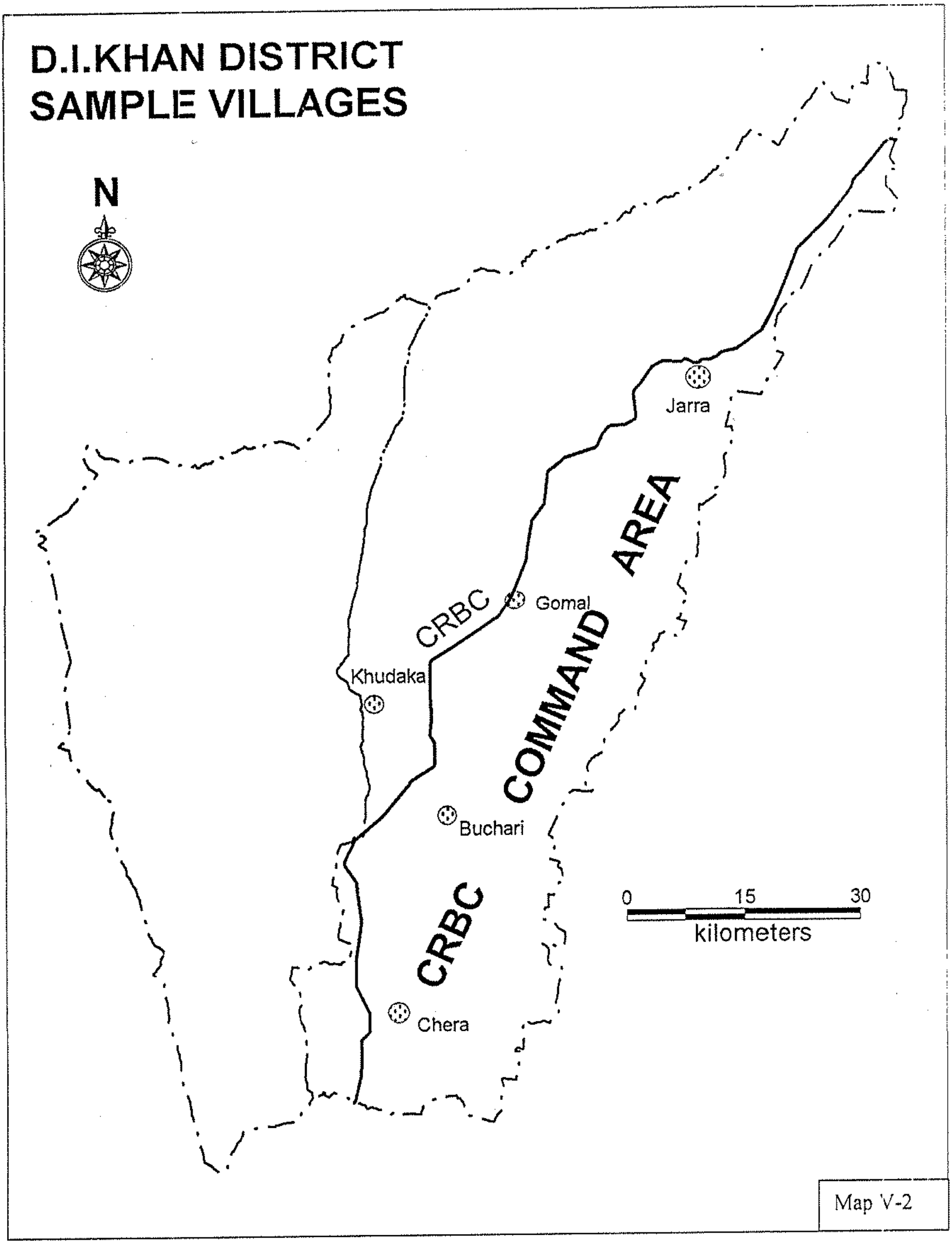
According to population census organization 1998, the population of Gomal was 4,291. It is highest amongst the sampled villages, followed by Jarra (1,597), Chera (1,569), Buchari (670) and Khudaka (594) (Table V-1). As far as intercensual increase is concerned, during census period 1972-1981, the highest change (95.2%) was recorded in mouza Jarra, moderate in Chera, Gomal, Buchari and little change in Khudaka. In the stated period, the major change in Jarra was mainly due to the fact that this area was under the command of old Paharpur canal and was intensively cultivated, whereas in Khudaka the limited change was due to the uncertain climatic factors. Little change in its population occurred during inter-censual period of 1981-98. the highest population change is reported from Gomal (159.2%). Area-wise, Gomal is the biggest mouza of the region and located right on the Tank-D.I.Khan road and in close proximity to D.I.Khan city.

Table V- 1

Population and area of sample villages, 1972- 1998

Sample villages	*Area in hectare*	*Population*			*Inter-censual change (%)*		*Density /hectare 1998*
		1972	*1981*	*1998*	*1972-81*	*1981-98*	
Jarra	518	630	1,230	1,597	95.2	29.8	3.08
Gomal	3,661	1,155	1,640	4,125	42	159.2	1.16
Buchari	550	307	385	670	25.4	74	1.22
Chera	725	671	966	1,569	44	62.4	2.16
Khudaka	320	323	373	594	15.4	59.2	1.85

Source: GoP, 1976; 1983 and 1999


D.I.KHAN DISTRICT
SAMPLE VILLAGES
N
Jarra
AREA
COMMAND
CRBC
Gomal
Khudaka
Buchari
CRBC
Chera
0
15
30
kilometers
Map V-2

Population density is an important tool to measure the man-land ratio (Sadhukhan, 1990; Khan, 1996). With the help of this technique, one could easily find the land capability to support population. It shows that, how much population can easily be supported by the productive agricultural land? According to population census organization (1998), the man-land ratio (number of person per hectare) was found highest in Jarra (3.08), followed by Chera (2.16), Khudaka (1.8), Buchari (2.16) and minimum is recorded at Gomal (1.16) (Table V-1). With the growth of population, the man-land ratio was found gradually, declining.

Literacy is an important key to find out the socio-economic pace of an area (Dubey, 1992; Khalid, 2003). In the sampled villages, the literacy ratio was found low as compared to the provincial and national average. This can be linked with the socio-economic development of the area. However, with the CRBIP, the awareness increased among the dwellers. In Jarra, the literacy ratio is comparatively high, mainly due to the existence of sedentary agriculture since long. The literacy ratio from 1981 to 1998 increased but at a slower pace. During 1981, the literacy ratio in Chera was only 1%, which increased almost six fold and marked the figure of 6%. Likewise, in Gomal, Buchari and Khudaka the literacy ratio was also increased, since 1981 (Table V-2). Currently, there are primary schools both for boys and girls in all the sampled villages and it is estimated that in the near future, the literacy ratio will further enhance. As the people are thirsty for knowledge, but due to lack of amenities and ignorance, schooling had a secondary significance.

Table V-2
Literacy of sample villages, 1972- 1998

Sample villages	*Literacy*		
	1972 (Number)	*1981 %*	*1998 %*
Jarra	114	19.6	31.2
Gomal	15	4.2	13
Buchari	11	5.7	12.9
Chera	-	1	6.3
Khudaka	12	6.3	15.5

Source: GoP, 1976; 1983 and 1999

Table V-3
Comparative Profile of sample villages

Sample villages	*Area in hectare*	*Population 1998*	*Inter-censual change (%) 1981-98*	*Density per ha 1998*	*Literacy 1998 (%)*	*Cultivated area*		*Canal irrigated area*		*Land holding Increased after CRBC (%)*	*Size of holding >6 ha in 2005 (%)*	*Per capita land in 2005 (ha)*	*Per capita cultivated land in 2005 (ha)*	*Land ownership after CRBC (%)*
						Pre CRBC (%)	*After CRBC (%)*	*Pre CRBC (%)*	*After CRBC (%)*					
Jarra	518	1,597	29.8	3.08	31.2	75	79	75	79	20	10	0.3	0.12	90
Gomal	3,661	4,125	159.2	1.16	13	34	66	0	50	30	20	0.81	0.36	75
Buchari	550	670	74	1.22	12.9	12	63	0	59	35	55	0.80	0.36	70
Chera	725	1,569	62.4	2.16	6.3	5	86	0	86	5	40	0.46	0.24	90
Khudaka	320	594	59.2	1.85	15.5	50	0	0	0	0	50	0.53	0.47	95

Source: GoP, 1999; Field survey, 2005; Revenue Records of sample mouza

5.8 DATA LIMITATIONS

During the course of study, limitation in almost all forms of relevant data was observed. Generally, it is a fashion amongst the government officials of most of the developing countries to pretend that a particular data is a state secrete (Smith, 1985) and the same is true for this study as well (see Appendices, a letter from the office of CRBIP). During data collection, most of the officials were reluctant to give permission to consult their files and reports. However, this limitation was overcome to a greater extent during discussion with the general public, community leaders, elderly people and officials of the related line agencies. The aim of the present study was explained to them with the help of official letter from the department of Geography, Urban & Regional Planning, University of Peshawar.

Revenue data was not fully available and was spread in pieces. Usually the patwari, destroy certain revenue record after a lapse of 12 years, due to which it was very difficult to locate the pre CRBC data. Detailed and intensive data for all the mouza of the district was the major limiting factor. Rod Kohi irrigation data was also not available for D.I.Khan district. Likewise, the land use and crops statistics were also not easily available. Obtaining CRBC reports posed great hindrance in the smooth process of research, as several times official of CRBC regretted that CRBC reports are confidential. This is strange in a developing country like Pakistan. Land use and cropping pattern data of D.I.Khan district for the year 1979-80 was not available. Likewise, before 1987-88, revenue data was not available for mouza Jarra. *Abiana* (water cess) data were obtained from Paharpur and CRBC irrigation circles, since 2001, while prior to this, *abiana* data were spread among various line agencies.

It would have been more desirable, if all the relevant information were made available for the researcher. However, an attempt has been made to use whatever information was available targeting the research objectives collected as exhaustively as possible. Many limitations experienced in the data collection were reduced to a greater extent. Hence, this study provides an insight to the ex post impact evaluation of CRBC and seek ways and means to improve it.

5.9 DATA ANALYSIS AND PRESENTATION

The collected data were finally analysed through computer based packages i.e. MS Office XP and GIS software. Then, it was made possible, to present the data in the form of maps, tables, statistical diagrams and description. Geographical Information system (GIS) was used to prepare ex post CRBC impacts maps using satellite imagery, cadastral maps and topographical sheets. Finally, the collected data and information were interpreted in the light of existing socio-economic and physio-ecological environment of the study area.

5.10 CONCLUSION

This chapter discussed the methodology adopted for carrying-out research as well as techniques for data collection and analysis. The chapter covered the research question, research hypothesis, research objectives, research variables, data needed for the study, data collection techniques, data analysis and presentation. Limitation and difficulties in the availability of data were also discussed. The data were collected through reconnaissance survey and observation, informal interviews and official reports collection, pilot survey and questionnaire survey. During data collection process, there were difficulty in tracing previous record, which created some hardships during data collection and analysis. The data were then analysed using various statistical techniques and computer accessories.

CHAPTER # VI

ENVIRONMENTAL IMPACTS OF CRBC ON THE LAND USE AND IRRIGATION PATTERN

Introduction

This chapter analyses the environmental impacts of CRBC on the land use and irrigation pattern. The chapter is divided into three major sections. It starts with the macro level analysis of CRBC impacts on the land use of the district D.I.Khan as a whole followed by micro level analysis of five sample villages located at different environmental settings. Section two assesses the macro level analysis of CRBC impacts on the irrigation pattern and micro level analysis of sample villages. Conclusion is given in the final section.

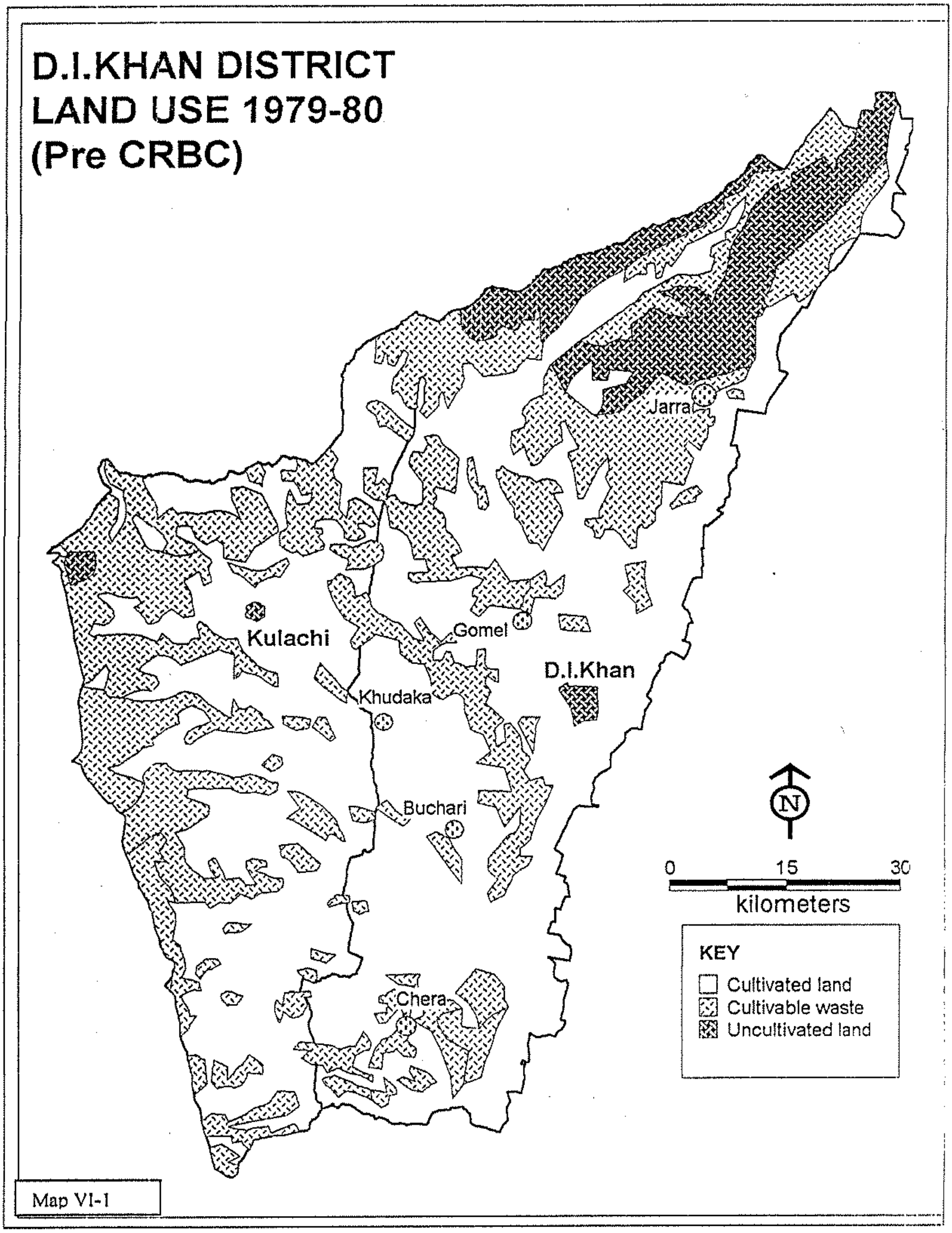
6.1 ENVIRONMENTAL IMPACTS OF CRBC ON THE LAND USE

6.1.1 Environmental impacts of CRBC on the land use of D.I.Khan district (Macro level analysis)

In D.I.Khan district, land use has been classified into cultivated, uncultivated and cultivable waste. The over all picture of environmental impacts of CRBC on the land use can be discerned from map VI-1, 2 and table 1 & 2. It can be seen that there are three land use classes including cultivated land, cultivable waste land and uncultivated land. The following discussion analyses the impacts of CRBC on various land use categories at macro level.

i. CULTIVATED LAND

In D.I.Khan district, cultivated area is the second largest land use category after cultivable waste (Table VI-1). The total reported area is 730,575 ha, out of which 232,036 ha was cultivated before CRBC in 1969-70. The table VI-1 & 2 indicates that after inception of CRBC, area under cultivation has increased to 238,678 ha in 1989-90. However, it declined to 233,100 ha in 1999-2000 (Figure VI-1). The increase in the cultivated area during 1989-90 was due to the inception of canal irrigation in the form of CRBC, whereas reduction in the cultivated area during 1999-2000 was attributed to the drought spell during 1997 to 2003 in Pakistan (Sheikh, 2004). It was in 2003-04 that the cultivated area once again increased and marked the figure of 236,371 ha, which is approximately 32% of the total reported area. While comparing pre and post CRBC macro level change in the cultivated area a positive change of 0.58% of the total reported area was recorded. Hence, there has been considerable enhancement in the cultivated area as a result of CRBC.


D.I.KHAN DISTRICT
LAND USE 1979-80
(Pre CRBC)
Jarra
Kulachi
Gomel
D.I.Khan
Khudaka
Buchari
Chera
N
0
15
30
kilometers
KEY
Cultivated land
Cultivable waste
Uncultivated land
Map VI-1

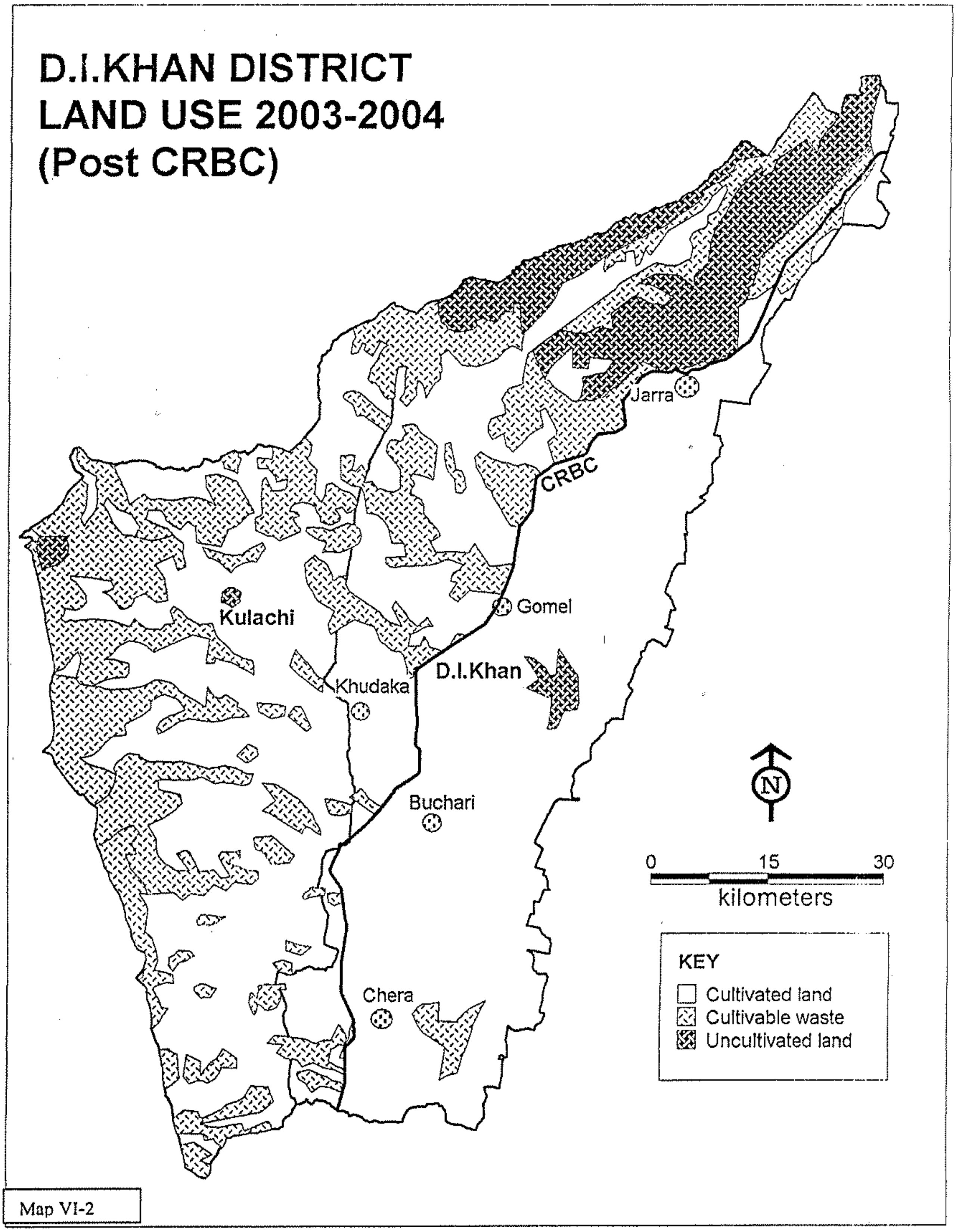

D.I.KHAN DISTRICT
LAND USE 2003-2004
(Post CRBC)
Jarra
CRBC
Gomel
Kulachi
D.I.Khan
Khudaka
Buchari
Chera
N
0
15
30
kilometers
KEY
Cultivated land
Cultivable waste
Uncultivated land
Map VI-2

Table VI-1

D.I.Khan district, Land utilization, 1969-70 to 2003-2004 (Area in ha)

Year	*Total Area*	*Cultivated Area*			*Area not available for cultivating*		
		Total	*Net Sown*	*Current fallow*	*Cultivable waste*	*Uncultivated area*	*Forest*
1969-70	730,575	232,036	113,292	118,744	366,132	366,047	4,048
1979-80	730,575	232,108	NA	NA	366,047	132,420	4,048
Post CRBC							
1989-90	730,575	238,678	131,688	106,990	355,561	132,428	3,908
1999-2000	730,575	233,100	89,339	143,761	361,116	132,451	3,908
2003-2004	730,575	236,371	104,512	131,859	357,809	132,487	3,908

Source: GoNWFP, 1975; 1980; 1991; 2000c and 2004c

Table VI-2

D.I.Khan District, Macro Analysis Change in Land Use

Land use	*Pre CRBC Phase*		*Post CRBC Phase*		*Recorded change (%age)*
	1979-80 (ha)	*1979-80 % share of total*	*2003-04 (ha)*	*2003-04 % share of total*	
Cultivated Area	232,108	31.77	236,371	32.35	+0.58
Cultivable waste	366,047	50.10	357,809	48.97	-1.13
Uncultivated area	132,420	18.12	132,487	18.13	+0.01

Source: GoNWFP, 1975; 1980; 1991; 2000c and 2004c

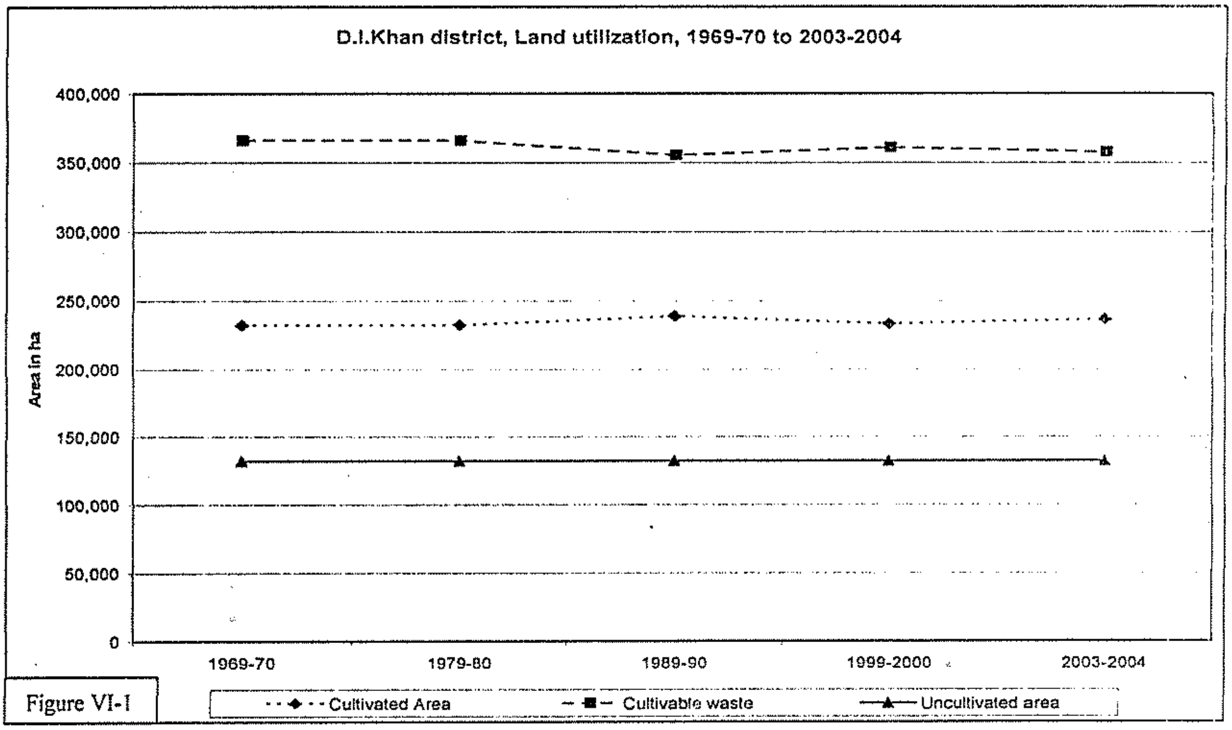


Figure VI-1

The map VI-1 & 2 shows that there is an uninterrupted belt of cultivated land in active floodplain of river Indus and eastern half of the piedmont plain. Pre construction of CRBC project, the active floodplain has been inundated each year in summer (see section 2.1.1 and map II-2). Presently, small but narrow track is still cultivated through annual summer floods. Map VI-1 indicates that before CRBC, the central and western part of the piedmont plain was cultivated through sporadic flood water in the hill torrents (Rod Kohi). However, after commissioning of CRBC, large portion of central and south-central piedmont plain has been brought under the command of canal irrigation (see Map II-2; Map VI-2). Subsequently, the previous uncertainty of crops failure was modified by the assured water supply. Map VI-1 & 2 further elaborates that in D.I.Khan district, cultivated land was also found in patches of hilly sandy plain and rolling sand plain. This hilly sandy and rolling sand plain is located off the CRBC command area and hence no impact is detected. Map VI-1 & 2 further elaborates that the cultivated land is found in an elongated strip (alluvial fans) in the western part of D.I.Khan district. Here, cropping pattern is similar to the canal command area, but due to stony soil small area is cultivated through Zam. Hence, this category is located outside the CRBC command area. Therefore no impact of CRBC is reported.

The cultivated area is further classified into net sown and current fallow (Plate VI-1). In the study area, net sown and current fallow varies from year to year. The figure VI-1 indicates that since 1999-2000, there has been constant increase in the net sown, whereas during the same period current fallow decreased. The analysis shows that as area under net sown increases, area under current fallow decreases and this mainly depends on the water availability. However, after CRBC there has been steady increase in the net sown particularly in tehsil D.I.Khan and corresponding decrease in the current fallow (Table VI-1). The analysis further reveals that fallowing of land outside the CRBC command area is attributed to a number of factors. The main factor was the shortage of irrigation water. The other factors were lack of human labour to managed extensive land as well as lack of capital.

ii. UNCULTIVATED LAND

In D.I.Khan district, large tract is uncultivated and hence agriculturally unproductive and devoted to settlement, gullies, torrent beds, canals, roads, water body and others. The table VI-1 indicates that before CRBC (1969-70), the uncultivated land was 132,408 ha, which after advent of CRBC has been gradually increased to 132,428 ha during 1989-90. This figure had been further increased to 132,487 ha in 2003-04. The table VI-2 shows ex post CRBC change in the uncultivated area that there has been a positive change of 0.01% (of the total reported area).

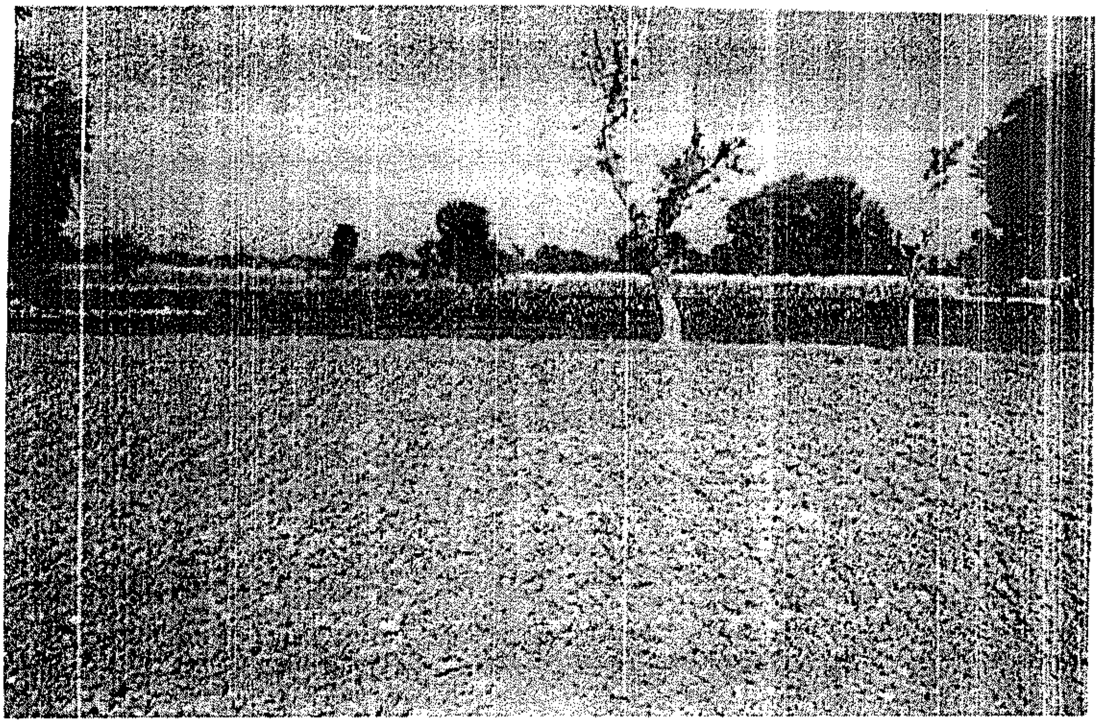


Plate VI-1.   Area under current fallow

Field survey together with the secondary data reveals that both cultivated and cultivable waste has been gradually consumed by the built-up area (uncultivated area). This gradual but consistent enhancement in the uncultivated area is attributed to the alarming increase in the population (see section 2.2), rapid increase in the area under housing, roads, canals and other infrastructures after the advent of CRBC.

iii. CULTIVABLE WASTE

In D.I.Khan district, both before and after inception of CRBC, cultivable waste is the largest land use category. The analysis reveals that there has been gradual reduction of cultivable waste especially after the advent of CRBC. The table VI- 1 & 2 indicates that a negative change in the cultivable waste has been recorded, when pre and post CRBC condition was compared. The table VI-2 discern that cultivable waste is the only land use class, which has recorded negative change of 1.13% after CRBC. The table VI-1 reveals that before CRBC, area under cultivable waste was 366,132 ha during 1969-70. It was mostly found in the rolling sand plain and meander floodplains (see section 2.1.2; map II-2; map VI-1 and 2). Large patches of cultivable waste were also found in the alluvial fans. Here, soil is gravely and usually far beyond the reach of Zam irrigation. Area under cultivable waste is also reported from piedmont plains, where availability of irrigation water is the primary requirement of this class (Plate VI-2 and 3).

After commissioning of CRBC, most of the meander floodplain and large part of the piedmont plain have been brought under the command of CRBC, due to which cultivable waste has been decreased to 355,561 ha in 1989-90. This figure was increased to 362,116 ha in 1999-2000, but once again area under cultivable waste decreased to 357,809 ha during 2003-04. The analysis found that cultivable waste has inverse relation with the cultivated area. As the cultivated land increases, the cultivable waste decreases and vice versa. Cultivable land undergoes frequent changes and a number of physical and socio-economic factors influence it. Field survey, Focus Group Discussions together with the statistical data reveals that increase in the cultivable waste during 1969-70 to 1999-2000 was mainly due to the non availability of water, whereas reduction since 1999-2000 was attributed to the introduction of canal irrigation (CRBC). Consequently, the farmers are continuously bringing their cultivable waste under cultivation. The analysis reveals that in D.I.Khan district, cultivable waste has large potential for the extension of cultivated land.

Forest is the smallest land unit. Owing to the low rainfall, forests are rarely found in the area. Area under forest is only reported from Kulachi tehsil (outside the CRBC command area) of district D.I.Khan. This type of land is either too high or distant apart to be irrigated by the

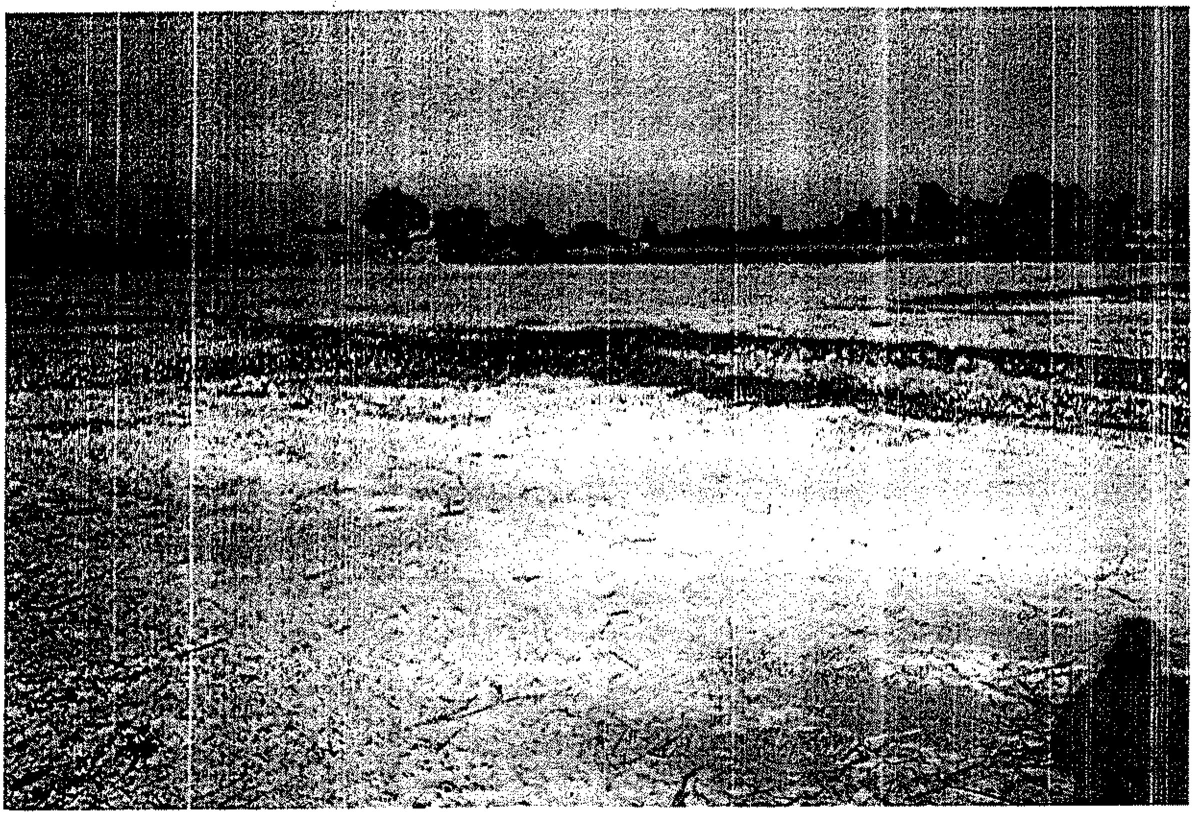


Plate VI-2. Cultivable Waste land outside the CRBC command area

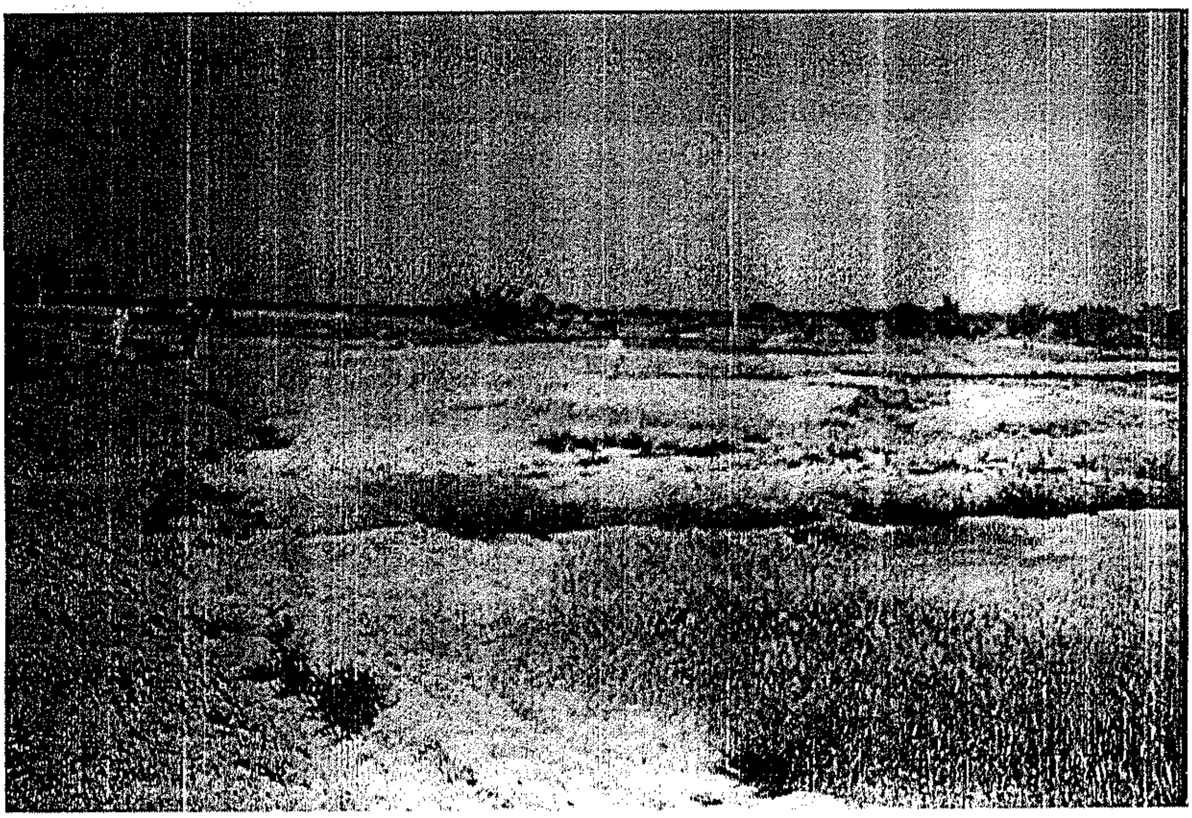


Plate VI-3. Cultivable Waste land outside the CRBC command area torrents/ zam etc. Such land is covered with sparse natural vegetation like *Prosopis spicigera (Jand), Acacia nilotica (Kikar), capparis aphylla (Karir) Tamarix (Farash)* (see section 2.1.5). The major use of this area includes livestock grazing and firewood collection (JICA, 1993). Area under forest cover was 4,048 ha during 1969-70, which shrank to 3,908 ha in 2003-2004 (Table VI-1). The reductions in forest land is mainly due to ruthless wood cutting, over gazing as well as clearing of forest land for cultivation and bringing land under built-up area.

6.1.2 Environmental impacts of CRBC on the land use of sample villages (Micro-Level Analysis)

This section presents the environmental impacts of CRBC on the land use and irrigation pattern at micro-level. To study intensively the pre and post CRBC impacts, five sample villages were selected from different environmental settings. One village was randomly selected from outside the CRBC command area (Khudaka) and four i.e. Jarra, Gomal, Buchari and Chera amongst the villages of the CRBC command area. The principal classes include uncultivated area, cultivable waste and cultivated land. Land uses were discussed with special reference to change in pre and post construction of CRBC.

i. JARRA

Mouza Jarra falls in CRBC stage I and received water from CRBC in 1988-89. Before the construction of CRBC, Jarra was under the command of old Paharpur canal. It has a total area of about 518 ha. The analysis reveals that in Jarra, land utilization has been greatly changed, after construction of CRBC. The Table VI-3 and 4 clearly indicates pre and post CRBC acreage of cultivated land, cultivable waste and uncultivated area. The figure VI-2 reveals that prior to CRBC, 101 ha was under cultivable waste, which has been increased to 247 in 1994-95. However, in 2003-04, the cultivable waste was gradually reduced to 55 ha (Table VI-3). The table VI-4 indicates that after comparing pre and post CRBC condition of cultivable waste, a negative change of 8.88% has been recorded. The statistical analysis together with the field survey reveals that increase in the cultivable waste was mainly due to waterlogging and salinity. However, the same land has been brought under cultivation through curative measures by the Salinity Control and Reclamation Project (SCARP) and CRBIP.

In Jarra, before CRBC (1987-88), the uncultivated land was only 28 ha but after CRBC, it increased to 36 ha in 1994-95 and further increased to 53 ha during 2003-04 (Table VI-3). The table VI-4 indicates that after comparing pre and post CRBC condition of uncultivated area a positive change of 1.89% of the total reported area has been registered. The comparative analysis further reveals that increase in the uncultivated land is mainly due to high demand of housing and other infrastructure for increasing population. Most of which constitute the built-up environment.

The map VI-3 clearly shows pre and post CRBC condition that major changes have occurred particularly change of cultivable waste to cultivated land and from cultivable waste to uncultivated land. In Jarra, there has been considerable enhancement in the cultivated land. Prior to CRBC, in 1987-88, cultivated area was 389 ha, which was mainly irrigated from old Paharpur canal. However, after CRBC the cultivated land was adversely affected by waterlogging and salinity due to which cultivated area reduced to 235 ha in 1994-95 (during this period the twin problem was at peak). After reclamation, a constant increase in the cultivated land was observed, which reached to the total figure of 410 ha during 2003-04. The table VI-4 indicates that after CRBC a net positive change of 4.06% of the total reported area has occurred in the cultivated area. During 1994-95, the cultivated land touched the minimum limit, whereas during the same year the cultivable waste reached the maximum-recorded figure of 247 ha. The statistical analysis reveals that cultivated land has inverse relation with the cultivable waste. It means that as the cultivated land increases the cultivable waste decreases and vice versa. The figure VI-2 also shows that after 1994-95, there has been continuous reduction in the cultivable waste, whereas cultivated land has been increased to a greater extent. The Map VI-3 clearly shows the changes in various land uses before and after the inception of CRBC.

Table VI-3
Jarra, land use 1987-88 to 2003-04 (area in ha)

Year	*Total area*	*Uncultivated land*	*Cultivable waste*	*Cultivated land*
1987-88	518	28	101	389
		Post CRBC		
1989-90	518	32	130	356
1994-95	518	36	247	235
1999-00	518	51	219	248
2003-04	518	53	55	410

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Jarra)

Table VI-4
Jarra, land use change, 1987-88 and 2003-04 (area in ha)

Land use	*Pre CRBC Phase*		*Post CRBC Phase*		*Change in % of total area*
	1987-88	*% of total area*	*2003-04*	*% of total area*	
Uncultivated land	28	5.40	53	10.23	+1.89
Cultivable waste	101	19.49	55	10.61	-8.88
Cultivated land	389	75.09	410	79.15	+4.06

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Jarra)

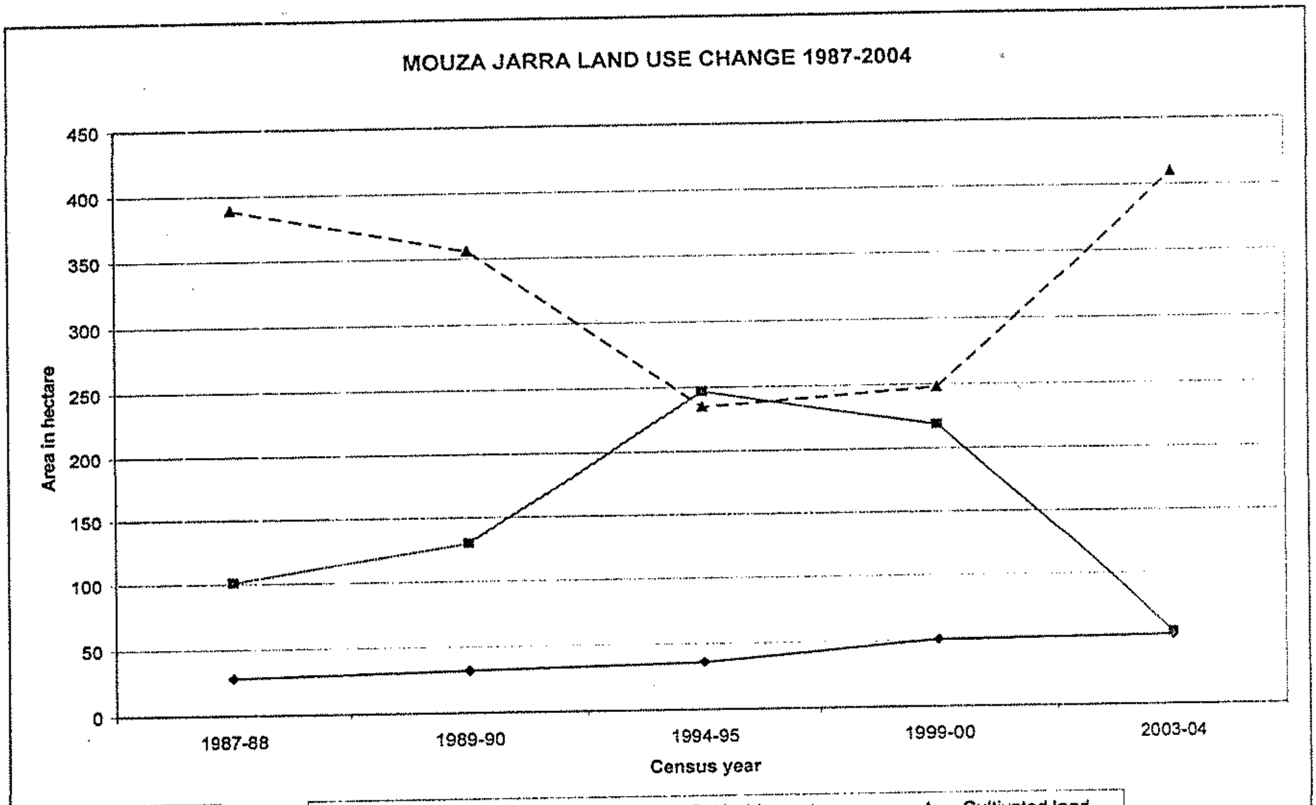


Figure VI-2

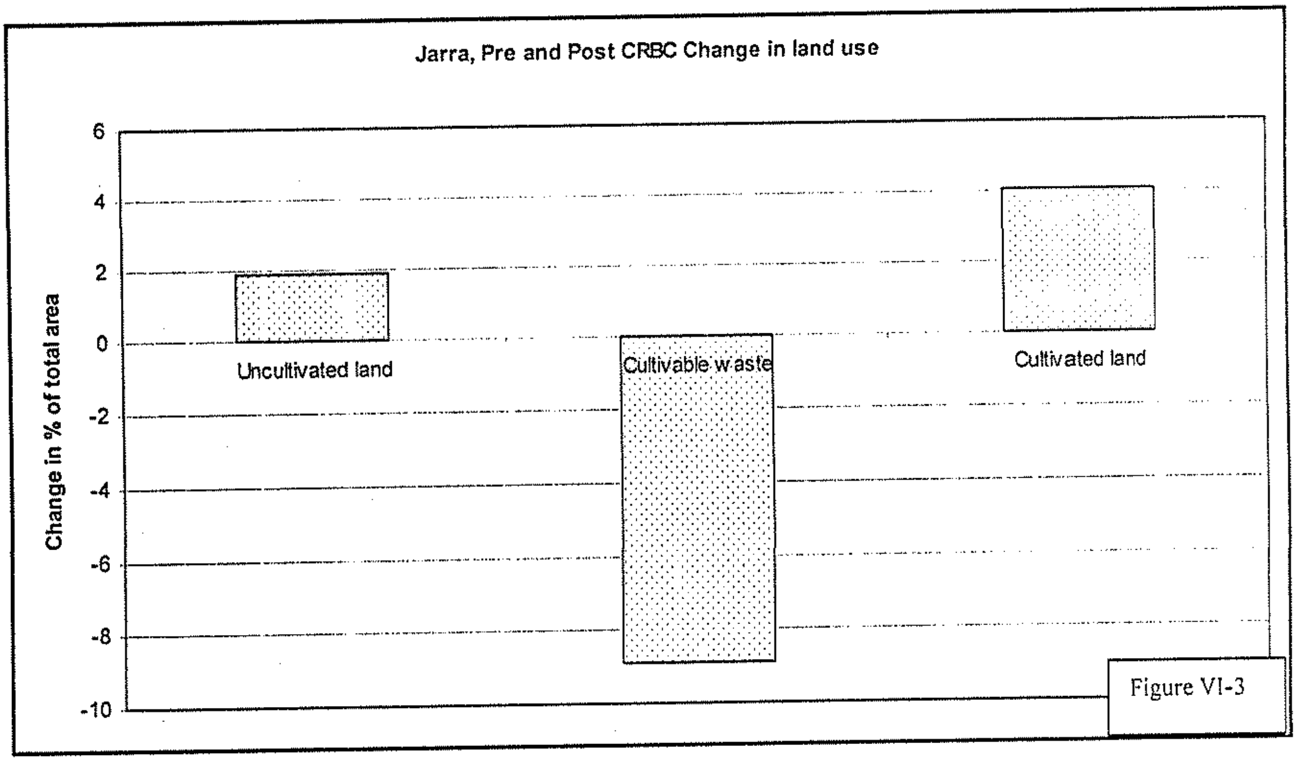
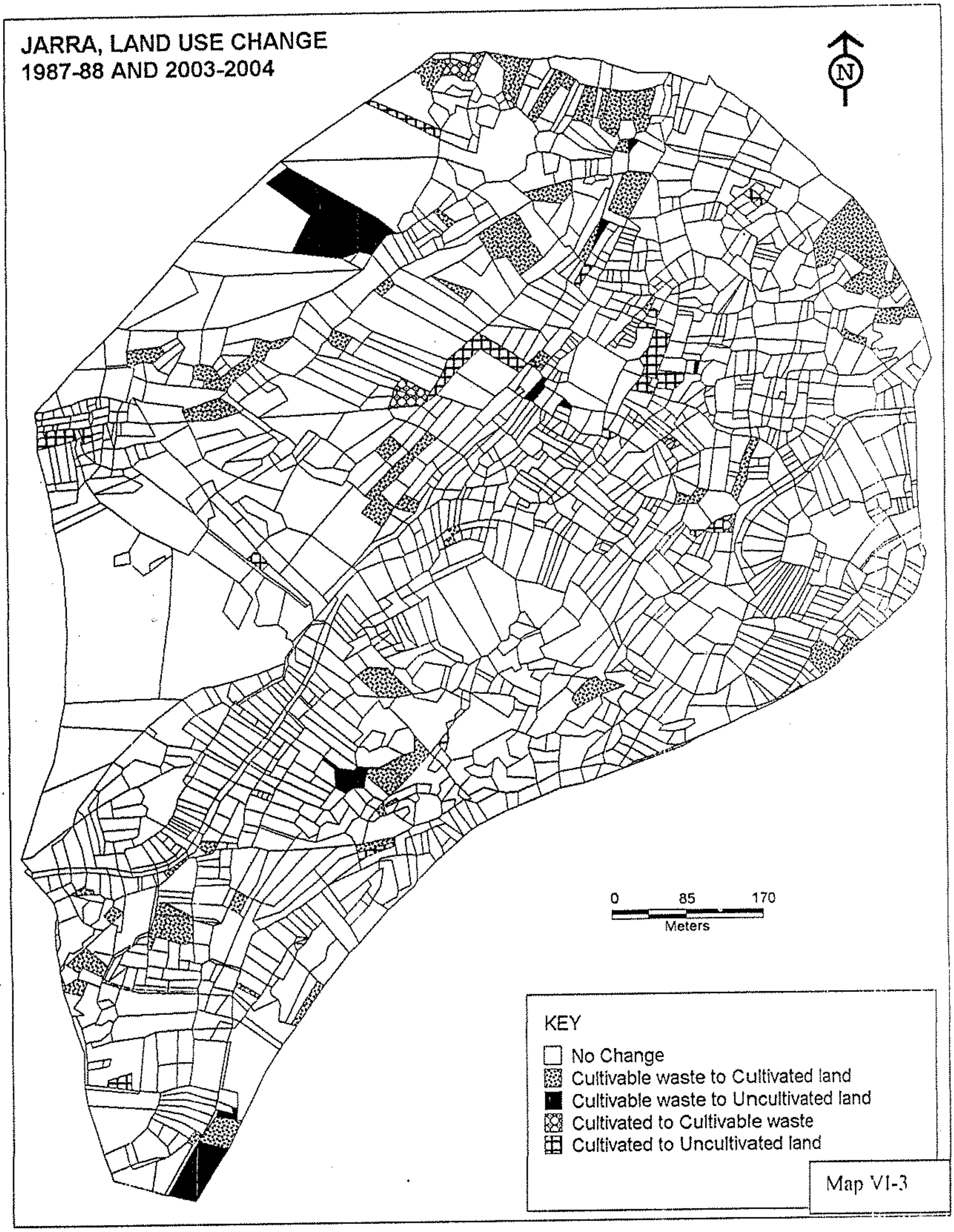


Figure VI-3


JARRA, LAND USE CHANGE
1987-88 AND 2003-2004
N
0
85
170
Meters
KEY
No Change
Cultivable waste to Cultivated land
Cultivable waste to Uncultivated land
Cultivated to Cultivable waste
Cultivated to Uncultivated land
Map VI-3

ii. GOMAL

Gomal is one of the biggest mouza in terms of area in district D.I.Khan. Mouza Gomal falls in CRBC stage II and canal irrigation through CRBC started in 1988-89, while prior to CRBC, well and Rod Kohi were the major forms of irrigation. Gomal has a total area of about 3,661 ha. In this village, CRBC passes through the western part of the mouza (Map VI-4). About two third land of the mouza is under the direct command of CRBC. The map VI-4 and figure VI-4 give temporal change in various land uses such as cultivated area, cultivable waste and uncultivated land. The temporal and spatial pattern of land use both before and after CRBC could better be understood from Map VI-4. The analysis reveals that large area was also found, where no change in land use has occurred.

It was found that the uncultivated area remained the smallest land use unit throughout the study period. Before CRBC, the uncultivated land was 106 ha during 1974-75, while after the inception of CRBC, it increased to 226 ha in 2003-04 (Table VI-5). This increase remained comparatively slow i.e. about 2 ha per year prior to CRBC, but then jumped to 5 ha per annum after the construction of CRBC. The analysis reveals that after construction of CRBC, settlements expanded, canals constructed and roads were built that's why the uncultivated area increased to a greater extent. The table VI-6 reveals that after CRBC, a net positive change of 2.27% has occurred in the uncultivated area (Figure VI-5).

In Gomal, before CRBC the cultivable waste has been the major land use class, but after CRBC, its share has been declined rapidly. The figure VI-4 shows that from 1974-75 to 1987-88 (pre CRBC period), area under cultivable waste remained almost the same but after CRBC, an abrupt change took place (Table VI-5). The cultivable waste reduced from 2,281 ha (pre CRBC) in 1987-88 to 1,119 ha after CRBC in 1988-89. However, after CRBC, from 1988-89 to 2003-04 a constant decrease has been observed. However, still very large area of about 1,018 ha (2003-04) was found under cultivable waste (Table VI-5). The table VI-6 indicates that in cultivable waste a negative change of 34.5% has occurred, when pre and post CRBC phases were compared.

Prior to CRBC, cultivated area was the second leading land unit after cultivable waste, but during post CRBC, it became the major land use class (Table VI-5). The analysis reveals that in Gomal cultivated area has gradually increased after the advent of CRBC. The analysis reveals that during pre CRBC period (1974-75 to 1987-88), area under cultivation was uncertain and there were several rises and falls. This was mainly due to their dependency on the uncertain availability of water. After CRBC, there has been constant increase in the cultivated land from

2,366 ha in 1988-89 to 2,417 ha in 2003-04. In one year from 1987-88 (pre CRBC) to 1988-89 (post CRBC), the cultivated land has increased two fold (Table VI-5). It is clear from map VI-4 that major changes were occurred after inception of CRBC. The analysis further indicates that in cultivated land a net positive change of 32.24% has been recorded, when pre and post CRBC phases compared and large scale cultivable waste has been brought under cultivation particularly in the CRBC command portion of village Gomal.

Table VI-5

Land use of Gomal, 1974 to 2004 (area in ha)

Year	*Total area*	*Uncultivated land*	*Cultivable waste*	*Cultivated area*
1974-75	3,661	106	2,739	816
1979-80	3,661	143	2,188	1,330
1984-85	3,661	143	2,271	1,247
1987-88	3,661	143	2,281	1,237
Post CRBC				
1988-89	3,661	176	1,119	2,366
1989-90	3,661	176	1,104	2,381
1994-95	3,661	207	1,069	2,385
1999-00	3,661	207	1,062	2,392
2003-04	3,661	226	1,018	2,417

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Gomal)

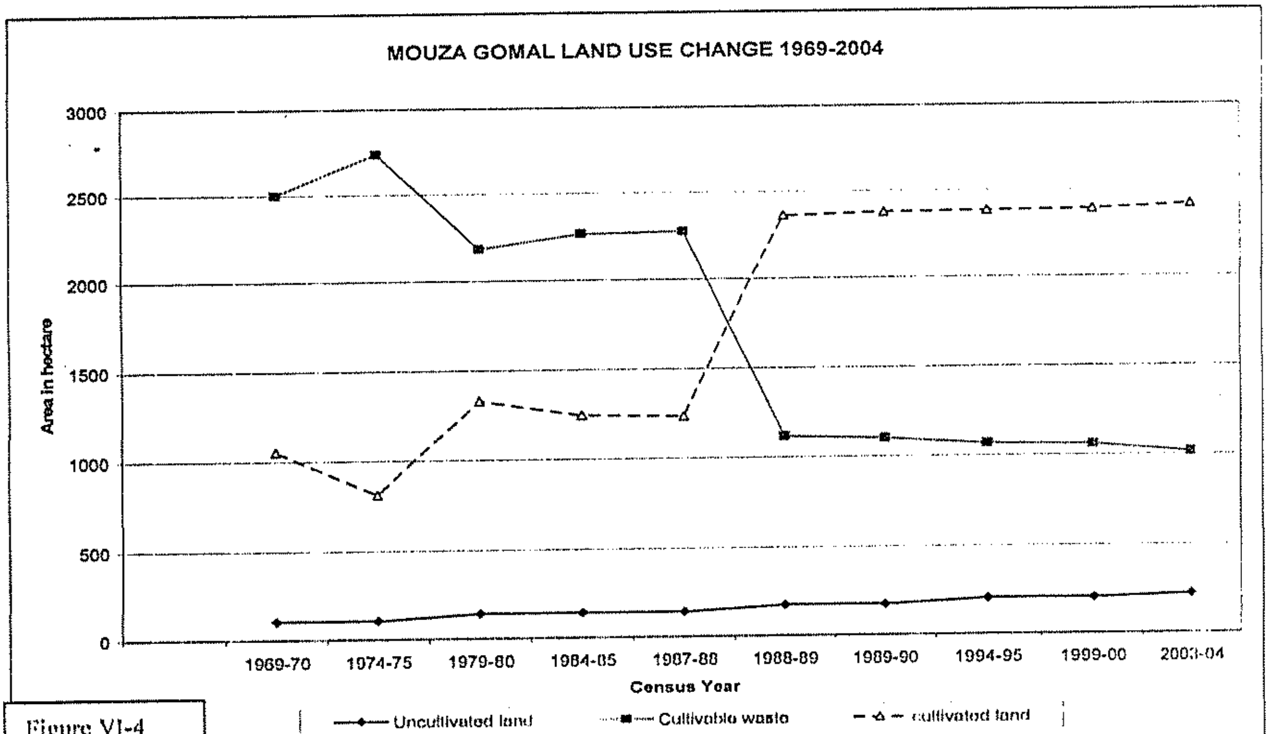


Figure VI-4

Table VI-6
Gomal, land use change, 1987-88 and 2003-2004

Land Use	*Pre CRBC Phase*		*Post CRBC Phase*		*Change in % of total area*
	1987-88	*% of total area*	*2003-04*	*% of total area*	
Total area	3,661	-	3,661	-	-
Uncultivated land	143	3.90	226	6.17	+2.27
Cultivable waste	2,281	62.30	1,018	27.80	-34.5
Cultivated area	1,237	33.78	2,417	66.02	+32.24

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Gomal)

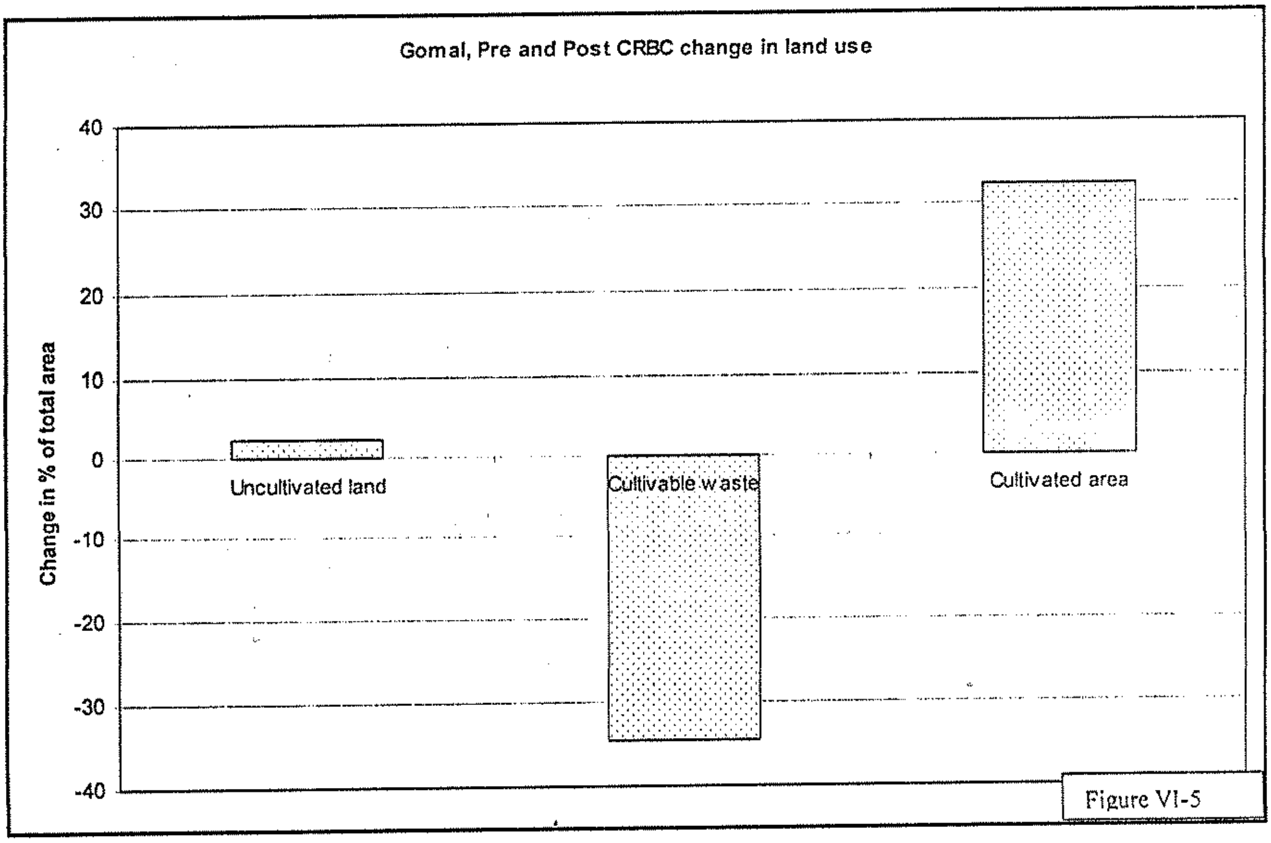
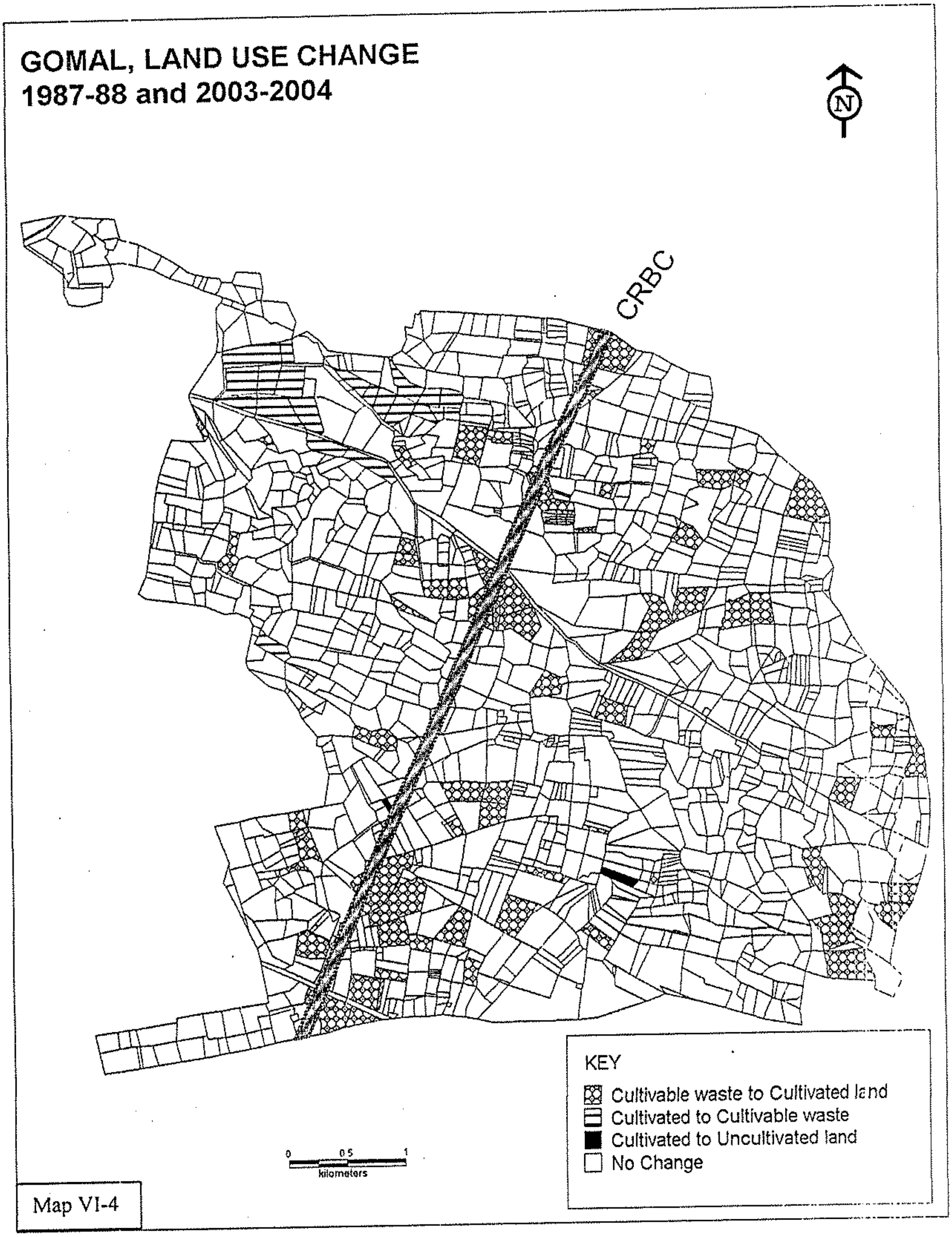


Figure VI-5


GOMAL, LAND USE CHANGE
1987-88 and 2003-2004
N
CRBC
KEY
Cultivable waste to Cultivated land
Cultivated to Cultivable waste
Cultivated to Uncultivated land
No Change
0
0.5
1
kilometers
Map VI-4

iii. BUCHARI

Mouza Buchari falls in CRBC stage III and received water through CRBC in 1994-95. Prior to the construction of CRBC, Rod Kohi was the only source of irrigation. Mouza Buchari has a total area of 550 ha, which is subdivided into uncultivated land, cultivable waste and cultivated land. The map VI-5 and Table VI-7 give a complete picture of changes in various land uses of mouza Buchari. Before CRBC, the uncultivated land was 190 ha in 1993-94, while after CRBC it increased to 198 ha in 2003-04. After comparing pre and post CRBC changes in uncultivated area, a net positive change of 1.46% has been registered. This increase in the uncultivated area is mainly attributed to the socio-economic development as a result of CRBC and increase in population.

Field survey together with the revenue record reveals that before CRBC cultivable waste remained the major land unit. Before CRBC, area under cultivable waste varied from year to year. The highest figure of 289 ha was recorded for cultivable waste in 1974-75, while minimum 232 ha has been registered in 1979-80 (Table VI-7). After CRBC, large area under cultivable waste was brought under CRBC command. As a result a gradual decrease in the cultivable waste has been registered. The analysis reveals that after CRBC area under cultivable waste has been reduced only to 6 ha in 2003-2004. While comparing pre and post CRBC changes it was found that a negative change of 51.99% has taken place in the cultivable waste (Table VI-8).

The map VI-5 and figure VI-6 shows the information about the changes in the cultivated area of mouza Buchari. It indicates that changes in land use particularly from cultivable waste to cultivated land has a predominant share followed by the conversion of cultivated into uncultivated land. Before CRBC, during 1974-75 to 1993-94, a gradual decrease with a few exceptions took place in the cultivated area (Table VI-7). The analysis reveals that this decrease is attributed to the dependence of cultivated area on the uncertain irrigation system of Rod Kohi. However, after the inception of CRBC, area under cultivation has been increased at a rapid pace. The analysis indicates that the cultivated area was only 133 ha during 1994-95, which increased to 345 ha in 2003-04. This three-fold increase in the size of cultivated land was mainly achieved through the introduction of perennial canal irrigation. The table VI-8 further elaborates that after CRBC a positive change of 50.36% of the total reported area has been recorded in the cultivated area.

Table VI-7
Land use of Buchari, 1974-75 TO 2003-04 (area in ha)

Year	*Total area*	*Uncultivated land*	*Cultivable waste*	*Cultivated land*
1974-75	550	190	289	71
1979-80	550	190	232	128
1984-85	550	190	251	109
1989-90	550	190	286	74
1993-94	550	190	292	68
Post CRBC				
1994-95	550	190	227	133
1999-2000	550	190	115	245
2003-04	550	198	6	345

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Buchari)

Table VI-8
Buchari, land use change, 1993-94 and 2003-2004

Land Use	*Pre CRBC Phase*		*Post CRBC Phase*		*Change in % of total area*
	1993-94	*% of total area*	*2003-04*	*% of total area*	
Total area	550	-	550	-	. -
Uncultivated land	190	34.54	198	36	+1.46
Cultivable waste	292	53.09	6	1.09	-51.99
Cultivated area	68	12.36	345	62.72	+50.36

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Buchari)

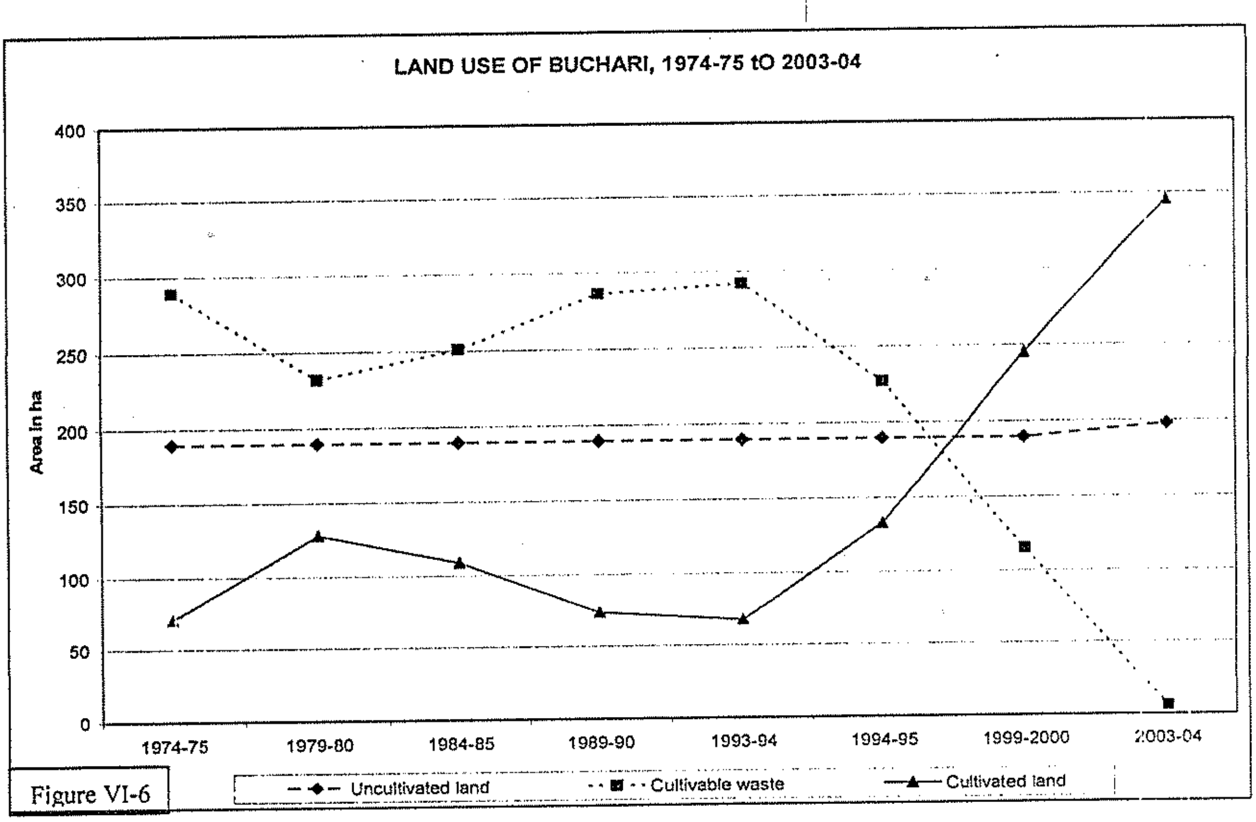
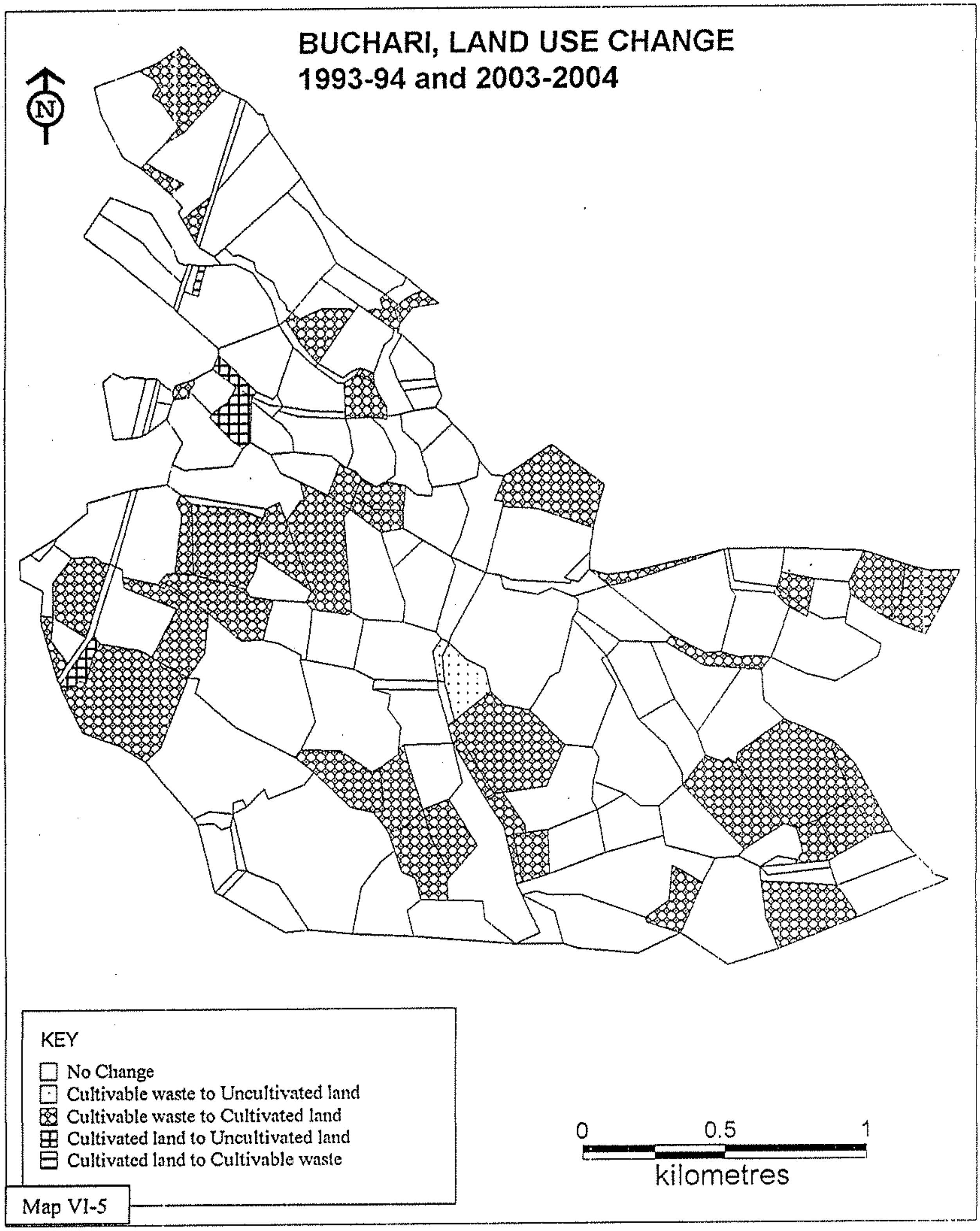


Figure VI-6


BUCHARI, LAND USE CHANGE
1993-94 and 2003-2004
N
KEY
No Change
Cultivable waste to Uncultivated land
Cultivable waste to Cultivated land
Cultivated land to Uncultivated land
Cultivated land to Cultivable waste
0
0.5
1
kilometres
Map VI-5

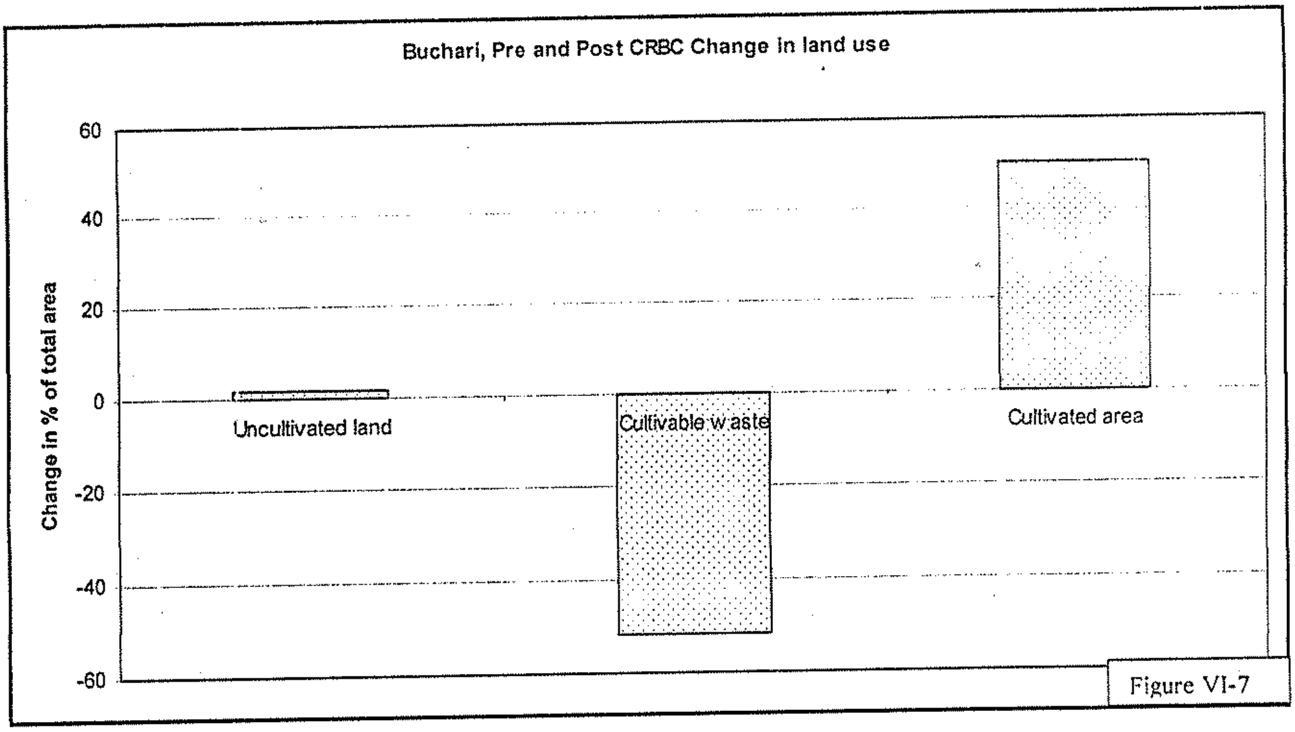


Figure VI-7

iv. CHERA

Mouza Chera falls in CRBC stage III. This village received water from CRBC in 2000-2001. Mouza Chera has a total area of 725 ha. Map VI-6 and figure VI-8 give a detailed review of mouza Chera land utilization both before and after CRBC. In Chera, the uncultivated land has comparatively minimum share then the other land units. The table VI-9 indicates that before CRBC 1967-68 to 1999-2000 the uncultivated area was 49 ha, which after CRBC has increased to 62 ha in 2003-2004. The revenue record together with the field survey reveals that this increase is attributed to the construction of new houses, roads and other built-up areas, which seems to be the impact of CRBC. The table VI-10 indicates that after CRBC a positive change of 1.80% has been recorded in uncultivated area (Figure VI-9).

The analysis further reveals that prior to CRBC, there was uncertainty in the cultivated area and cultivable waste, while after CRBC there has been constant increase in the area under cultivation and corresponding decrease in the cultivable waste. The figure VI-8 further indicates that before CRBC, the cultivable waste varies from year to year, however maximum (640 ha) was recorded in 1999-2000 and minimum (307 ha) in 1979-80. The highest cultivable waste in the stated period is considered to be the direct manifestation of drought condition in the country (Sheikh, 2004). After the inception of CRBC, large area under cultivable waste has been brought under cultivation. After CRBC area under cultivable waste was 246 ha in 2000-2001, which reduced to 36 ha in 2003-2004. The table VI-10 indicates that after CRBC a negative change of 54.34% has been recorded in the cultivable waste. The analysis also reveals that after CRBC, decrease in the cultivable waste has registered the correspondent increase in the cultivated area.

In Chera, cultivated land was the most important land unit. The analysis reveals that there has been consistent increase in the cultivated area as a result of CRBC. The table VI-9 shows that prior to CRBC, cultivated land varied from year to year. However, after commissioning of CRBC, in 2000-2001 about 422 ha was cultivated as against 36 ha, during pre CRBC in 1999-2000 (Table VI-9). After that area under cultivation used to increase continuously and reached to 627 ha in 2003-04. The table VI-10 indicates that after CRBC a positive change of 52.55% has been recorded in the cultivated acreage.

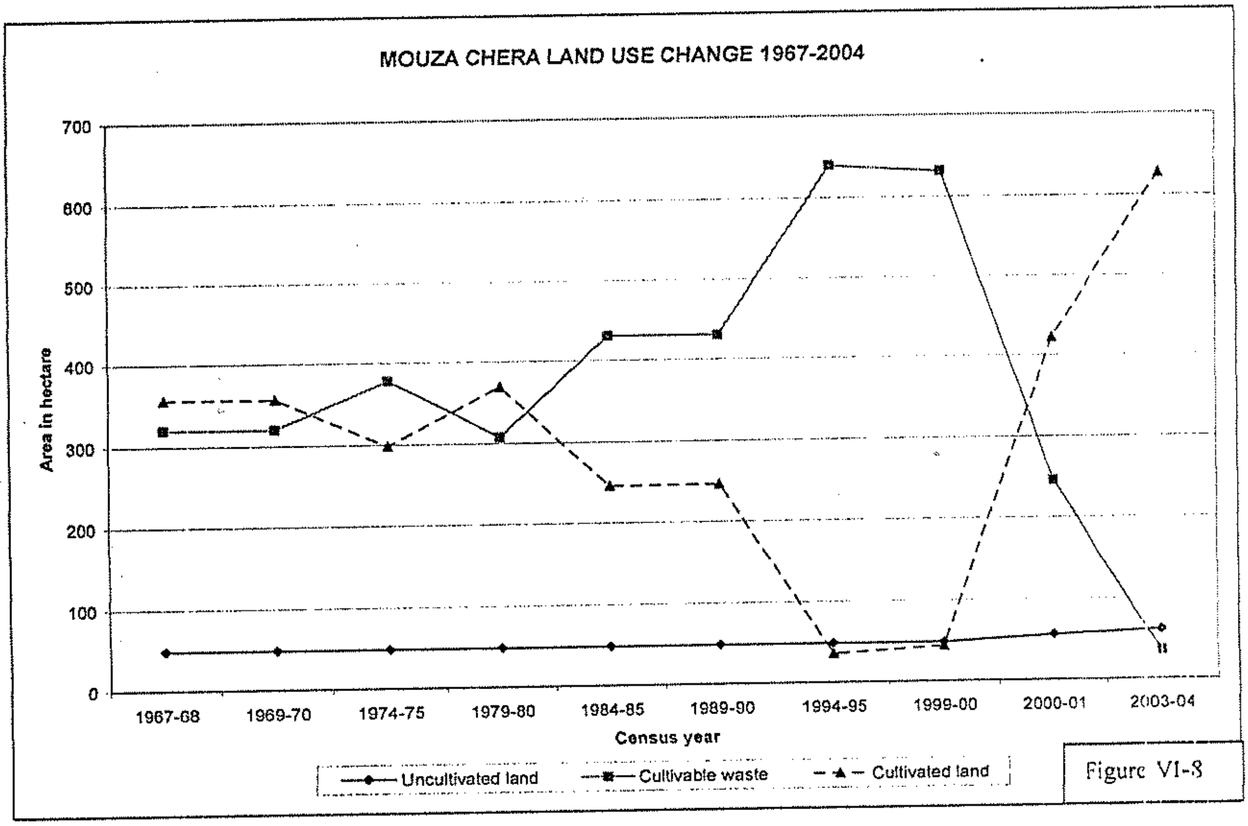


Figure VI-8

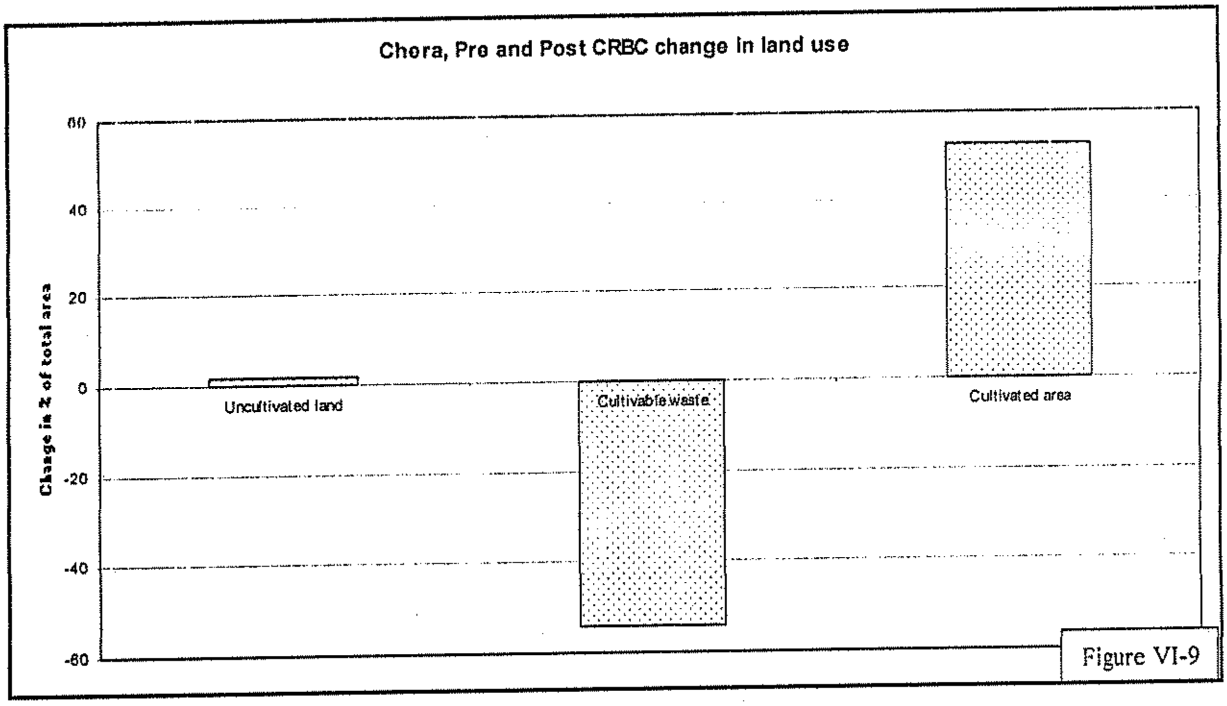


Figure VI-9

Table VI-9
Chera, Land use, 1967-68 to 2003-04 (area in ha)

Year	*Total area*	*Uncultivated land*	*Cultivable waste*	*Cultivated land*
1967-68	725	49	320	356
1969-70	725	49	320	356
1974-75	725	49	378	298
1979-80	725	49	307	369
1984-85	725	49	430	246
1989-90	725	49	430	246
1994-95	725	49	632	45
1999-00	725	49	640	36
Post CRBC				
2000-01	725	57	246	422
2003-04	725	62	36	627

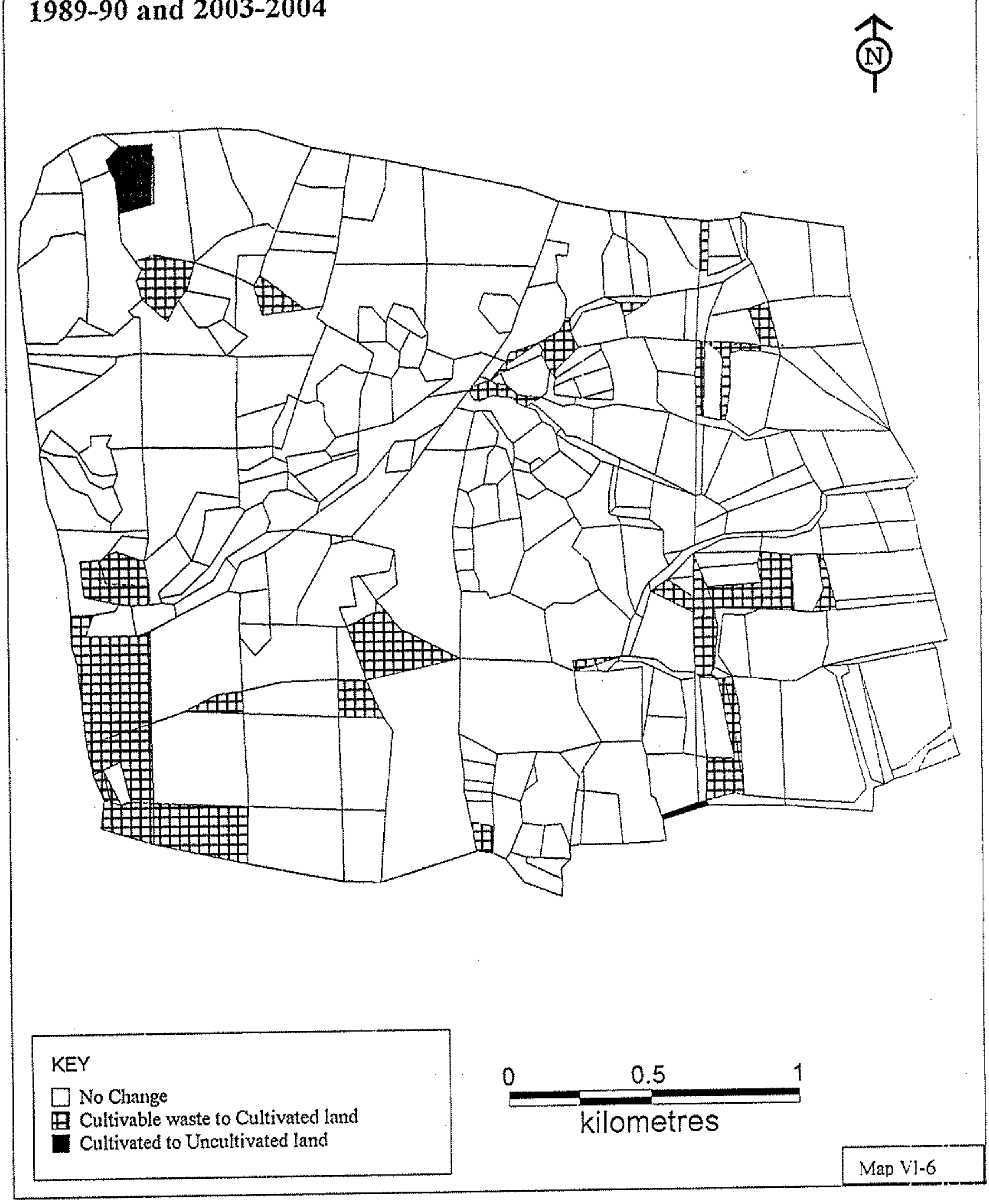
Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Chera)

Table VI-10
Chera, land use change, 1989-1990 and 2003-2004

Land Use	*Pre CRBC Phase*		*Post CRBC Phase*		*% change*
	1989-90	*% of total area*	*2003-04*	*% of total area*	
Total area	725	-	725	-	-
Uncultivated land	49	6.75	62	8.55	+1.80
Cultivable waste	430	59.31	36	4.96	-54.34
Cultivated area	246	33.93	627	86.48	+52.55

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Chera)

CHERA LAND USE CHANGE
1989-90 and 2003-2004



v. KHUDAKA

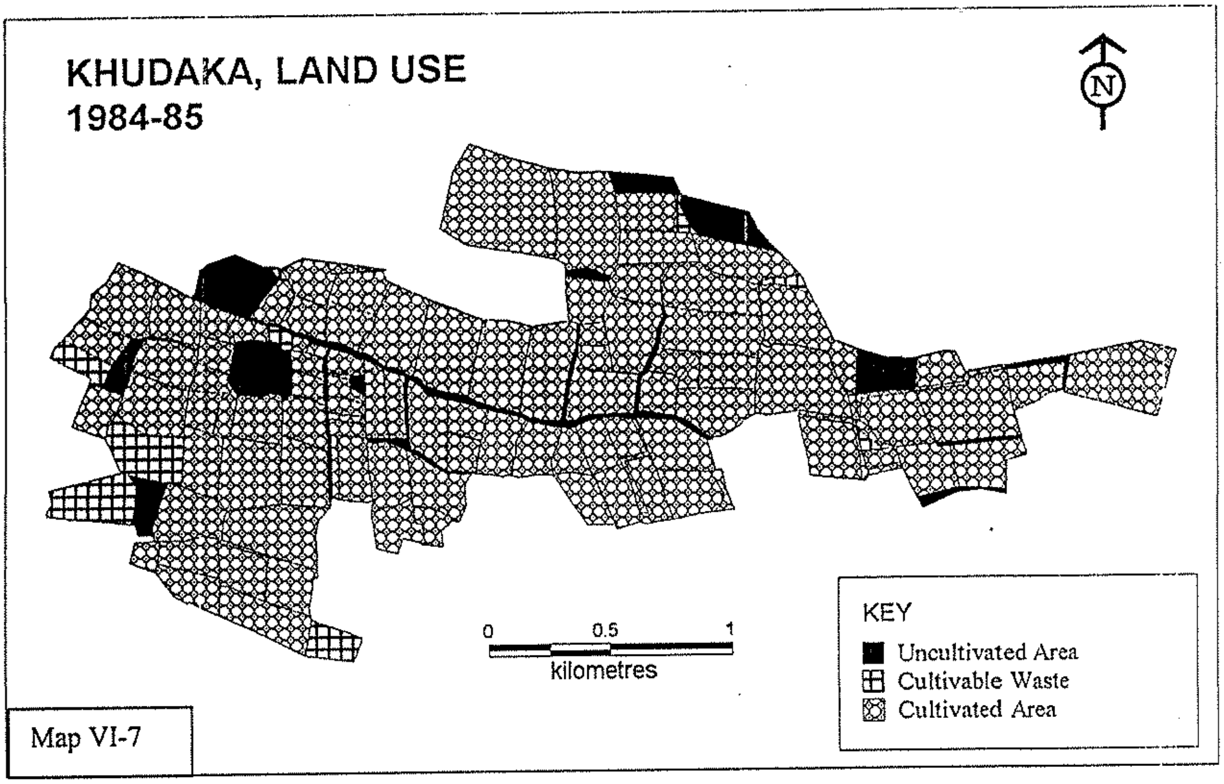
Khudaka is one of the sampled villages located outside the CRBC command area. This village lies right on the left bank of Luni hill torrent. In Khudaka, Rod Kohi is the only means of irrigation. Here, groundwater is saline and deep; hence not fit for both drinking and irrigation. Mouza Khudaka has a total area of about 320 ha and classified into uncultivated, cultivated and cultivable waste. It is clear from the figure VI-10 that there has been constant fluctuation in the land utilization in the last three decades. The large-scale variation was found in both the areas of cultivable waste and cultivated land, whereas uncultivated land remained static land unit. The figure VI-10 shows that uncultivated land was found same (32 ha) throughout the study period. The analysis reveals that during the study period no change has been recorded in the uncultivated area.

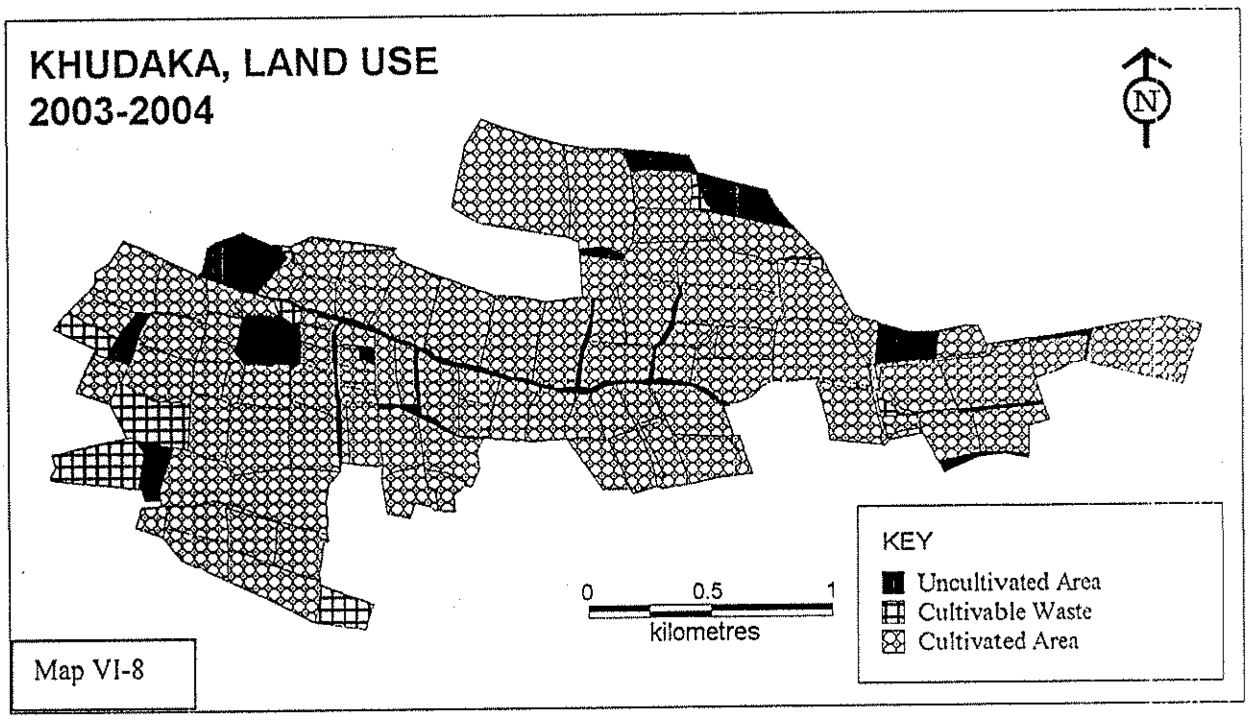
The figure VI-10 shows that there has been constant increase in the cultivable waste with few exceptions from 1966-67 to 2003-04. The figure VI-10 shows that there were regular spells of minimum cultivable waste from 1966-67 to 1984-85, which indicates favourable climatic conditions, which has resulted an increase in the cultivated area. The table VI-11 shows that after CRBC a net positive change of 85.93% has been registered in the cultivated area. The share of the cultivated area and cultivable waste has direct relationship with the availability of water. Under favourable climatic conditions most of the land was found under cultivation but during drought condition large area was found under cultivable waste. The analysis shows that during 1966-67 and 1984-85, the maximum proportion of cultivated land was mainly because of favourable climatic condition during the stated period. However, during the period of 1989-90, 1999-2000 and onward even a single plot was not cultivated as a result the ratio of cultivable waste has increased many folds due to prevailing drought condition in the country (Sheikh, 2004). After comparing pre (1984-85) and post CRBC (2003-2004) conditions, a negative change of 85.93% has been recorded in the cultivated area (Figure VI-11). The analysis concludes that due to its location outside the CRBC command area there has been no impact of CRBC on the land use of village Khudaka.

Table VI-11
Khudaka, land use change, 1984-85 and 2003-2004

Land Use	*Pre CRBC Phase*		*Post CRBC Phase*		*% change*
	1984-85	*% of total area*	*2003-04*	*% of total area*	
Total area	320	-	320	-	-
Uncultivated land	32	9.99	32	9.99	0
Cultivable waste	13	4.06	288	89.99	+85.93
Cultivated area	275	85.93	0	0	-85.93

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Khudaka)


KHUDAKA, LAND USE
1984-85
N
0
0.5
1
kilometres
KEY
Uncultivated Area
Cultivable Waste
Cultivated Area
Map VI-7


KHUDAKA, LAND USE
2003-2004
N
0
0.5
1
kilometres
KEY
Uncultivated Area
Cultivable Waste
Cultivated Area
Map VI-8

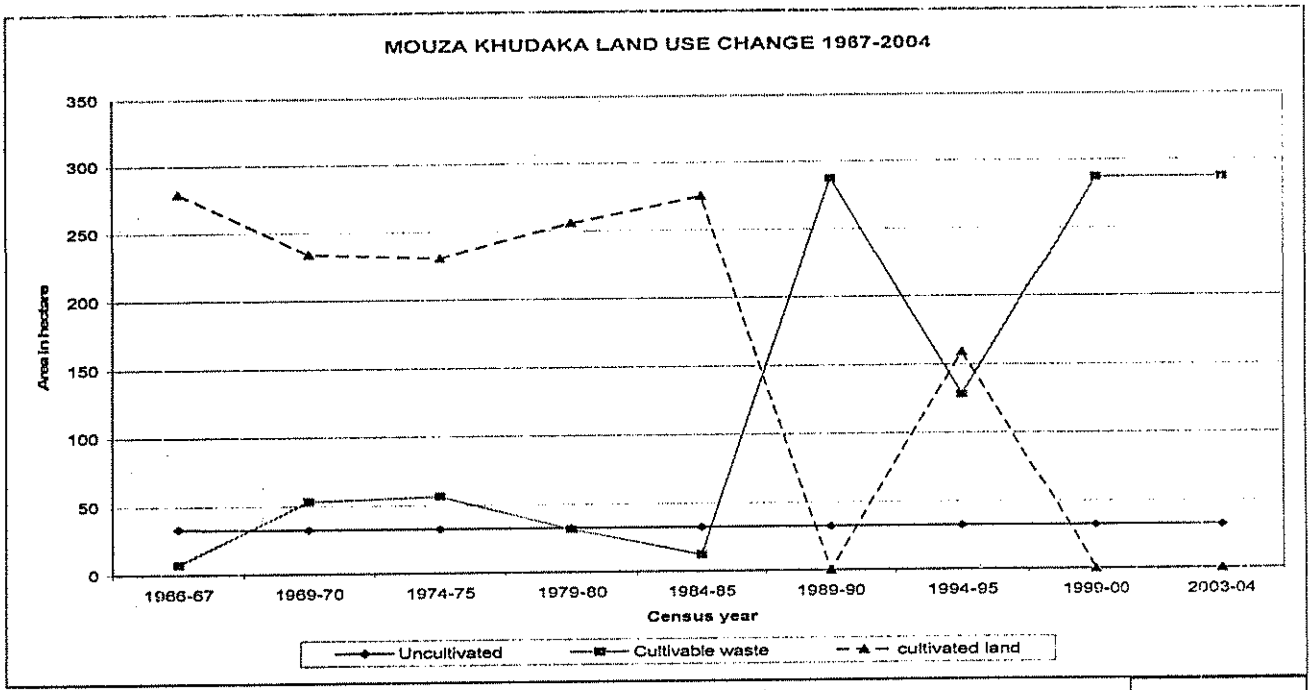


Figure VI-10

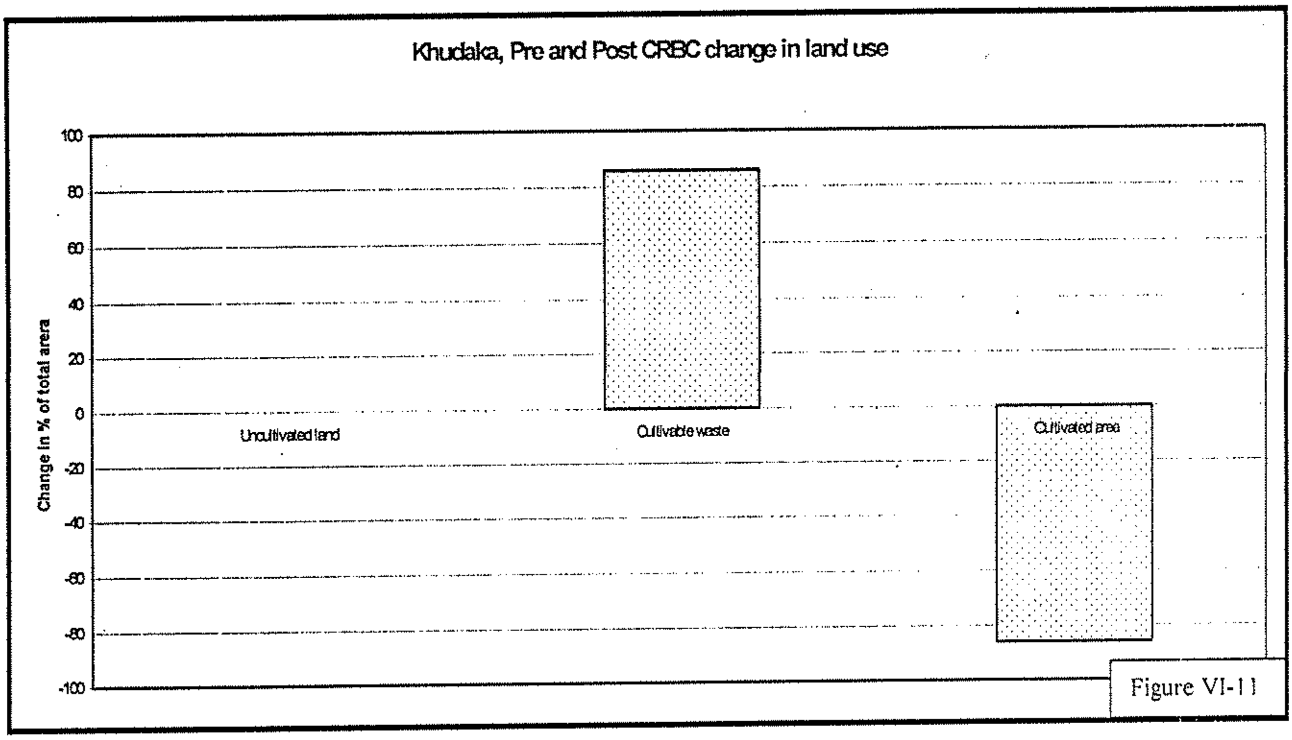


Figure VI-11

6.1.3 People perceptions about the impacts of CRBC on the land use

The respondents were inquired about *the impacts of CRBC on the cultivated, uncultivated and cultivable waste land?* A predominant majority of the respondents were of the view that after CRBC their cultivated land has been significantly increased. The analysis further reveals that the impacts of CRBC on the cultivated land are very significant. There has been constant increase in the cultivated area, after CRBC and corresponding decrease in the cultivable waste land. In Chera more than two-third of the respondents replied that their cultivated area has increased. They were of the view that with the CRBC they brought extensive cultivable waste land under cultivation (Table VI-12). However, nearly one-third of the respondents replied that no change has occurred in their cultivated area. In Jarra, half of the respondents replied that their cultivated land is the same as it was prior to the inception of CRBC. This situation is mainly due to the fact that prior to CRBC this village was under the command of old Paharpur canal. In Gomal and Buchari, the higher proportion of unchanged (same) cultivated area is due to the fact that before CRBC the cultivated land in the sample villages was either rainfed, Rod Kohi or well irrigated and the same land has been brought under the command of CRBC. However, significant decrease in the cultivable waste was also recorded. Contrary to this, no impacts of CRBC on the land use of Khudaka was registered.

Table VI-12
Impacts of CRBC on cultivated land and cultivable waste

Sample village	*Cultivated area (%)*			*Cultivable waste (%)*		
	Increased	*Decreased*	*Unchanged*	*Increased*	*Decreased*	*Unchanged*
Jarra	20	20	60	0	30	70
Gomal	40	5	55	0	35	65
Buchari	40	5	55	0	70	30
Chera	70	0	30	0	100	0
Khudaka	0	0	100	0	0	100

Source: Field survey, 2005

6.2 ENVIRONMENTAL IMPACTS OF CRBC ON THE IRRIGATION PATTERN

6.2.1 Environmental impacts of CRBC on the irrigation pattern of D.I.Khan district (Macro level analysis)

In D.I.Khan district, canal irrigation has remained one of the major sources of irrigation both before and after the inception of CRBC. The table VI-13 indicates that irrigated area varies from year to year. However, there has been constant increase in the total irrigated area, since 1969-70. The statistical analysis reveals that pre CBRC (1969-70), total irrigated land was 52,023 ha as compared to post CRBC 145,798 ha, during 2002-03 (Figure VI-12). The table VI-14 indicates that after CRBC a net positive change of 10.77% of the total reported area has been recorded in the irrigated area. The increase in the irrigated area is attributed to the CRBC. Therefore, after inception of CRBC, canal irrigated area has been considerably increased (Table VI-13 & 14; Map VI-9 & 10).

Presently, the share of canal irrigated area is more than all the other categories. Prior to the construction of CRBC, in 1969-70 canal-irrigated area was only 16,517 ha, which makes 6.5% of the cultivated area. During the stated period, Paharpur canal was the major source of canal irrigation. The share of canal irrigated area was constantly improved particularly after the commissioning of CRBC. In the initial phase of CRBC (1989-90), area under canal irrigation has shown an increase (61,608 ha). This was further multiplied and reached to 127,498 ha in 2002-03. It means that from 1969-70 to 2002-03 canal irrigated area was increased more than seven fold (Table VI-13). It is also clear from the table VI-14 that a positive change of 10.05% has been registered after the advent of CRBC. The farmer has also brought considerable area under the command of CRBC. The analysis reveals that this large-scale increase in the canal irrigated area is attributed to the inception of CRBC. There is direct relationship between canal irrigated area and cultivated land. The table VI-1, 13 & 14 indicates that after CRBC both canal irrigated and cultivated area have been gradually increased.

The analysis further reveals that pre CRBC in 1969-70, area under lift irrigation was 24,656 ha as against canal irrigated area of 16,517 ha (Table VI-13). This indicates that prior to CRBC area under lift irrigation was more than the canal irrigated area. During pre CRBC phase (1979-80) area under lift irrigation was 13,000 ha. However, after commissioning of CRBC in 1989-90 area under lift irrigation increased to 26,395 ha, which was subsequently decreased to 18,300 ha in 2002-2003 (Table VI-13). The overall decrease in the area under lift irrigation is mainly because the same land was brought under the command of CRBC. The macro analysis reveals that after comparing pre (1979-80) and post (2002-03) CRBC, area under lift irrigation has shown a positive change of 0.73% (Table VI-14). The uncertainty in area under lift irrigation is also attributed to the establishment of new tube wells both in public and private sectors (see section 2.3.1). Area under lift irrigation has recorded positive change but maximum change in the canal irrigated area is mainly due to the consistent and cheap source of irrigation i.e. CRBC as compared to other sources of irrigation.

Table VI-13

D.I.Khan district, Area irrigated by different sources, 1969-70 to 2003-04 (Area in ha)

Year	*Total Irrigated Area*	*Total Canal irrigated*	*Lift irrigation*	*Other Sources*
1969-70	52,023	16,517	24,656	10,850
1979-80	67,110	54,110	13,000	-
Post CRBC				
1989-90	88,195	61,608	26,395	192
1999-00	119,915	104,080	15,652	183
2002-03	145,798	127,498	18,300	-

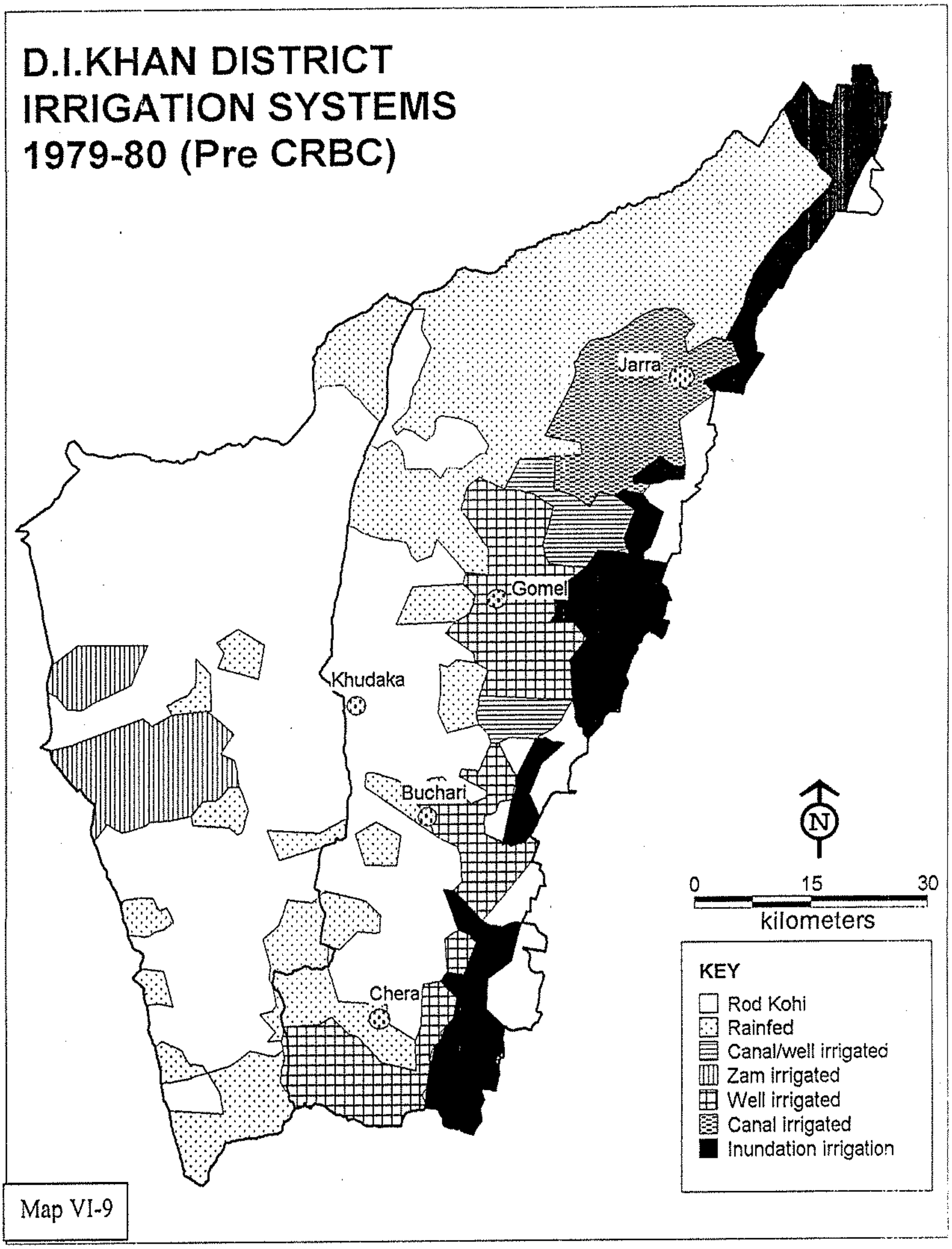
Source: GoNWFP, 1975; 1980; 1991; 2000a and 2004

Table VI-14

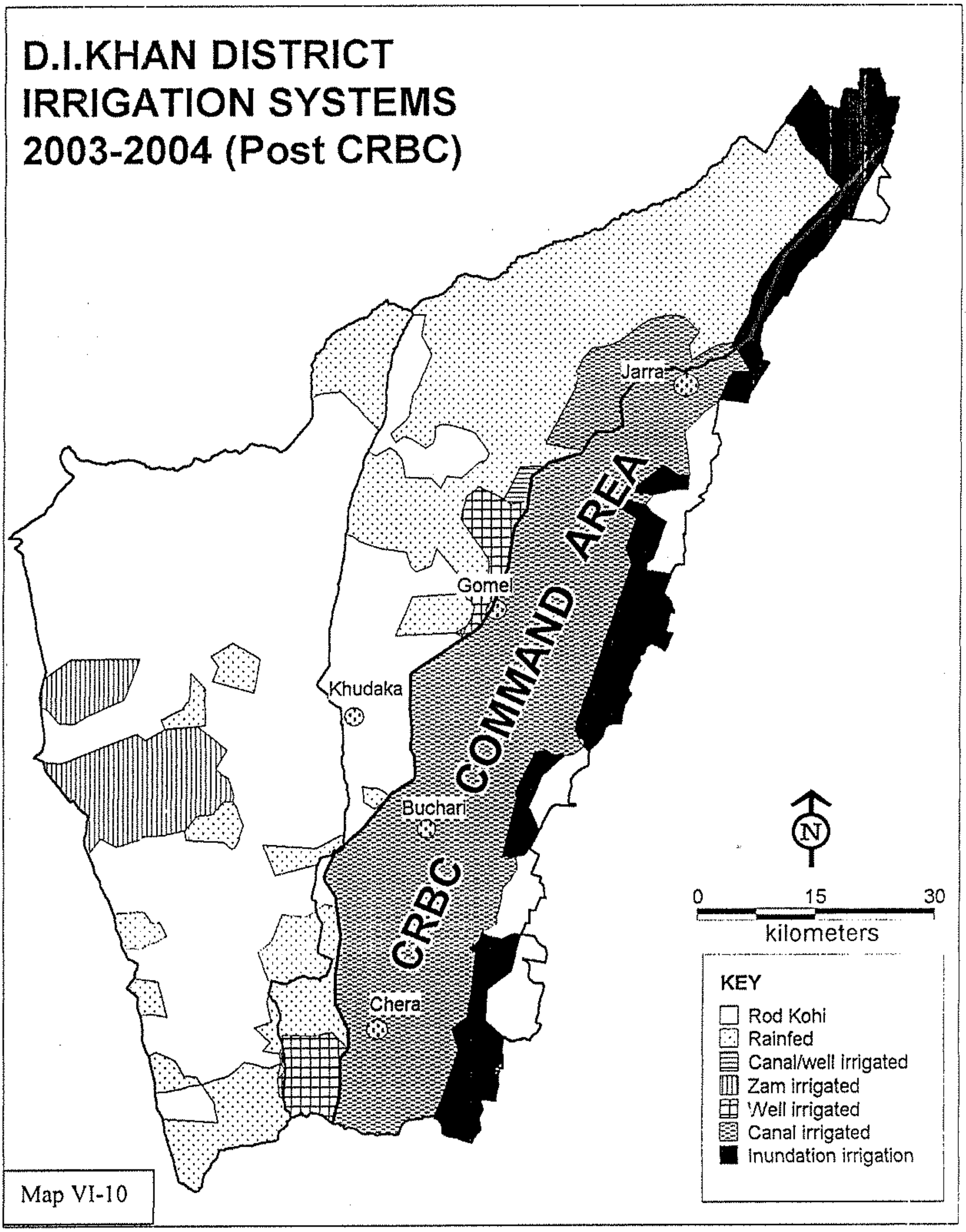
Macro level change in irrigation pattern

Parameters	*Pre CRBC Phase (1979-80)*		*Post CRBC Phase (2003-04)*		*Recorded change in %age*
	Area in ha	*% share of total area*	*Area in ha*	*% share of total area*	
Total Irrigated Area	67,110	9.18	145,798	19.95	+10.77
Total Canal irrigated	54,110	7.4	127,498	17.45	+10.05
Lift irrigation	13,000	1.77	18,300	2.50	+0.73

Source: GoNWFP, 1980; and 2004


D.I.KHAN DISTRICT
IRRIGATION SYSTEMS
1979-80 (Pre CRBC)
Jarra
Gomel
Khudaka
Buchari
Chera
N
0
15
30
kilometers
KEY
Rod Kohi
Rainfed
Canal/well irrigated
Zam irrigated
Well irrigated
Canal irrigated
Inundation irrigation

Map VI-9


D.I.KHAN DISTRICT
IRRIGATION SYSTEMS
2003-2004 (Post CRBC)
CRBC COMMAND AREA
Jarra
Gomel
Khudaka
Buchari
Chera
N
0
15
30
kilometers
KEY
Rod Kohi
Rainfed
Canal/well irrigated
Zam irrigated
Well irrigated
Canal irrigated
Inundation irrigation

Map VI-10

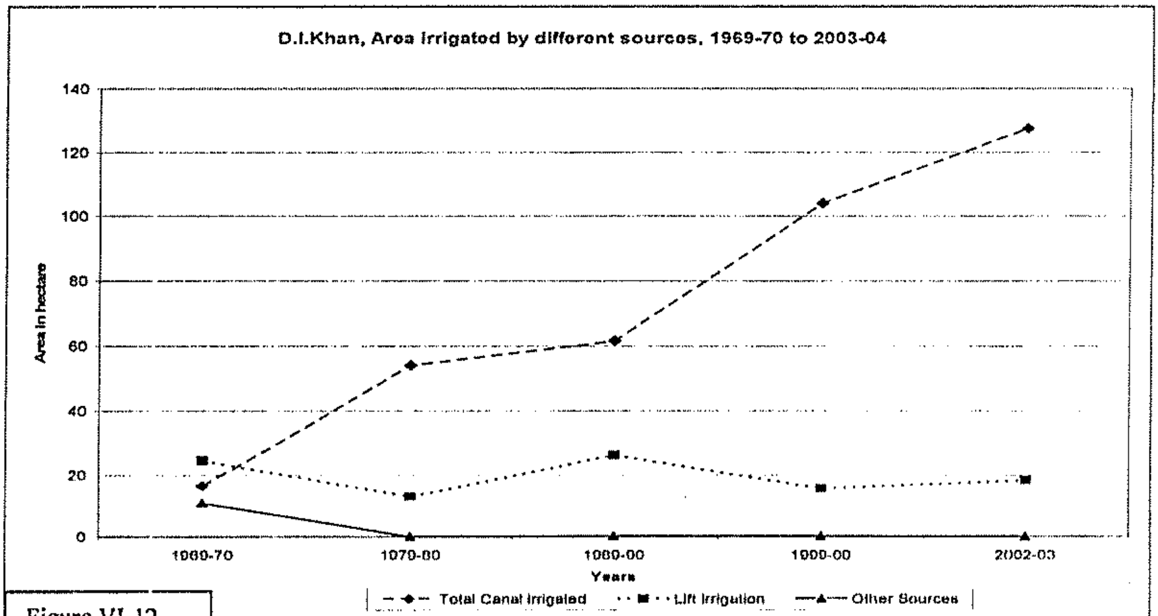


Figure VI-12

6.2.2 Environmental impacts of CRBC on the irrigation pattern of sample villages (Micro level analysis)

For micro-level assessment, the irrigated area of sampled villages was further subdivided into Rod Kohi, lift and canal irrigated. For getting clear picture of various water sources available for agricultural land, rainfed area was also included. The irrigation system in the five sampled villages is discussed in the following paragraphs with particular reference to pre and post CRBC condition. The analysis reveals that after CRBC, area under canal irrigation has been increased particularly in the villages of CRBC command area.

i. JARRA

In Jarra, two major sources of water were found including canal and rainfall. In Jarra, canal irrigation remained a predominant source of irrigation throughout the study period. In the sampled village, canal irrigation is reported, since 1902, when old Paharpur canal was constructed. The table VI-15 indicates that there were certain ups and downs in the canal irrigated areas from 1987-88 (pre CRBC) to 2003-2004 (post CRBC). Before CRBC, canal irrigated area was 387 ha in 1987-88, while after CRBC, canal irrigated area has increased to 408 ha in 2003-2004. Likewise, both pre and post CRBC small area was also reported as rainfed. The analysis found that area under rainfed cultivation was found negligible as compared to canal irrigated throughout the study period from 1987-88 to 2003-2004. While comparing pre and post CRBC conditions of canal irrigation a positive change of 4.05% has been reported in village Jarra (Table VI-16).

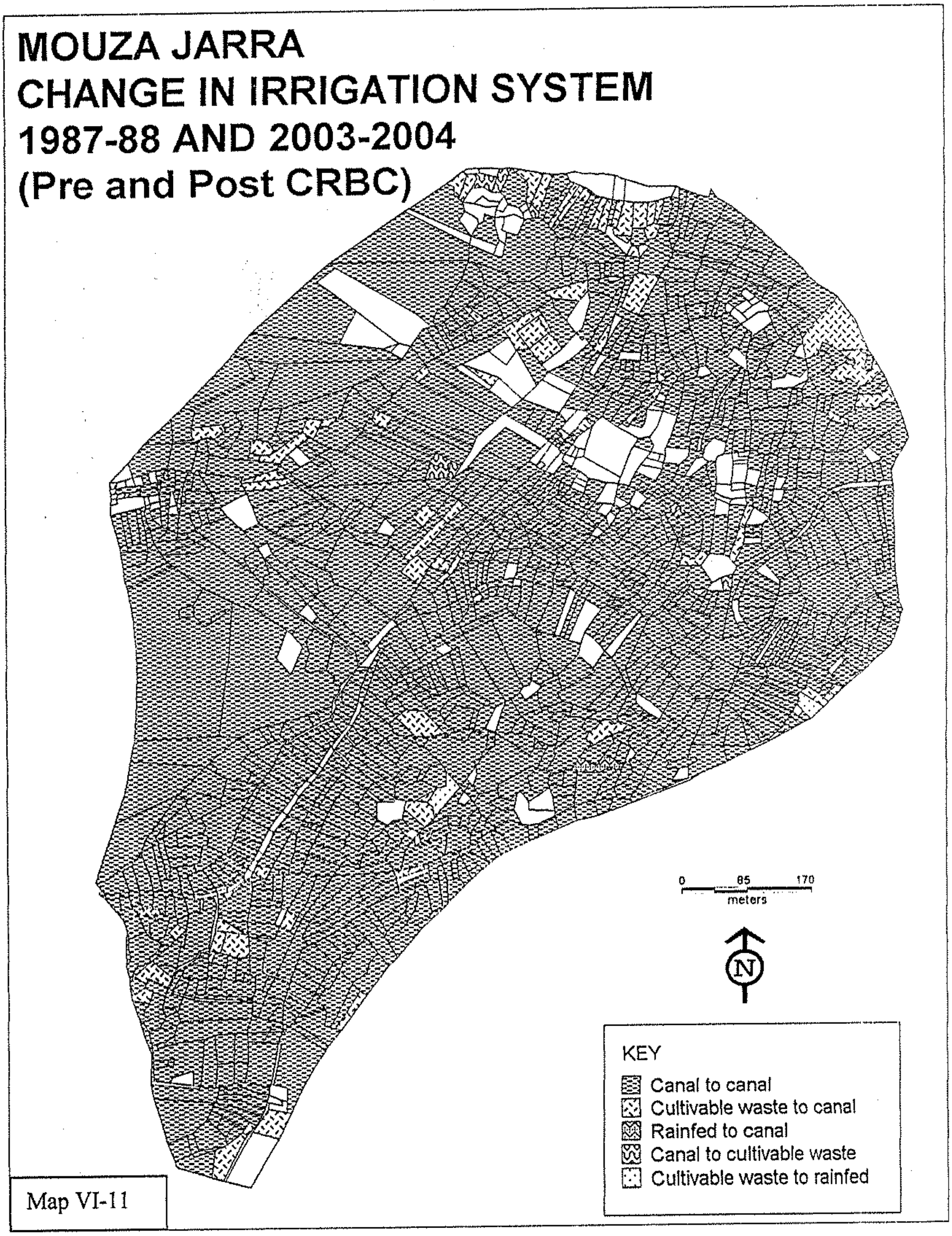

MOUZA JARRA
CHANGE IN IRRIGATION SYSTEM
1987-88 AND 2003-2004
(Pre and Post CRBC)
0
85
170
meters
N
KEY
Canal to canal
Cultivable waste to canal
Rainfed to canal
Canal to cultivable waste
Cultivable waste to rainfed
Map VI-11

Table VI-15
Irrigated area, Jarra, 1987-88 TO 2003-04 (area in ha)

Year	*Total area*	*Cultivated land*	
		Rainfed	*Canal irrigated*
1987-88	518	2	387
Post CRBC			
1989-90	518	-	356
1994-95	518	-	235
1999-00	518	-	248
2003-04	518	2	408

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Jarra)

Table VI-16
Jarra, change in irrigated area, 1987-88 and 2003-04 (area in ha)

Type of land	*Pre CRBC*		*Post CRBC*		*Change in % of total area*
	1987-88	*% Share of the total area*	*2003-2004*	*% Share of the total area*	
Total area	518	-	518	-	-
Canal irrigated	387	74.71	408	78.76	+4.05
Rainfed	2.	0.38	2	0.38	0

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Jarra)

ii. GOMAL

In Gomal, three different mode of irrigation were found including well irrigated, Rod Kohi and canal irrigated (Map VI-12). The analysis reveals that prior to CRBC well and Rod Kohi was the dominant sources of irrigation, while small area was also found under rainfed cultivation. The revenue record reveals that in Gomal, prior to CRBC there were 13 tube wells, out of which, 7 were in government control, while 6 were privately managed. Prior to CRBC well was the major source of irrigation in Gomal (Table VI-17). According to revenue record before CRBC in 1987-88, area under well irrigation was 832 ha. This has been reduced to 21 ha in 2003-04 after inception of CRBC. The table VI-18 reveals that after comparing pre and post CRBC condition of well irrigated acreage, a negative change of 22.14% has occurred (Figure VI-13).

In Gomal Rod Kohi is the next important mode of irrigation both pre and post CRBC. The table VI-17 indicates that area under Rod Kohi largely varies from year to year. The variation in the Rod Kohi acreage is mainly due to its dependence on the rainfall over the catchment area. Prior to CRBC, area under Rod Kohi was 387 ha in 1987-88, which has been increased to 492 ha after CRBC in 2003-2004. The table VI-18 elaborates that during pre and post CRBC condition a positive change of 2.86% has been registered (Figure VI-13).

The table VI-17 reveals that after inception of CRBC, a constant increase has occurred in the canal irrigated area. A comparison of pre and post CRBC conditions of canal irrigated area indicates that a positive change of 49.65% has registered (Table VI-18 and Figure VI-13). During post CRBC, in 1989-90, 416 ha was under canal irrigation, which was increased fourfold and marked the figure of 1,818 ha during 2003-04 (Table VI-17). It can finally be concluded that a negative change has been detected in well irrigated acreage, whereas a radical positive change has been recorded in the canal irrigated area.

Table VI-17
Gomal, irrigated area, 1969 to 2004 (area in ha)

Year	*Total area*	*Cultivated area*			
		Wells	*Rod Kohi*	*Rainfed*	*Canal irrigated*
1969-70	3,661	575	452	26	-
1974-75	3,661	669	147	-	-
1979-80	3,661	1,213	117	-	-
1984-85	3,661	1,130	117	-	-
1987-88	3,661	832	387	18	-
Post CRBC					
1988-89	3,661	517	1,255	178	416
1989-90	3,661	517	562	32	1,270
1994-95	3,661	389	245	147	1,605
1999-00	3,661	238	242	108	1,805
2003-04	3,661	21	492	86	1,818

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Gomal)

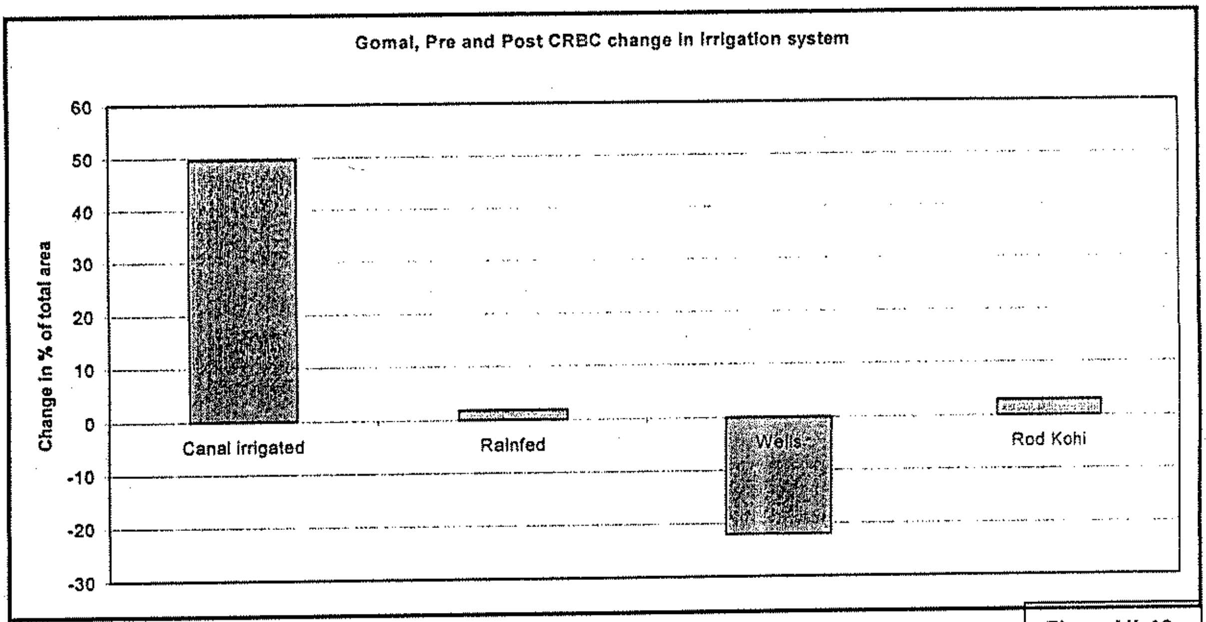


Figure VI-13

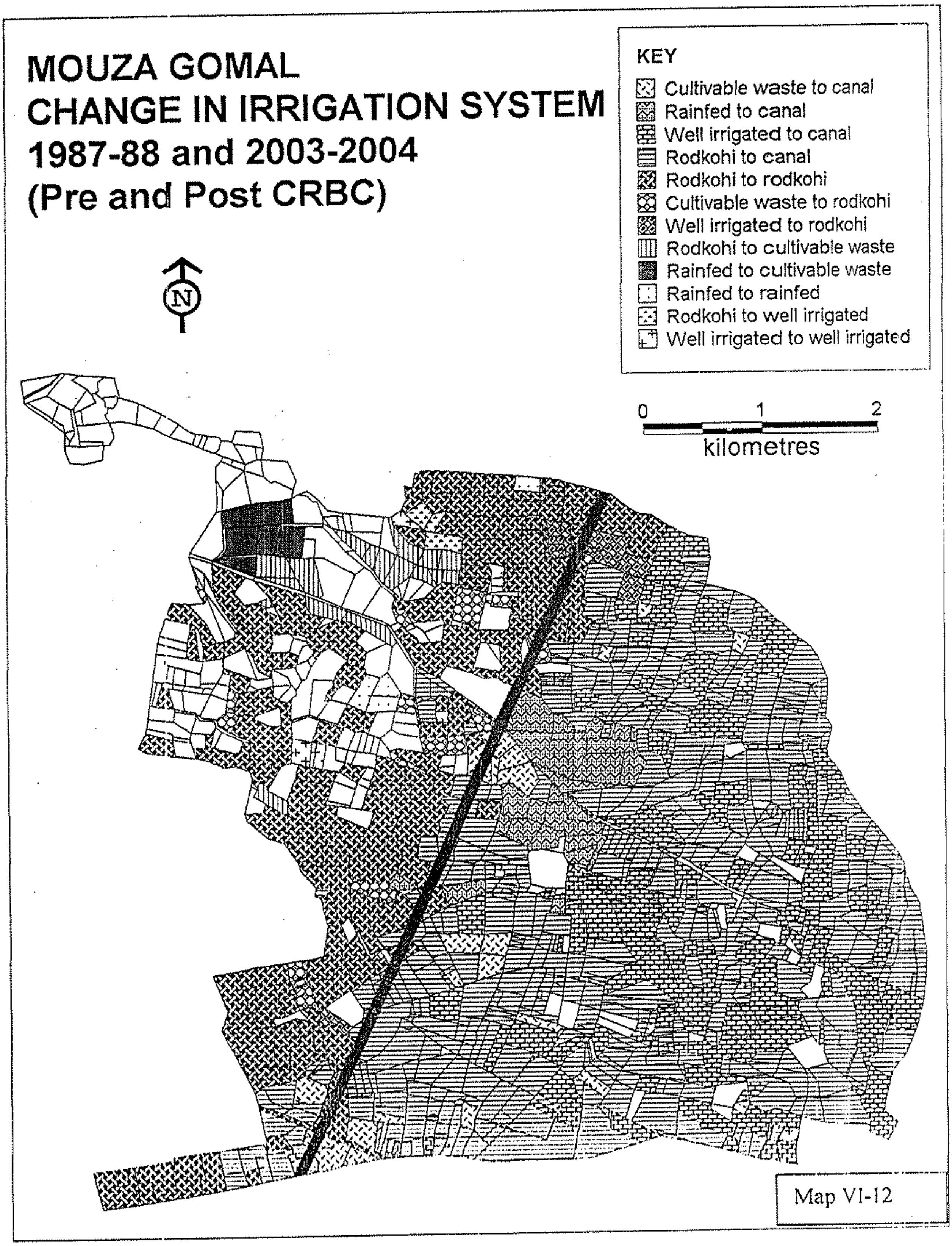

MOUZA GOMAL
CHANGE IN IRRIGATION SYSTEM
1987-88 and 2003-2004
(Pre and Post CRBC)
N
KEY
Cultivable waste to canal
Rainfed to canal
Well irrigated to canal
Rodkohi to canal
Rodkohi to rodkohi
Cultivable waste to rodkohi
Well irrigated to rodkohi
Rodkohi to cultivable waste
Rainfed to cultivable waste
Rainfed to rainfed
Rodkohi to well irrigated
Well irrigated to well irrigated
0 1 2
kilometres
Map VI-12

Table VI-18
Gomal, change in irrigated area, 1987-88 and 2003-2004 (area in ha)

Type of land	*Pre CRBC*		*Post CRBC*		*Change in % of total area*
	1987-88	*% Share of the total area*	*2003-2004*	*% Share of the total area*	
Total area	3,661	-	3,661	-	-
Canal irrigated	0	-	1,818	49.65	+49.65
Rainfed	18	0.49	86	2.34	+1.85
Wells	832	22.72	21	0.57	-22.14
Rod Kohi	387	10.57	492	13.43	+2.86

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Gomal)

iii. BUCHARI

In Buchari, before the inception of CRBC, the cultivated land was entirely dependent on rainfall and Rod Kohi. Field survey together with the FGD's reveals that in Buchari prior to CRBC farmers prefer to cultivate their land after rainfall. During 1969-70, area under rainfed cultivation was only 3 ha, which gradually increased to 232 ha in 1979-80. However, during 1984-85 to 1993-94, not even a single plot was found under rainfed cultivation. The analysis reveals that after canal irrigation in the form of CRBC, rainfed area reduced from 81 ha in 1994-95 to 22 ha in 2003-04 (Map VI-13). This was mainly due to the prevailing dry condition in the area and largely due to the inception of canal irrigation.

The table VI-19 elaborates that area under Rod Kohi irrigation varies from year to year. Before CRBC, maximum area under Rod Kohi (109 ha) was recorded during 1984-85, whereas it was zero from 1969-70 to 1974-75. However, after inception of CRBC, area under Rod Kohi reduced to zero in 2003-2004, while comparing pre and post CRBC condition of Rod Kohi area, a negative change of 12.36% has been noted (Figure VI-14).

In Buchari, canal irrigation started after the inception of CRBC. The analysis reveals that after CRBC, a gradual increase has been registered in canal irrigated area. In the initial stage of CRBC (1994-95), area under canal irrigation was 52 ha, which gradually increased to 323 ha in 2003-04 (Table VI-19). A comparison of pre and post CRBC condition of canal irrigated area reveals that a positive change of 58.72% has occurred (Figure VI-14). Field observation together with the Focus Group Discussions reveals that area under Rod Kohi and rainfed was gradually brought under canal irrigation. This indicates positive impacts of CRBC on the cultivated acreage of mouza Buchari.

Table VI-19

Buchari, irrigated area, 1969-70 to 2003-04 (area in ha)

Year	*Total area*	*Cultivated area*		
		Rainfed	*Rod Kohi*	*Canal irrigated*
1969-70	550	3	-	-
1974-75	550	71	-	-
1979-80	550	232	1	-
1984-85	550	-	109	-
1989-90	550	-	74	-
1993-94	550	-	68	-
Post CRBC				
1994-95	550	81	-	52
1999-2000	550	-	-	245
2003-04	550	22	-	323

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Buchari)

Table VI-20

Buchari, change in irrigated area, 1993-94 and 2003-04 (area in ha)

Type of land	*Pre CRBC*		*Post CRBC*		*Change in % of total area*
	1993-94	*% Share of the total area*	*2003-2004*	*% Share of the total area*	
Total area	550	-	550	-	-
Canal irrigated	0	-	323	58.72	+58.72
Rainfed	0	-	22	4	+4
Rod Kohi	68	12.36	0	-	-12.36

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Buchari)

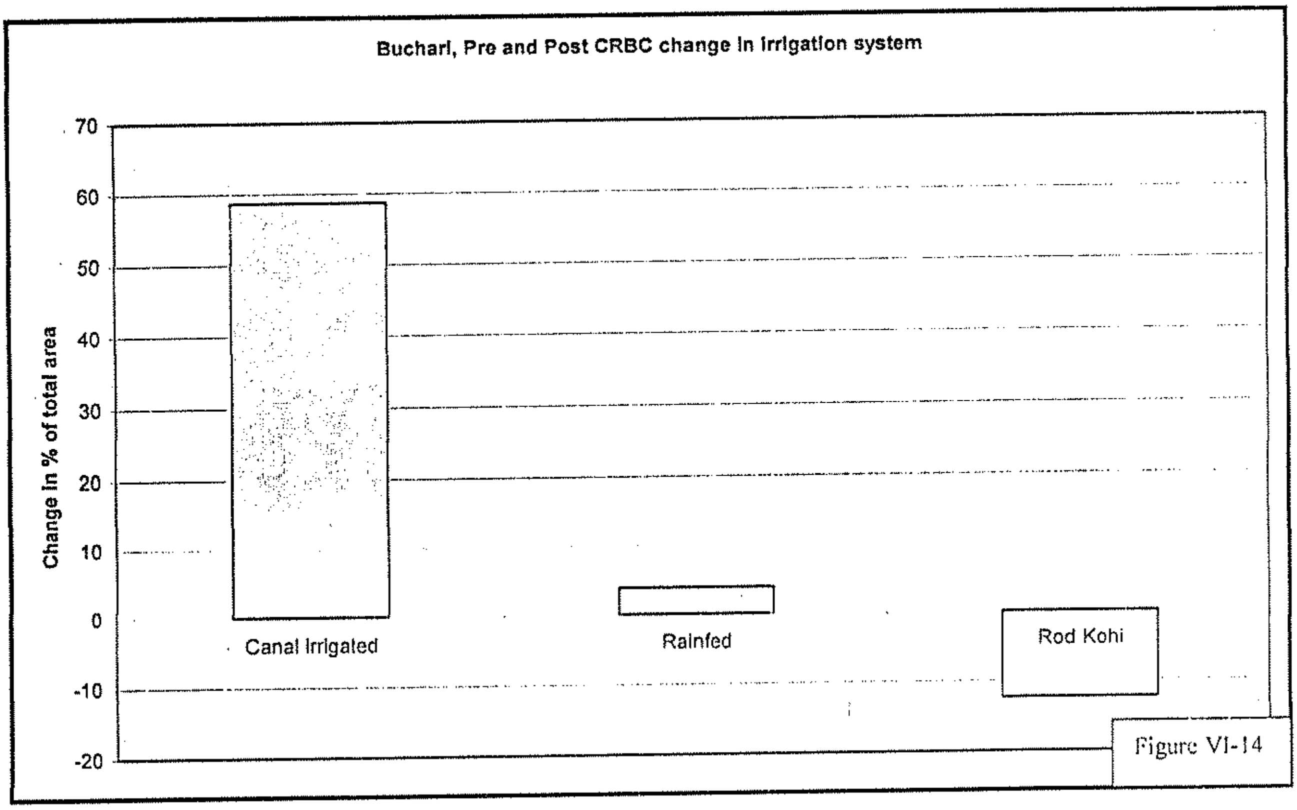
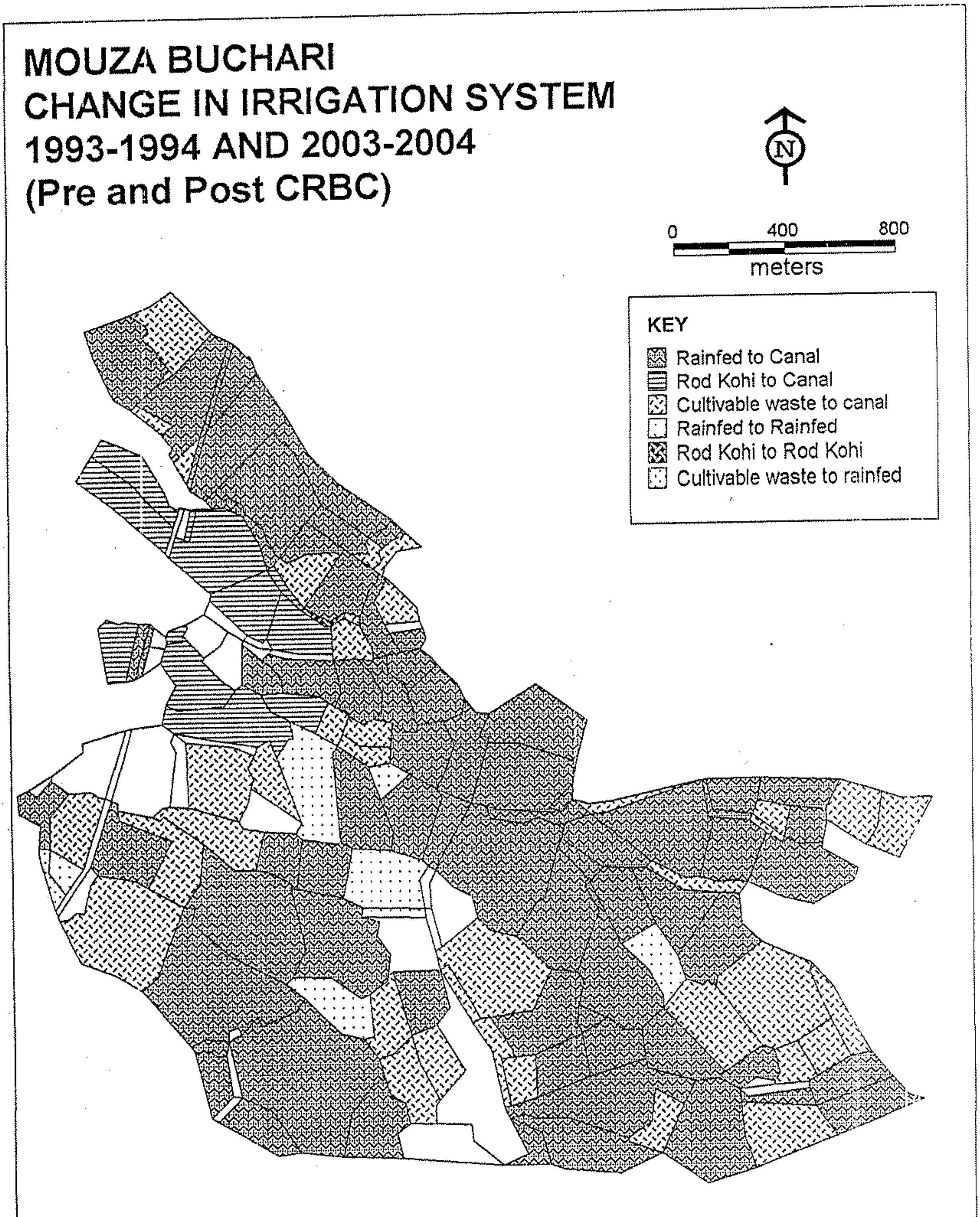


Figure VI-14


MOUZA BUCHARI
CHANGE IN IRRIGATION SYSTEM
1993-1994 AND 2003-2004
(Pre and Post CRBC)
N
0
400
800
meters
KEY
Rainfed to Canal
Rod Kohi to Canal
Cultivable waste to canal
Rainfed to Rainfed
Rod Kohi to Rod Kohi
Cultivable waste to rainfed

Map VI-13

iv. CHERA

In Chera, during the study period, rainfed, Rod Kohi and canal-irrigated area were found. The Table VI-21 gives cultivated acreage under various water sources. Before the inception of CRBC, rainfall and Rod Kohi were the two dominant sources of water. It means that prior to CRBC cultivated land was entirely dependent on the uncertain climatic condition. Therefore, during pre CRBC, the cultivated acreage varied from very meagre 36 ha in 1999-2000 to maximum 369 ha in 1979-80. However, after the inception of canal irrigation in the form of CRBC, the cultivated acreage under Rod Kohi and rainfall dropped to zero, whereas area under canal irrigation increased from zero in 1999-2000 to 627 ha in 2003-2004 (Map VI-14). The table VI-22 reveals that after CRBC a positive change of 86.48% has recorded in the canal irrigated acreage, whereas in rainfed area a negative change of 33.93% has occurred (Figure VI-15). This indicates that CRBC has brought greater changes in the mode of water supply to the cultivated area.

Table VI-21
Chera, irrigated area, 1967-68 to 2003-04 (area in ha)

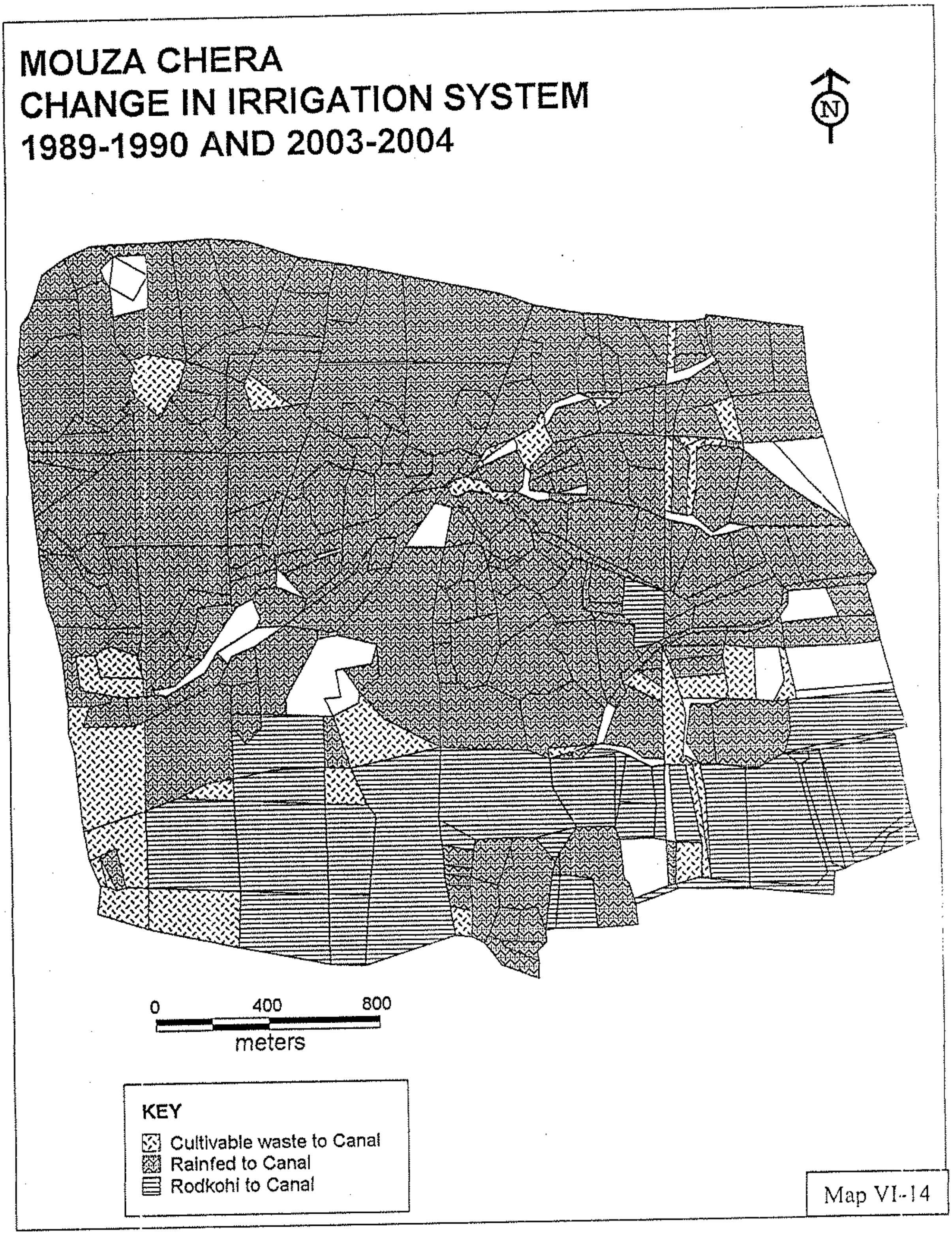
Year	*Total area*	*Cultivated area*		
		Rainfed	*Rod Kohi*	*Canal irrigated*
1967-68	725	311	45	-
1969-70	725	311	45	-
1974-75	725	281	17	-
1979-80	725	317	52	-
1984-85	725	205	41	-
1989-90	725	246	-	-
1994-95	725	29	16	-
1999-00	725	20	16	-
Post CRBC				
2000-01	725	-	-	422
2003-04	725	-	-	627

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Chera)

Table VI-22
Chera, change in irrigated area, 1989-90 and 2003-04 (area in ha)

Type of land	*Pre CRBC*		*Post CRBC*		*Change in % of total area*
	1989-90	*% Share of the total area*	*2003-2004*	*% Share of the total area*	
Total area	725	-	725	-	-
Canal irrigated	0	-	627	86.48	+86.48
Rainfed	246	33.93	0	-	-33.93

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Chera)


MOUZA CHERA
CHANGE IN IRRIGATION SYSTEM
1989-1990 AND 2003-2004
N
0
400
800
meters
KEY
Cultivable waste to Canal
Rainfed to Canal
Rodkohi to Canal
Map VI-14

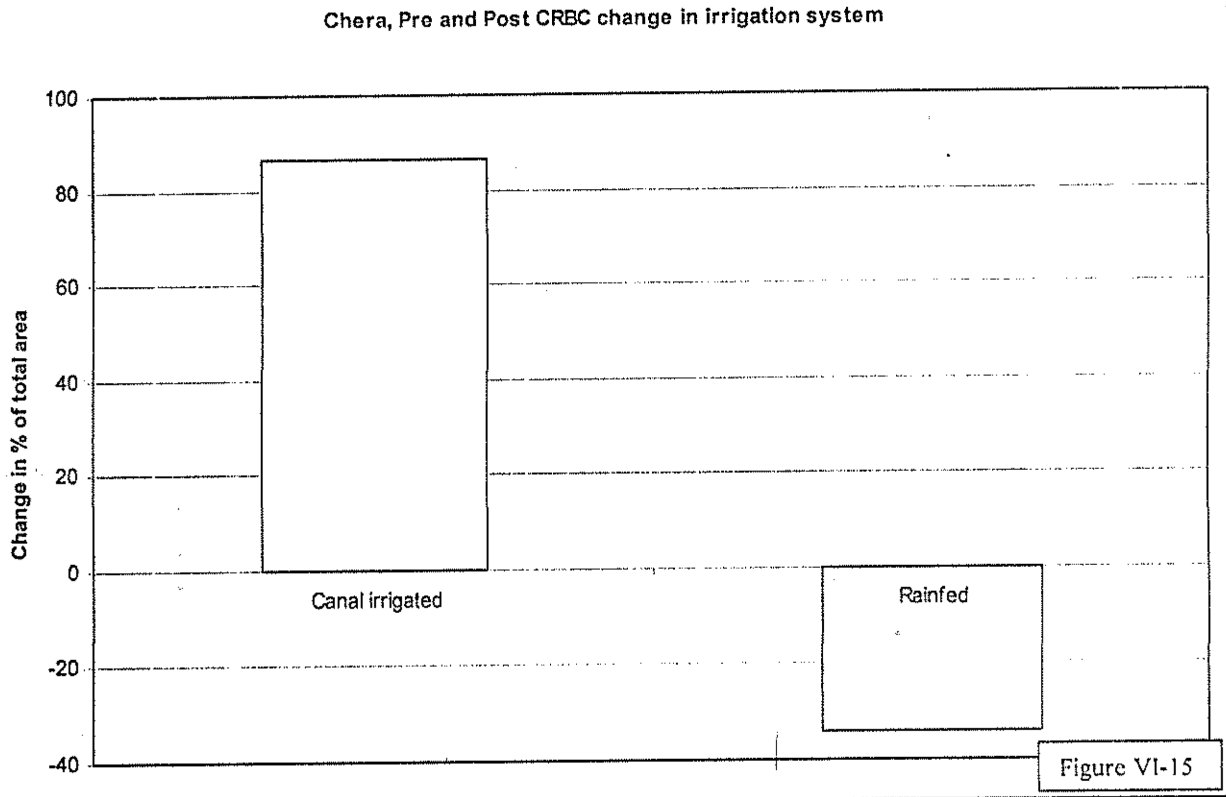


Figure VI-15

v. KHUDAKA

Mouza Khudaka the sampled village lies off the CRBC command area. The table VI-12 shows that Rod Kohi remains the predominant source of irrigation throughout the study period from 1966-67 to 2003-04 (Plate VI-4). The table VI-23 further indicates that in 1989-90, 1999-2000 and 2003-04, even a single plot was not cultivated, because of its dependence on sporadic rainfall and also drought condition that prevailed in the country from 1997-2003 (Sheikh, 2004). The table VI-24 indicates that after comparing pre (1984-85) and post CRBC (2003-2004) condition of Rod Kohi irrigated area, a negative change of 85.93% was registered. The map VI-15 indicates that in Khudaka, because of its location outside the CRBC command area, no impact of CRBC on the irrigation system was detected. The irrigation system was the same as it was prior to CRBC.

Table VI-23

Khudaka, irrigated area, 1967-68 to 2003-2004 (area in ha)

Year	*Total area*	*Cultivated area*	
		Rainfed	*Rod Kohi*
1966-67	320	-	279
1969-70	320	-	234
1974-75	320	-	231
1979-80	320	-	256
1984-85	320	-	275
1989-90	320	-	0
1994-95	320	-	159
1999-00	320	-	0
2003-04	320	-	0

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Khudaka)

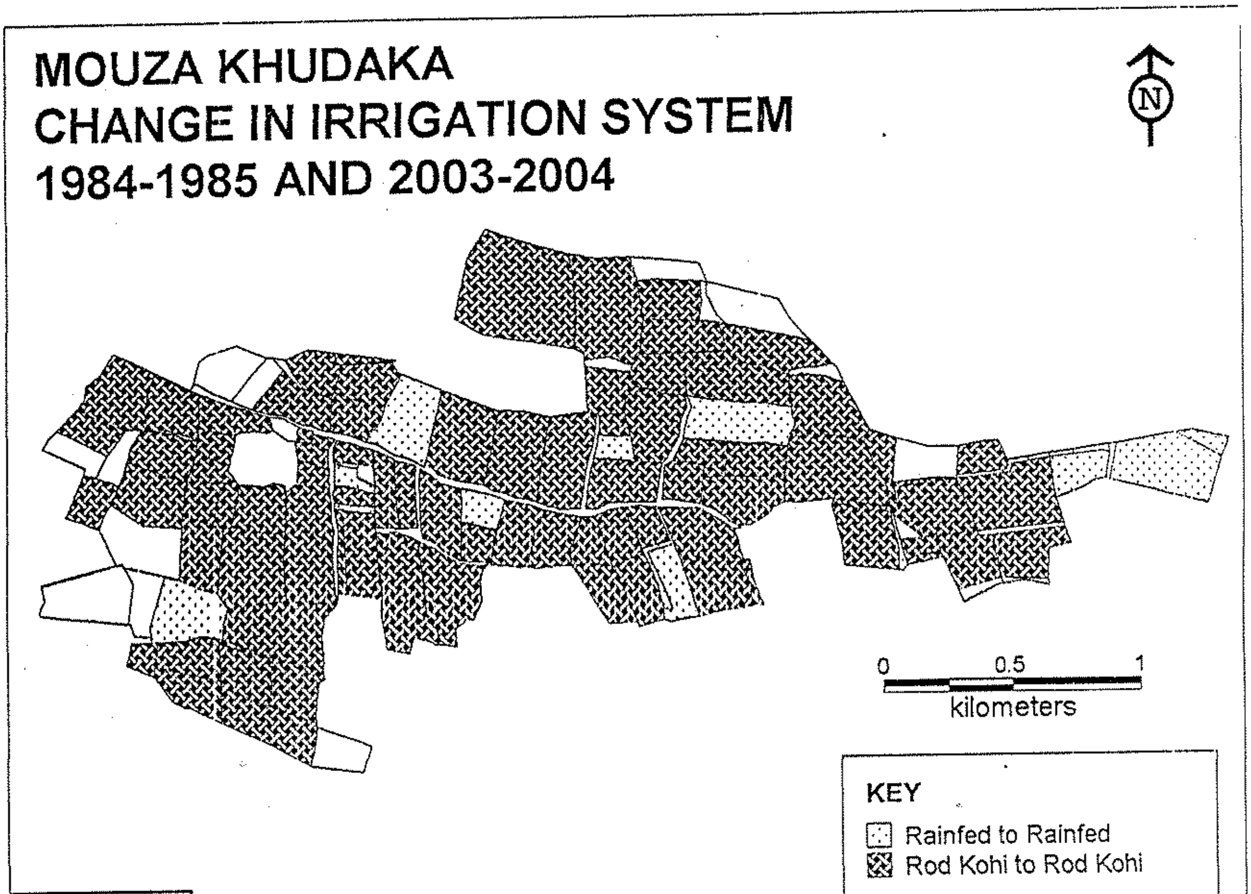
Table VI-24

Khudaka, change in irrigated area, 1984-85 and 2003-2004 (area in ha)

Type of land	*Pre CRBC*		*Post CRBC*		*Change in % of total area*
	1984-85	*% Share of the total area*	*2003-2004*	*% Share of the total area*	
Total area	320	-	320	-	-
Rod Kohi	275	85.93	0	-	-85.93
Rainfed	0	-	0	-	0

Source: Revenue record (Lal Kitab and Khasra Gardawari of Mouza Khudaka)

Plate VI-4. Khudaka, area under Rod Kohi irrigation



Map VI-15

6.3 CONCLUSION

This chapter discussed the environmental impacts of CRBC on the land use and irrigation pattern both at macro and micro level. It was found from the analysis CRBC is the land mark intervention in this arid area, where scare rainfall, mostly saline groundwater (unfit both for drinking and irrigation) were some of limiting physical factors. CRBC had brought large scale changes in the land utilization after CRBC. Such impact changes vary from positive to negative and might vary from local to region level.

The macro level analysis revealed that changes in the land use had been recorded after CRBC. It was found that there had been considerable enhancement in the cultivated area as a result of CRBC. The recorded change in the cultivated area was positive 0.58% of the total reported area. After CRBC net sown has been increased particularly in the CRBC command area and corresponding decrease in the current fallow was recorded. The macro analysis further revealed that the uncultivated area was also consistently increased. It was found from the analysis that uncultivated area had engulfed extensive prime agricultural land due to expansion of new settlements, industries, construction of roads, canals, etc. This is an irreversible negative impact on the local area of this canal-irrigated region. The analysis found that after CRBC area under cultivable waste was gradually decreased. When pre and post CRBC condition of cultivable waste was compared a negative change of 1.13% was recorded. This is the only land use class where negative change has been registered.

The micro level analysis of land use revealed that after CRBC, changes have occurred in all the land use classes. After CRBC, in the sample villages Jarra, Gomal, Buchari and Chera, a positive change was recorded in the uncultivated area. However, in Khudaka no change was detected in the uncultivated area, mainly because of their locations outside the CRBC command area. The micro level analysis further revealed that prior to CRBC in almost all the sample villages cultivable waste was remained the major land unit, but after CRBC its share was largely reduced. In sample villages Jarra, Gomal, Buchari and Chera, a negative change in the cultivable waste occurred during the study period, whereas in Khudaka a positive change was recorded. The micro level analysis of change in the cultivated area revealed that after CRBC a positive change was noted particularly in the CRBC command area. However, the situation was found reverse in the sample village Khudaka, where negative change in the cultivated area was recorded.

The macro level analysis of irrigation pattern revealed that canal irrigated area was gradually increased after commissioning of CRBC. The analysis further revealed that after CRBC in the total irrigated area a net positive change of 10.77% was recorded. The study also found that from 1969-70 to 2002-03 canal irrigated area was increased more than seven fold and a positive change of 10.05% was registered. The analysis further revealed that this large-scale increase in the canal irrigated area is attributed to the inception of CRBC.

It was found from the micro level analysis of irrigation pattern that prior to CRBC, Rod Kohi was the major source of irrigation in almost all the sampled villages. However, in the sampled village Jarra both pre and post CRBC, canals were the dominant source of irrigation. It was found that after the inception of CRBC, a positive change was occurred in the canal irrigated acreage. Similarly, in Gomal, Buchari and Chera, a positive change in the canal irrigated acreage has taken place when pre and post CRBC conditions were compared. However, negative change in the Rod Kohi acreage was registered. Contrary to this, in the sampled village Khudaka no significant impact of CRBC on the irrigation pattern was detected.

ENVIRONMENTAL IMPACTS OF CRBC ON THE CROPPING PATTERN AND CROPPING INTENSITY

Introduction

The previous chapter discussed the environmental impacts of CRBC on the land use and irrigation pattern of D.I.Khan district, while this chapter assesses the environmental impacts of CRBC on the cropping pattern and cropping intensity. This chapter is divided into three sections. Section one deals with the environmental impacts of CRBC on the cropping pattern, whereas section two describes the impacts of CRBC on the cropping intensity. Each section is further classified into two sub-sections and focuses on the macro and micro level analysis. Conclusion is given in the final section.

7.1 ENVIRONMENTAL IMPACTS OF CRBC ON THE CROPPING PATTERN

7.1.1 Environmental impacts of CRBC on the cropping pattern of D.I.Khan district (Macro level analysis)

This section deals with the environmental impacts of CRBC on the cropping pattern of D.I.Khan district. The cropping pattern is a dynamic phenomenon. It is because of the fact that all the impact factors vital for cropping pattern is consistently changing. Availability of water in the form of irrigation is an important factor, which influence the cropping pattern of any region. Therefore, irrigation in the form of CRBC has resulted in enormous changes in the cropping pattern of D.I.Khan district. In D.I.Khan district, wide variety of crops is cultivated ranging from arid to humid. Kharif (summer crops) and Rabi (winter crops) in the D.I.Khan district are discussed in the following sub-sections. The analysis is based on the data that ranges from 1969-70 to 2003-2004. In this section an attempt has been made to compare the situation before and after CRBC.

A. Kharif crops

In D.I.Khan district, variety of Kharif crops are grown, but the most important are rice, sugarcane, cotton, maize, millet, sorghum, pulses, oilseed, Kharif vegetables and fruits. Prior to the inception of CRBC sorghum and millet were the major crops grown in the district. These are the crops which respond better even if little water is applied. However, after CRBC sugarcane, rice and orchards took the lead and were largely introduced in the Kharif season. It is evident from figure VII-3 that a negative change has been registered in sorghum, millet, maize, and oilseed, whereas positive changes have been recorded in sugarcane, rice, orchard and vegetables after CRBC. The analysis further reveals that after CRBC sugarcane, rice, orchard, vegetable are newly introduced crops in the Kharif cropping system. These crops require plenty of water and give good results after application of water, which was made available after CRBC.

Table VII-1

D.I.Khan District, Change in pre and Post CRBC cropping pattern

Cropping Season	Crops	Pre CRBC		Post CRBC		Change in %age
		Area (ha)	*% of total area*	*Area (ha)*	*% of total area*	
Kharif	Rice	1,872	0.256	7,981	1.092	0.836
	Sugarcane	3,197	0.438	11,565	1.583	1.145
	Cotton	2,152	0.295	2,041	0.279	-0.015
	Maize	1,619	0.222	1,189	0.163	-0.059
	Millet	8,299	1.136	1,454	0.199	-0.937
	Sorghum	13,927	1.906	2,917	0.399	-1.507
	Pulses	118	0.016	4,229	0.579	0.563
	Oilseed	243	0.033	1.2	0.000	-0.033
	Vegetable	1	0.000	495	0.068	0.068
	Fruit	316	0.043	9,433	1.291	1.248
Rabi	Wheat	53,360	7.304	58,028	7.94	0.638
	Barley	1,863	0.255	805	0.110	-0.145
	Pulses	8,866	1.214	20,035	2.742	1.529
	Oilseed	8,380	1.147	1,625	0.222	-0.925
	Fruit	21	0.003	370	0.051	0.048

Source: GoNWFP, 1975; 1980; 1991; 2000c; 2004 and 2005

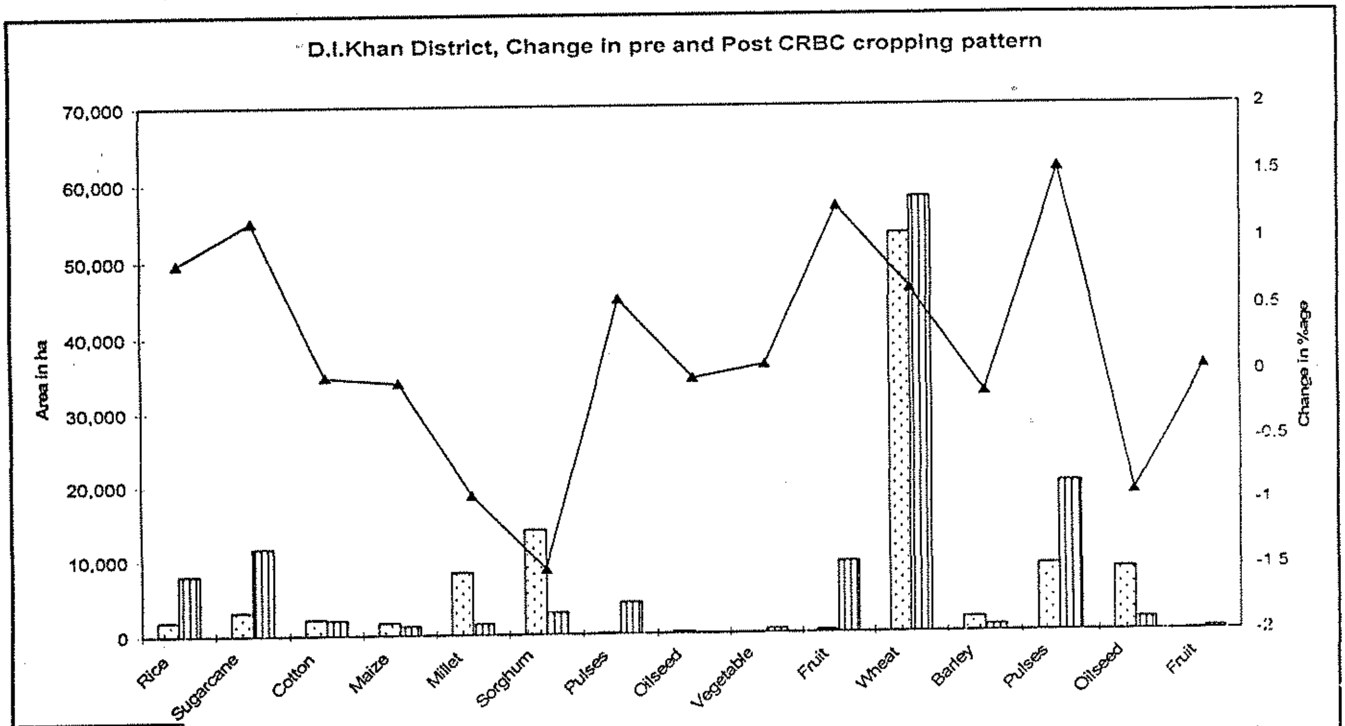


Figure VII-1

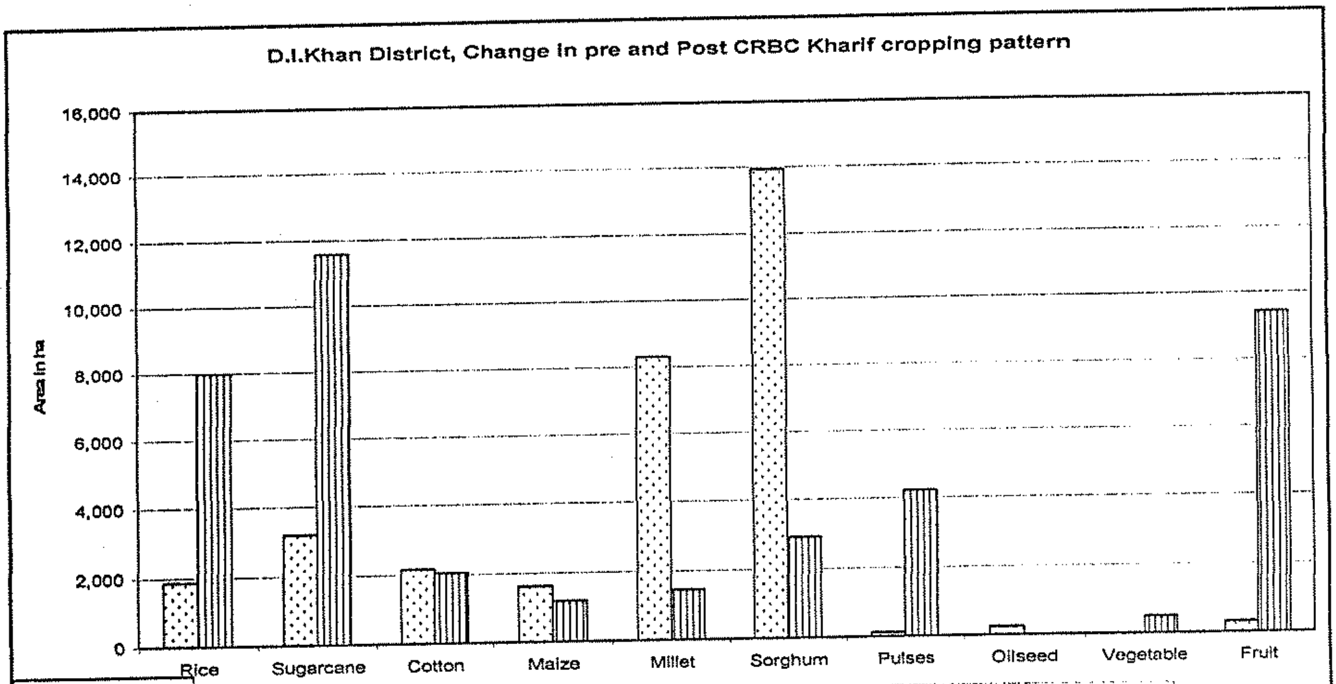


Figure VII-2

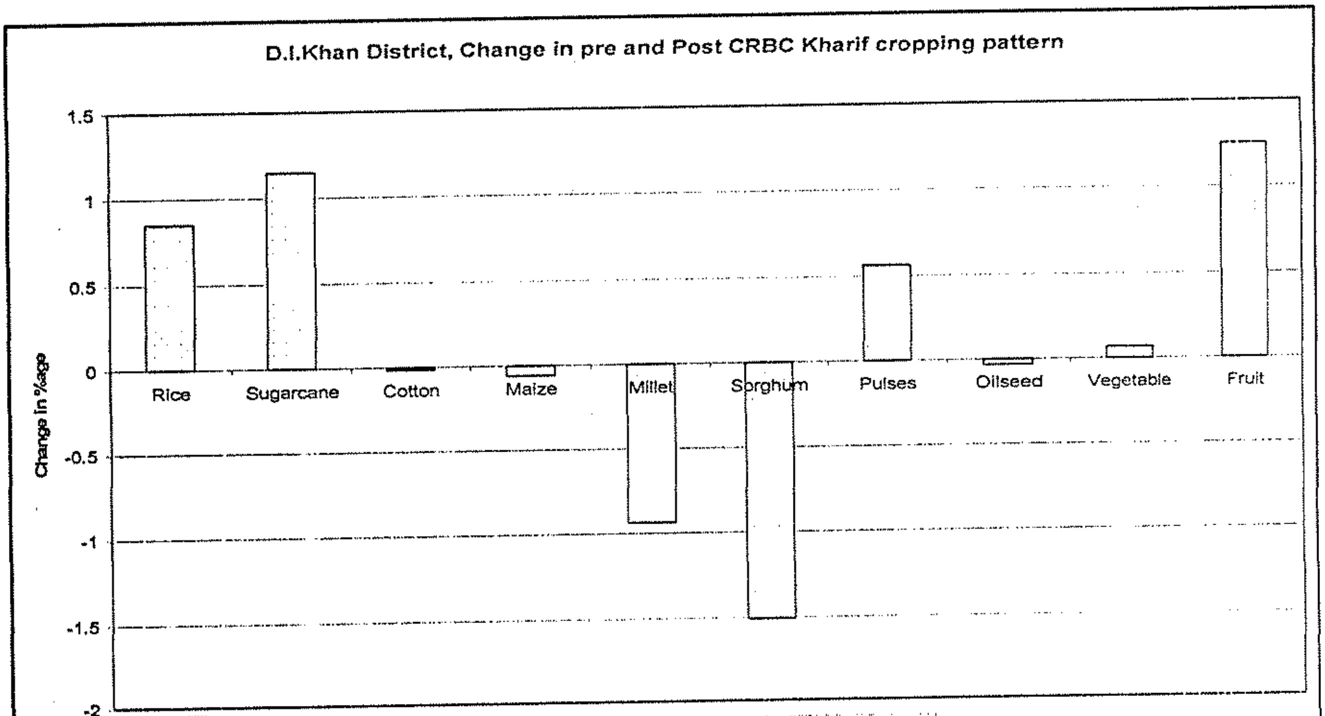


Figure VII-3

In NWFP, rice was cultivated on 68,411 ha during 2000, out of which 13.6% was reported from D.I.Khan district alone (GoNWFP, 2000c). It was found that during 1970 (pre CRBC), rice was cultivated on 1,872 ha as against 3,915 ha in 1990 (after CRBC). Rice is one of the water loving crops and can only be cultivated in irrigated areas. After canal irrigation in the form of CRBC, area under rice crop further improved and reached to 7,981 ha after CRBC (TableVII-1). After comparing pre and post CRBC condition of rice crop, a positive change of 0.836% (of the total geographical area of D.I.Khan district) was recorded (Figure VII-3). It reflects that in last 30 years, area under rice crop increased almost four fold, representing 483% increase, which indicate farmer's trend towards the water loving crops after commissioning of CRBC.

In D.I.Khan district, sugarcane locally called as *Kamad* is an important cash crop (Said, 1971). The analysis reveals that before CRBC in D.I.Khan district 3,197 ha were under sugarcane, which after CRBC has increased to 11,565 ha (Table VII-1; Figure VII-2). The consistent increase in the area under sugarcane indicates that because of availability of more irrigation water in the form of CRBC the farmer look for the water loving crop. The analysis elaborates that after comparing pre and post CRBC condition, a positive change of 1.145% (of the total geographical area of D.I.Khan district) was registered (Figure VII-3). The analysis further indicates that sugarcane acreage has been increased almost three fold in last thirty years. This rapid increase in the sugarcane acreage is mainly due to the inception of canal irrigation.

In NWFP, cotton was grown on 401 ha in the year 2000, out of which 300 ha (75%) was reported from D.I.Khan district alone (GoNWFP, 2000c). In D.I.Khan district, cotton acreage has been reported both in pre as well as post construction of CRBC. The table VII-1 indicates that before CRBC, cotton was grown on 2,152 ha. However, after CRBC it has decreased to 2,041 ha (Figure VII-2). The data reveals that after comparing pre and post CRBC conditions, a negative change of 0.015% (of total geographical area of D.I.Khan district) was occurred (Figure VII-3).

In D.I.Khan district, maize is a Kharif crop. The Table VII-1 elaborates that before CRBC area under maize crop in 1970 was 1,619 ha, which after CRBC decreased to 1,189 ha. The Figure VII-2 shows that there has been constant decrease in the area under maize crop. The analysis reveals that after comparing pre and post CRBC condition of maize acreage, a negative change of 0.059 % (of the total geographical area of D.I.Khan district) has been recorded. This is mainly due to the introduction of canal irrigation system and its competition with high return crops.

Millet is extensively cultivated in D.I.Khan for a long time. Before CRBC, millet was a predominant crop of un-irrigated area, but it was also grown over the irrigated land. The table VII-1 indicates that before CRBC millet was sown on 8,299 ha, which gradually reduced to 1,454 ha after inception of CRBC. The analysis reveals that before CRBC in 1970, 81% millet (6,720 ha) was grown over un-irrigated area, whereas after CRBC this share has been reduced to 67% (1,169 ha) in 2005. The figure VII-3 reveals that a negative change of 0.937% (of the total geographical area of D.I.Khan district) has been registered after CRBC. It indicates that currently millet lost its importance due to the introduction of canal irrigation specifically in the CRBC command area. More water is now available. Therefore, the farmer switched over to water loving crops like sugarcane and rice.

Sorghum is a Kharif crop and locally known as *jowar*. Primarily, it was used as cereals but presently it is cultivated as a fodder crop. The table VII-1 indicates that before CRBC area under sorghum was 13,927 ha, which sharply decreased to 2,917 ha after CRBC. The data reveals that since long it is predominantly grown on un-irrigated areas. The analysis reveals that after comparing pre and post CRBC condition, a negative change of 1.507 % has taken place (Figure VII-3). This is the highest recorded negative change amongst the entire Kharif crops.

In D.I.Khan district, Kharif pulses are grown on extensive area. The table VII-1 shows that there has been constant increase in the area under Kharif pulses. In D.I.Khan district, before CRBC area under Kharif pulses were 118 ha as against 4,229 ha after CRBC. The analysis also reveals that a positive change of 0.563% (of the total geographical area of D.I.Khan district) has been recorded when pre and post CRBC Kharif pulses were compared (Figure VII-3). This indicates that after the inception of CRBC, area under Kharif pulses greatly increased. Since the inception of CRBC, Kharif pulses are widely grown on irrigated land as compared to un-irrigated.

In D.I.Khan district, Kharif oilseed is grown on limited area. The data reveals that Kharif oilseed is largely reported from un-irrigated land as compared to irrigated land. In D.I.Khan district, before CRBC acreage under Kharif oilseed was 243 ha, which gradually reduced to 1.2 ha after CRBC (Table VII-1). The Figure VII-3 reveals that after comparing pre and post CRBC condition, a negative change of 0.033% (of the total geographical area of D.I.Khan district) has been recorded. The analysis further reveals that the acreage is gradually decreasing because of trend towards other crops.

In Kharif cropping season, vegetables are grown in small plots and restricted to irrigated areas. In D.I.Khan district, important Kharif vegetables include pea, onion, turnip, carrot, spinach, tomato, cauliflower, cabbage, radish etc. The analysis reveals that before CRBC, area under Kharif vegetables was 1 ha, which increased to 495 ha after CRBC. The analysis further reveals that with the availability of assured water supply in the form of CRBC, there has been gradual increase in the area under vegetables as it requires water at frequent interval. The figure VII-3 indicates that in Kharif vegetables, a positive change of 0.068% (of the total geographical area of D.I.Khan district) has taken place, when pre and post CRBC changes were compared.

In D.I.Khan district, important Kharif fruits are watermelon, muskmelon, dates, apple and mango. Among the fruit crops, muskmelon is extensively cultivated in D.I.Khan district. The table VII-1 indicates that before CRBC, area under Kharif fruits were 316 ha, which after inception of CRBC increased to 9,433 ha. With the introduction of canal irrigation system the organized orchard farming has been greatly increased. The comparative analysis of pre and post CRBC reveals that area under all Kharif fruits largely increased and a positive change of 1.248% (of the total geographical area of D.I.Khan district) has been taken place (Figure VII-3). This is the highest recorded change amongst all the Kharif crops. Hence, it can be concluded that new water loving crops have been introduced after launching of CRBC.

B. Rabi crops

This section deals with the Rabi or winter crops. In D.I.Khan district, important Rabi crops are wheat, barley, Rabi pulse, oilseed, and fruits. The analysis reveals that there has been constant increase in Rabi acreage particularly after the inception of CRBC (Table VII-1; figure VII-4)). After comparing pre and post CRBC changes in Rabi cropping pattern it was found that a negative change has been recorded in oilseed and barley, whereas positive changes have occurred in wheat, pulses and fruits (Figure VII-5). The following discussion gives the analytical review of CRBC impacts on individual Rabi crops.

In D.I.Khan district, wheat is the most important Rabi crop both in terms of value and acreage. The share of wheat crop to the total cropped area is about 40% and that of Rabi is more than 70%. It is grown in the entire district except the rugged and bare terrain, whose soil discourages its cultivation. Its distribution and acreage reflects a close association with the canal irrigation. Wheat grows well in the irrigated lands, but it is also cultivated under rainfed areas. Irrigated areas rank first in order of yield and acreage. Before CRBC in 1969-70, total area under wheat on irrigated land was 31,903 ha as against 40,636 ha after CRBC in 2002-2003 (GoNWFP, 1975 and 2004). Although, prior to CRBC it was cultivated (on un-irrigated area) on 21,457 ha in 1969-70, which dropped to 7,395 ha after CRBC in 2002-2003. It was found that increase in acreage over irrigated area is mainly due to the introduction of canal irrigation in the form of

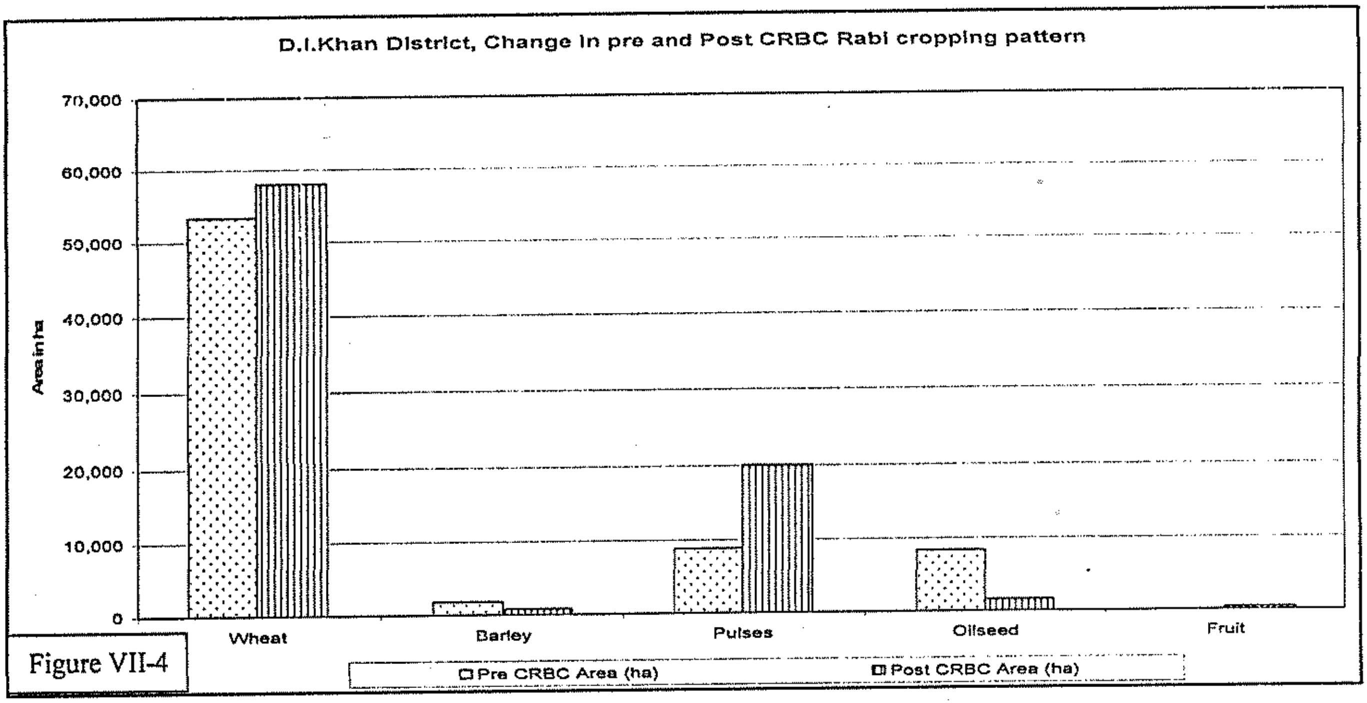


Figure VII-4

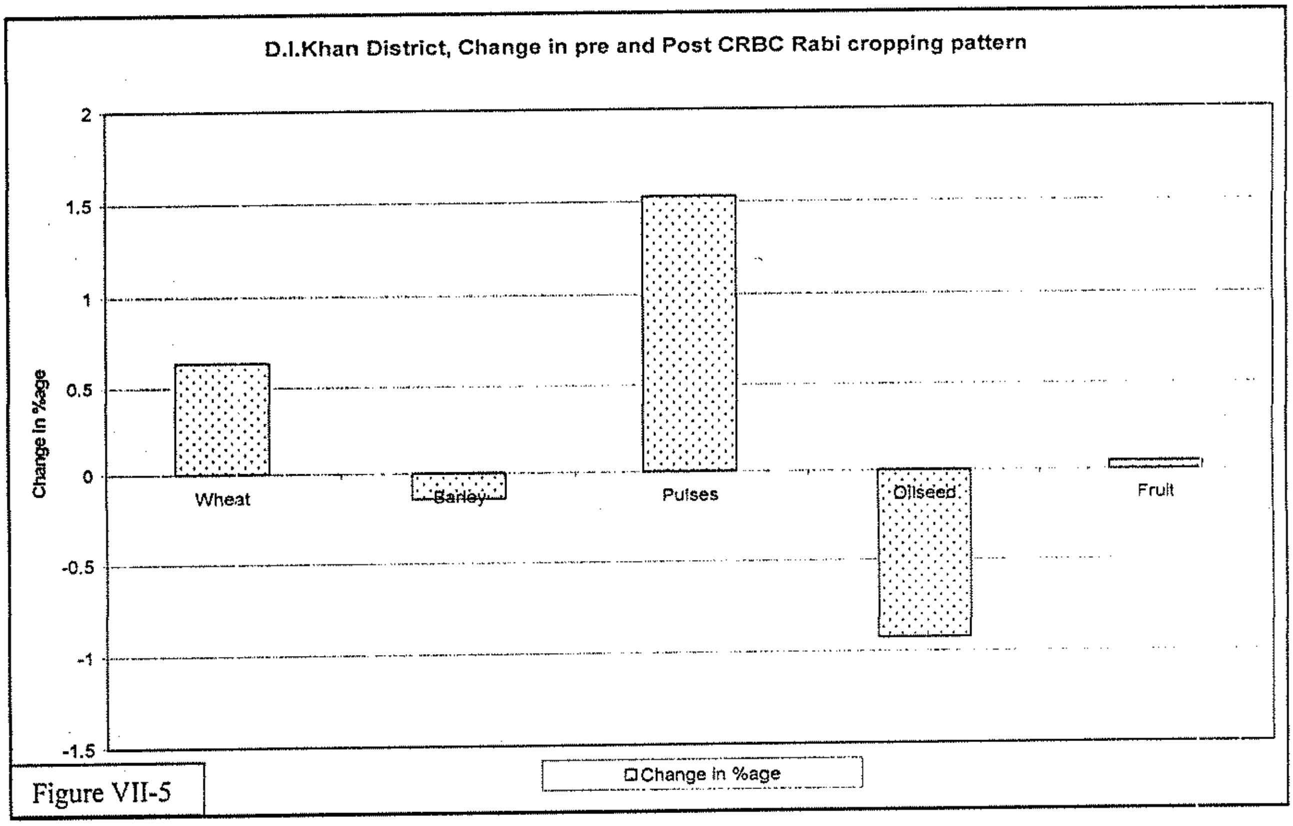


Figure VII-5

CRBC. The comparative analysis indicates that there is very little fluctuation in the area under wheat crop but sharp decline in the acreage over un-irrigated area. The analysis reveals that presently one fifth of the acreage is reported from un-irrigated areas, whereas the rest is from irrigated areas. The analysis further reveals that wheat acreage has increased from pre CRBC 53,360 ha to post CRBC 58,028 ha (Table VII-1; Figure VII-4). The figure VII-5 further elaborates that after comparing pre and post CRBC condition a positive change of 0.638% (of the total geographical area of D.I.Khan district) was recorded.

Barley is a Rabi crop. In D.I.Khan district, before CRBC barley was grown on 1,863 ha, which has shown a gradual decrease and marked a figure of 805 ha after CRBC (Table VII-1)? It was also found that prior to CRBC barley was predominantly grown over un-irrigated areas, however after CRBC major proportion of barley has been reported from irrigated area. After comparing pre and post CRBC condition of barley a negative change of 0.145% has been noted (Figure VII-5). After CRBC, the declining trend in the acreage of barley was mainly due to the farmer's preferences to more economic return crops.

In D.I.Khan district, gram locally called as *nakhud* and lentil locally known as *masoor* are the important Rabi pulses (Plate VII-1 and 2). The table VII-1 reveals that area under Rabi pulses has been rapidly increased since the introduction of canal irrigation. The data reveals that pre CRBC, Rabi pulses was grown on 8,866 ha as against 20,035 ha after CRBC (Table VII-1). The statistical data further reveals that the acreage of pulses increased more than two fold in last 30 years. It is clear from figure VII-5 that a positive change of 1.529% (of the total geographical area of D.I.Khan district) has been registered after CRBC. It is mainly due to the fact that compared to other Rabi crops, Rabi pulses is more profitable and the physical factors contributing much to its significance. It is therefore widely grown over the irrigated and un-irrigated area, but in both the cases acreage is gradually enhancing.

In Rabi, various varieties of oilseed are grown in D.I.Khan district. The most important are rapeseed, mustard and sunflower. They are sown primarily to produce edible oil. The table VII-1 reveals that there has been gradual reduction in the acreage of Rabi oilseed. Before the introduction of canal irrigation system, Rabi oilseed was extensively cultivated. The analysis reveals that before CRBC oilseed was grown on 8,380 ha as against 1,625 ha after CRBC (Table VII-1). The analysis further indicates that before CRBC out of total acreage of Rabi oilseed, 1,133 ha was on irrigated land and 7,247 ha on un-irrigated, but after CRBC, the acreage sharply declined to 759 ha on irrigated and 866 ha on un-irrigated land. The figure VII-5 reveals that a

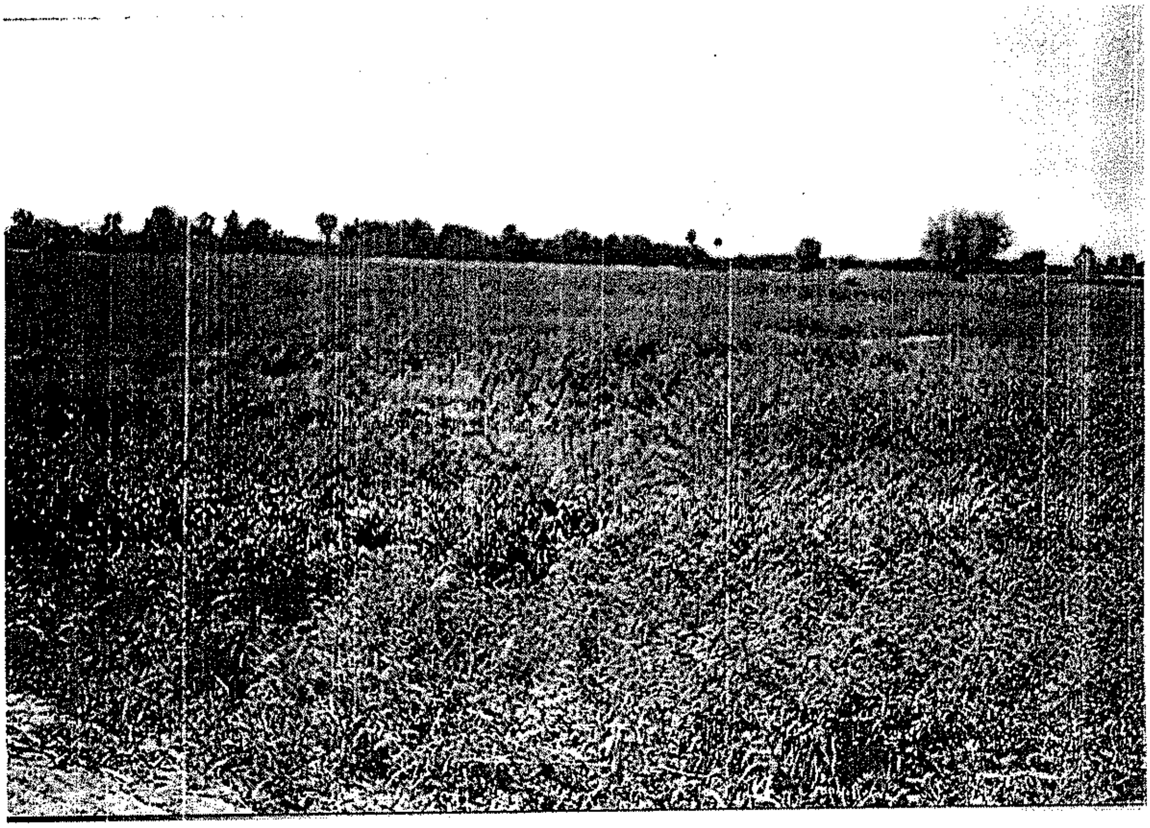


Plate VII-1.   Gram crop in CRBC command area

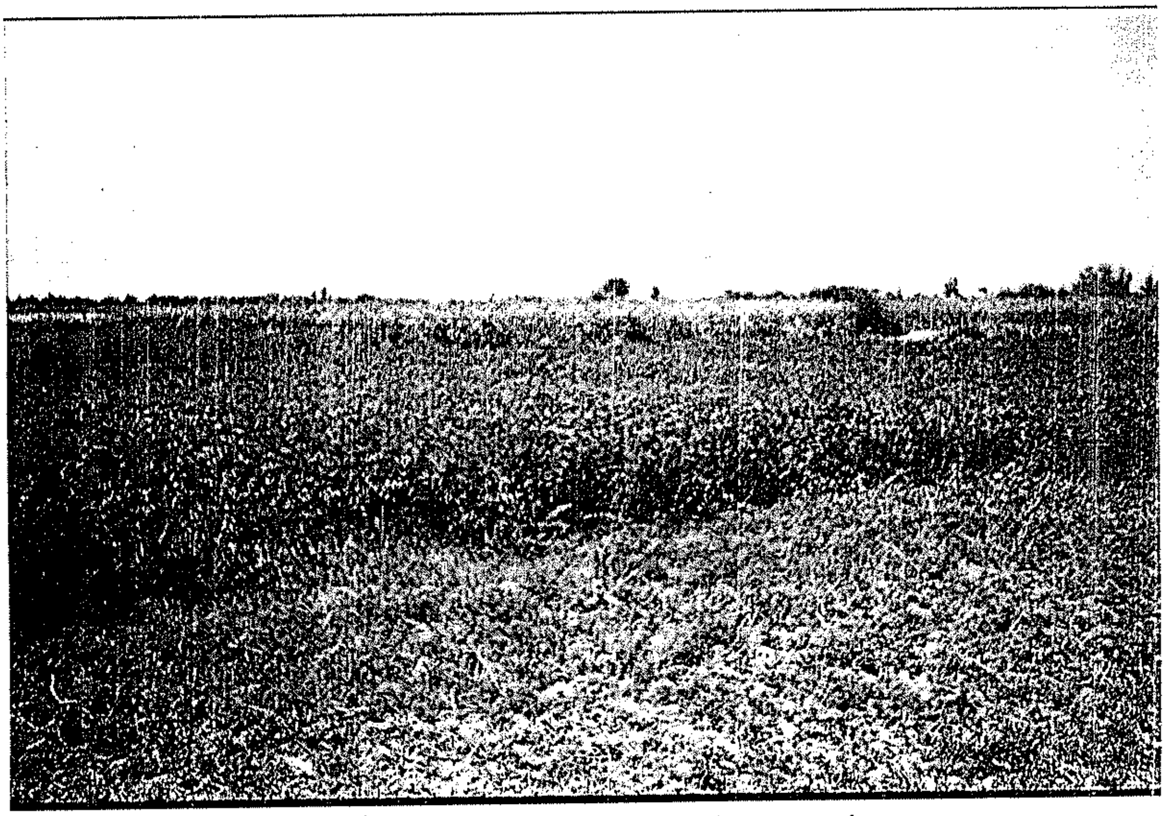


Plate VII-2.   Lentil in the CRBC command area negative change of 0.925% (of the total geographical area of D.I.Khan district) has been recorded, when pre and post CRBC condition of oilseed acreage was compared.

In D.I.Khan district, important Rabi fruits are citrus, guava and banana. Acreage-wise citrus fruit lead all other types. The analysis reveals that before CRBC area under citrus fruits was 19 ha, which after inception of canal irrigation increased to 211 ha. Another important Rabi fruit is guava, before CRBC it was grown on 2 ha, which several fold increased and marked the figure of 140 ha after canal irrigation. Likewise, before CRBC, banana was not cultivated, however after inception of canal irrigation, it was found over 19 hectare. Growing banana is a new trend, introduced after inception canal irrigation as it requires plenty of water. It was found that prior to CRBC only 21 ha was under Rabi fruit, which several fold multiplied and reached to 370 ha after inception of canal irrigation (Table VII-1). The analysis further reveals that during the stated period a positive change of 0.048% (of the total geographical area of D.I.Khan district) has been recorded (figure VII-5). It is mainly due to the fact that fruits require water at a proper time, which was made possible through CRBC. It also indicates farmer trend towards horticulture, which has comparatively high economic return.

7.1.2 Environmental impacts of CRBC on the cropping pattern of sample villages (Micro-level analysis)

This section presents the environmental impacts of CRBC on the cropping pattern at micro-level. In the sample villages, both Kharif and Rabi cropping pattern were found. The dominant crops and respective positive and negative changes have been discussed in detailed. However, for intensive analysis each cropping season was analysed at micro-level.

A. Kharif cropping pattern

The following discussion assesses the impacts of CRBC on the Kharif cropping pattern of sample villages with special reference to pre and post CRBC condition.

i. JARRA

Jarra a sampled village is irrigated through canals in addition to rainfed cultivation. Before CRBC, Jarra was under the command of old Paharpur canal. In Jarra, during Kharif sugarcane, rice, maize, sorghum, fodder, pulses, vegetables and fruits are grown (Table VII-2). However, during the study period the dominant Kharif crops were sugarcane and rice, which hold maximum land cover (Figure VII-6). Maize, sorghum and fodder were also grown, but due to competition with more productive crops it was found on limited area. The figure VII-7 reveals that after comparing pre and post CRBC condition, it was found that positive changes were recorded in sugarcane and fruits, whereas negative changes reported in rice and fodder. However, the situation was found the same for maize and sorghum (Table VII-3). Out of total cultivated area of about 400 ha, almost half remained under Kharif crops throughout the period from 1987 (before CRBC) to 2004 (after CRBC). Map VII-1 and 2 shows that both before and after the construction of CRBC, the current fallow dominated the Kharif scene. The table VII-2 indicates that before and after CRBC water loving crops such as rice and sugarcane remained the major contributors of Kharif acreage, which has led to the problem of waterlogging (Plate VII-3).

Field survey and secondary information reveals that after CRBC, cultivated land was severely affected by waterlogging and salinity. Therefore, in 1990 area under Kharif crops was declined. The figure VII-6 shows that before CRBC the two water loving crops (rice and sugarcane) dominated the scene, which after inception of canal irrigation encouraged the twin problem but after reclamation once again the farmer switched over to water loving crops. According to responses and perception survey, trend towards mix farming (growing crops within the orchard) were also found, which is economically more productive (Plate VII-4).

Table VII-2
Jarra, temporal change in Kharif cropping pattern, 1987-2004 (Area in ha)

Period	*Year*	*Sugarcane*	*Rice*	*Maize*	*Sorghum*	*Fodder*	*Pulses*	*Fruit*	*Total*
Pre CRBC	1987	23	100	1	1	19	0	3	147
Post CRBC	1990	34	33	2	0	2	2	0	73
	1995	43	81	3	5	2	7	0	141
	2000	10	12	2	1	2	0	1	28
	2004	107	9	1	1	4	0	13	135

Source: Revenue record (Lal Kitab of Mouza Jarra), 1987-2004

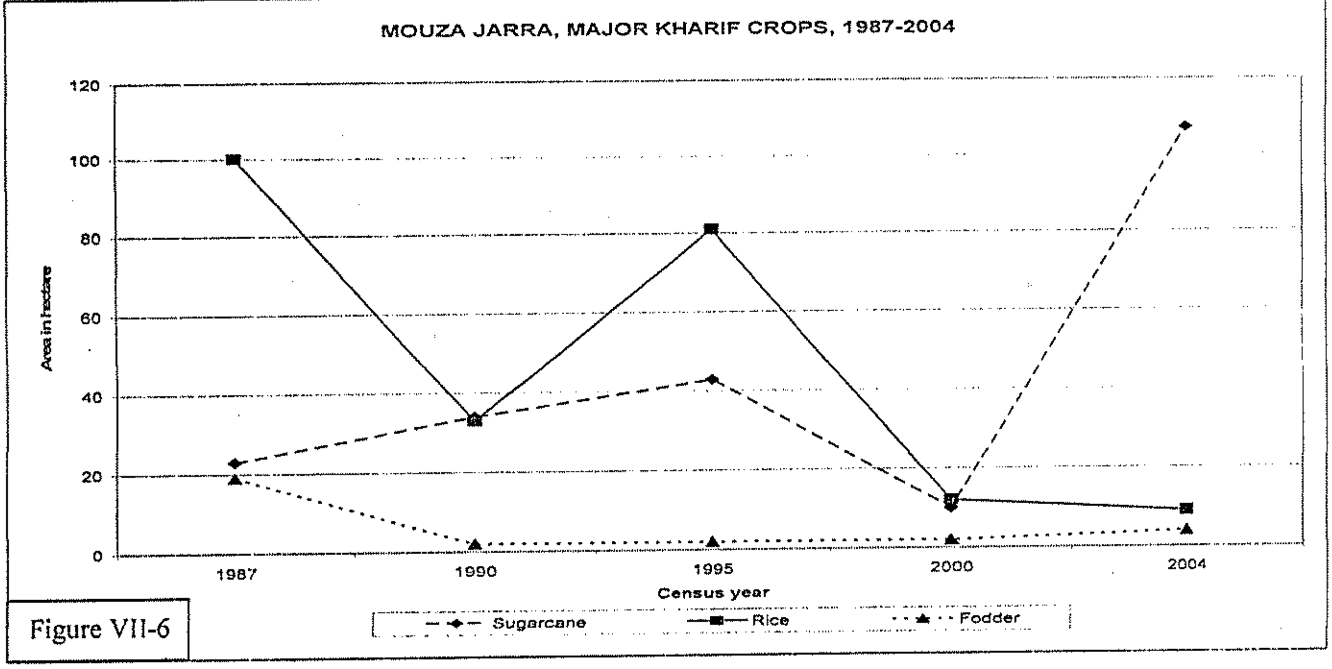


Figure VII-6

Table VII-3

Temporal Change in Kharif Cropping pattern of sample villages (Area in ha)

Mouza	*Period*	*Sugarcane*	*Rice*	*Maize*	*Sorghum*	*Millet*	*Oilseed*	*Fodder*	*Pulses*	*Fruit*
Jarra	Pre CRBC area	23	100	1	1	0	0	19	0	3
	% of total area	4.440	19.305	0.193	0.193	0.000	0.000	3.668	0.000	0.579
	Post CRBC area	107	9	1	1	0	0	4	0	13
	% of total area	20.656	1.737	0.193	0.193	0.000	0.000	0.772	0.000	2.510
	Change in %age	16.216	-17.568	0.000	0.000	0.000	0.000	-2.896	0.000	1.931
Gomal	Pre CRBC area	4	144	12	40	0	0	50	0	0
	% of total area	0.109	3.933	0.328	1.093	0.000	0.000	1.366	0.000	0.000
	Post CRBC area	596	160	46	9	0	0	51	5	0
	% of total area	16.280	4.370	1.256	0.246	0.000	0.000	1.393	0.137	0.000
	Change in %age	16.170	0.437	0.929	-0.847	0.000	0.000	0.027	0.137	0.000
Buchari	Pre CRBC area	0	0	0	6	0	0	0	0	0
	% of total area	0.000	0.000	0.000	1.091	0.000	0.000	0.000	0.000	0.000
	Post CRBC area	118	79	29	13	0	0		17	0
	% of total area	21.455	14.364	5.273	2.364	0.000	0.000	0.000	3.091	0.000
	Change in %age	21.455	14.364	5.273	1.273	0.000	0.000	0.000	3.091	0.000
Chera	Pre CRBC area	0	0	0	91	32	6	26	0	5
	% of total area	0.000	0.000	0.000	12.552	4.414	0.828	3.586	0.000	0.690
	Post CRBC area	59	0	0	21	0	0	0	254	0
	% of total area	8.138	0.000	0.000	2.897	0.000	0.000	0.000	35.034	0.000
	Change in %age	8.138	0.000	0.000	-9.655	-4.414	-0.828	-3.586	35.034	-0.690
Khudaka	Pre CRBC area	0	0	0	0	0	0	0	0	0
	% of total area	0	0	0	0	0	0	0	0	0
	Post CRBC area	0	0	0	0	0	0	0	0	0
	% of total area	0	0	0	0	0	0	0	0	0
	Change in %age	0	0	0	0	0	0	0	0	0

Source: Revenue record of the sample villages

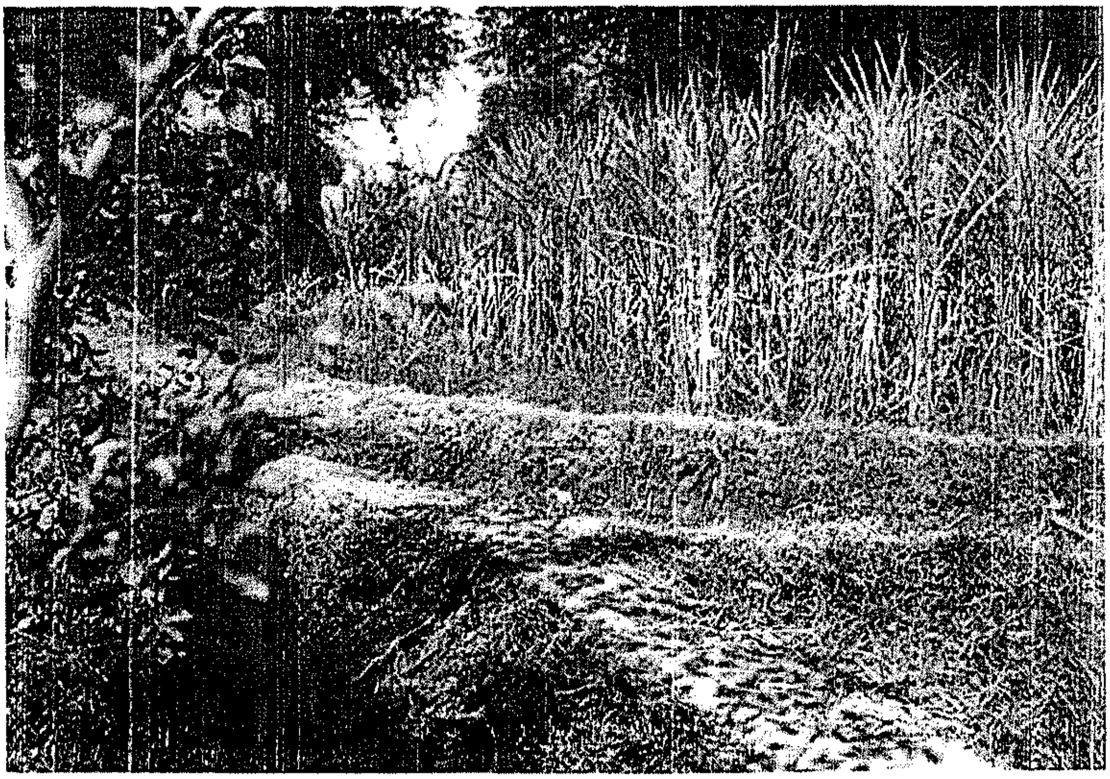
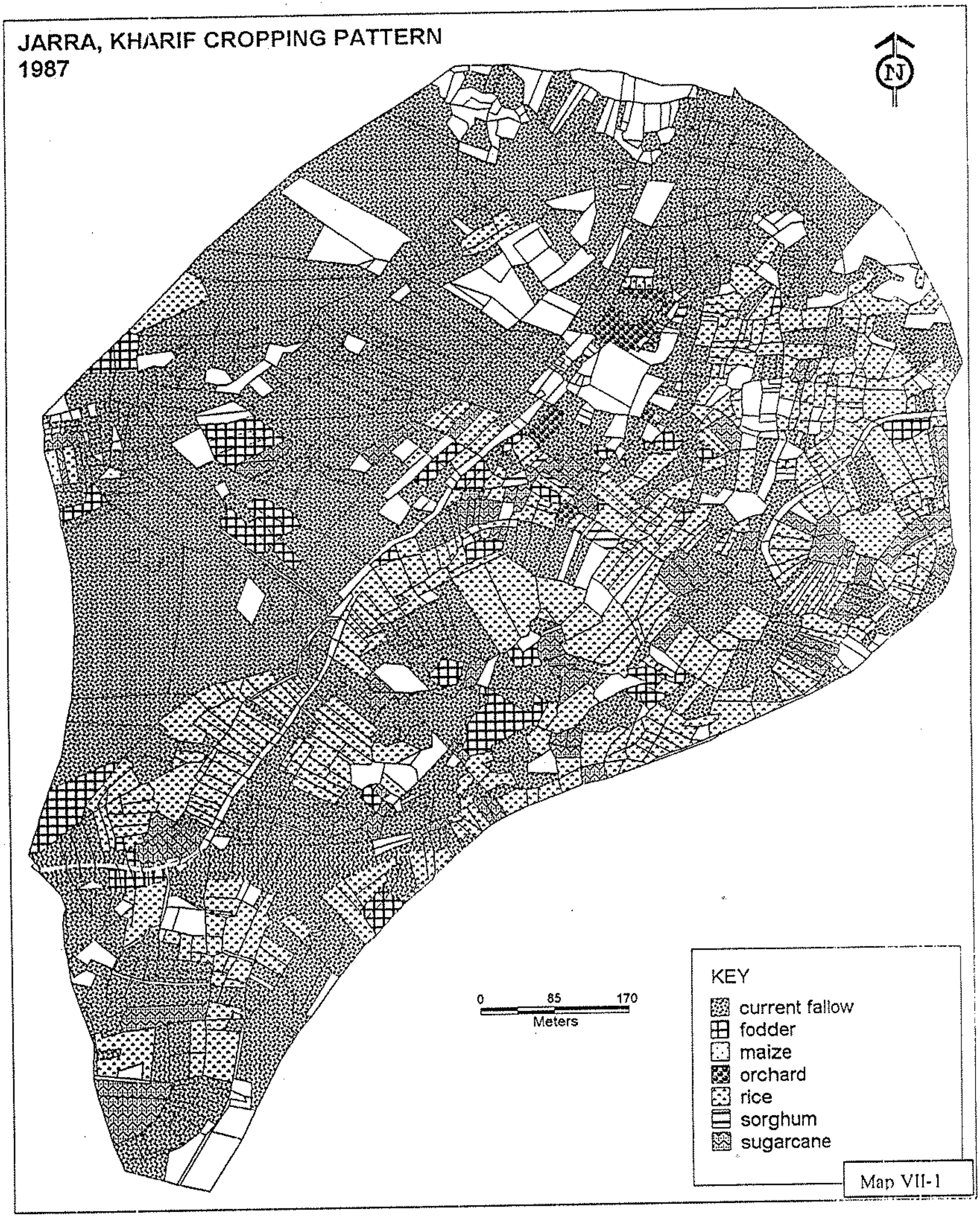
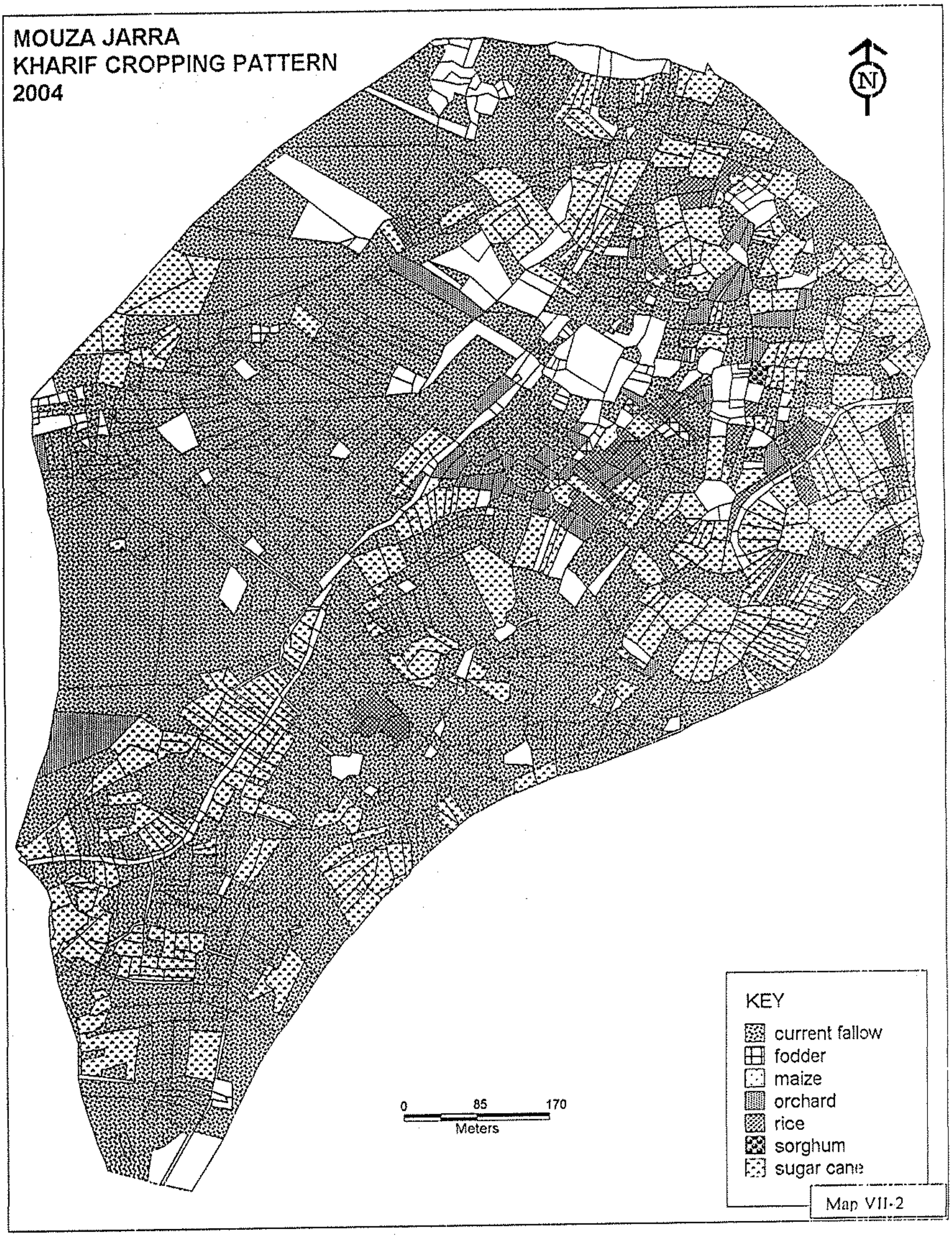


Plate VII-3. Area under sugarcane crop

Plate VII-4. Dates orchards and Lined watercourse in Paharpur area (CRBC Stage I)


JARRA, KHARIF CROPPING PATTERN
1987
N
0
85
170
Meters
KEY
current fallow
fodder
maize
orchard
rice
sorghum
sugarcane
Map VII-1


MOUZA JARRA
KHARIF CROPPING PATTERN
2004
N
0
85
170
Meters
KEY
current fallow
fodder
maize
orchard
rice
sorghum
sugar cane
Map VII-2

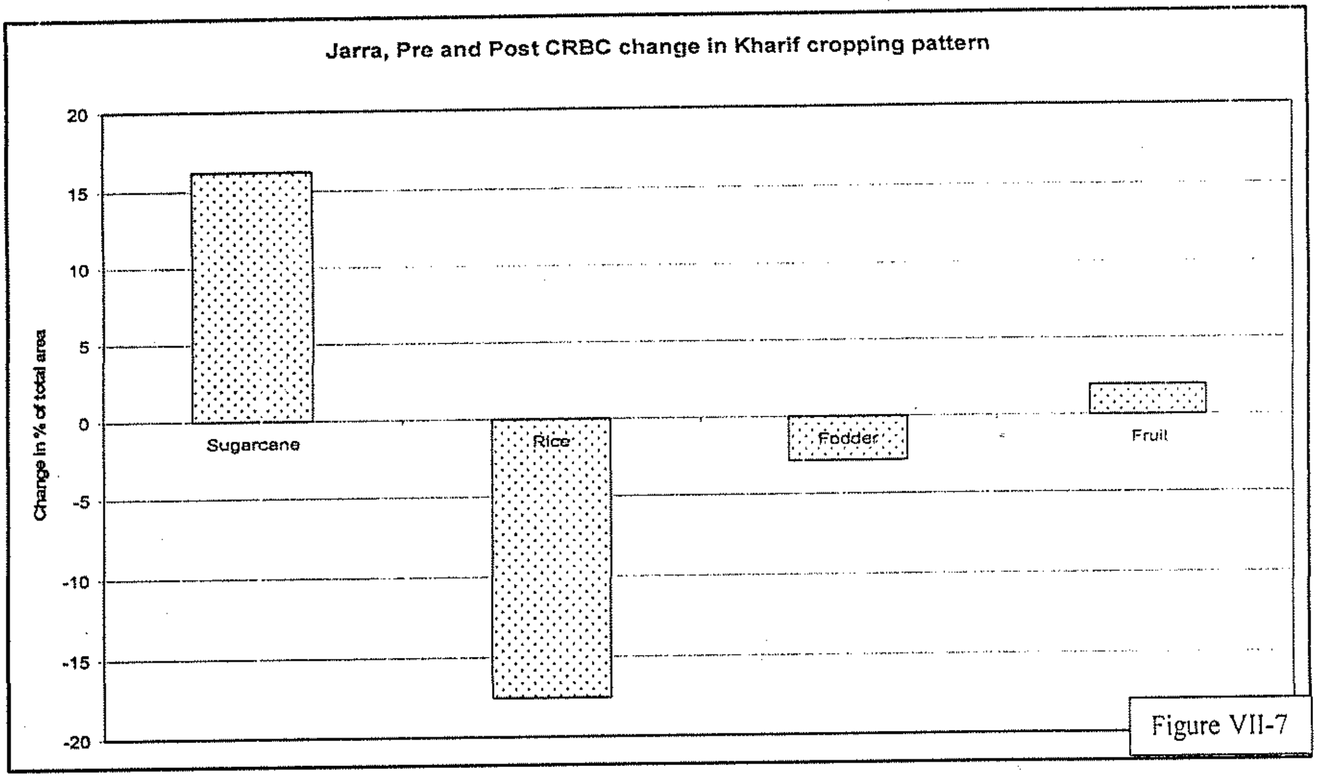
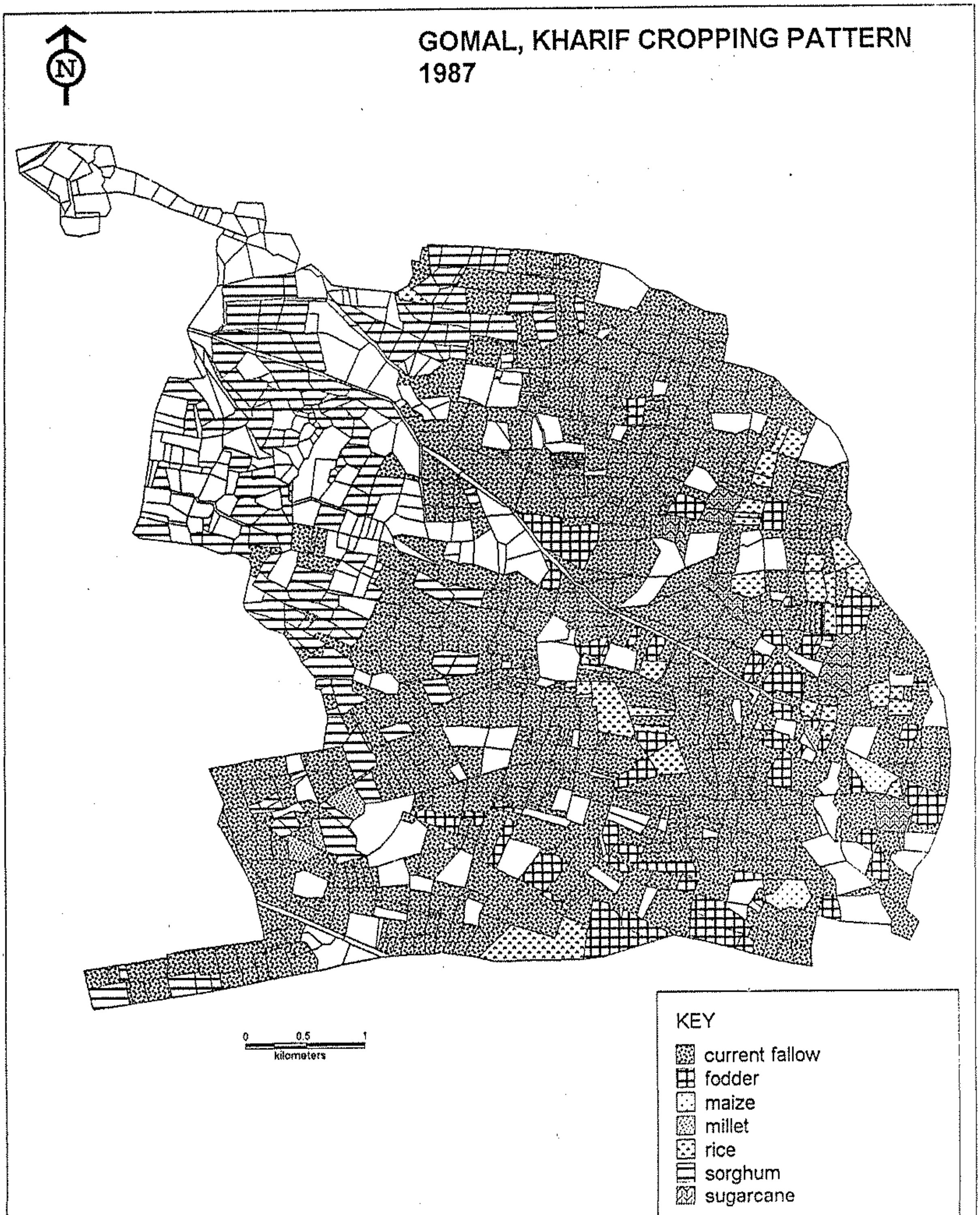


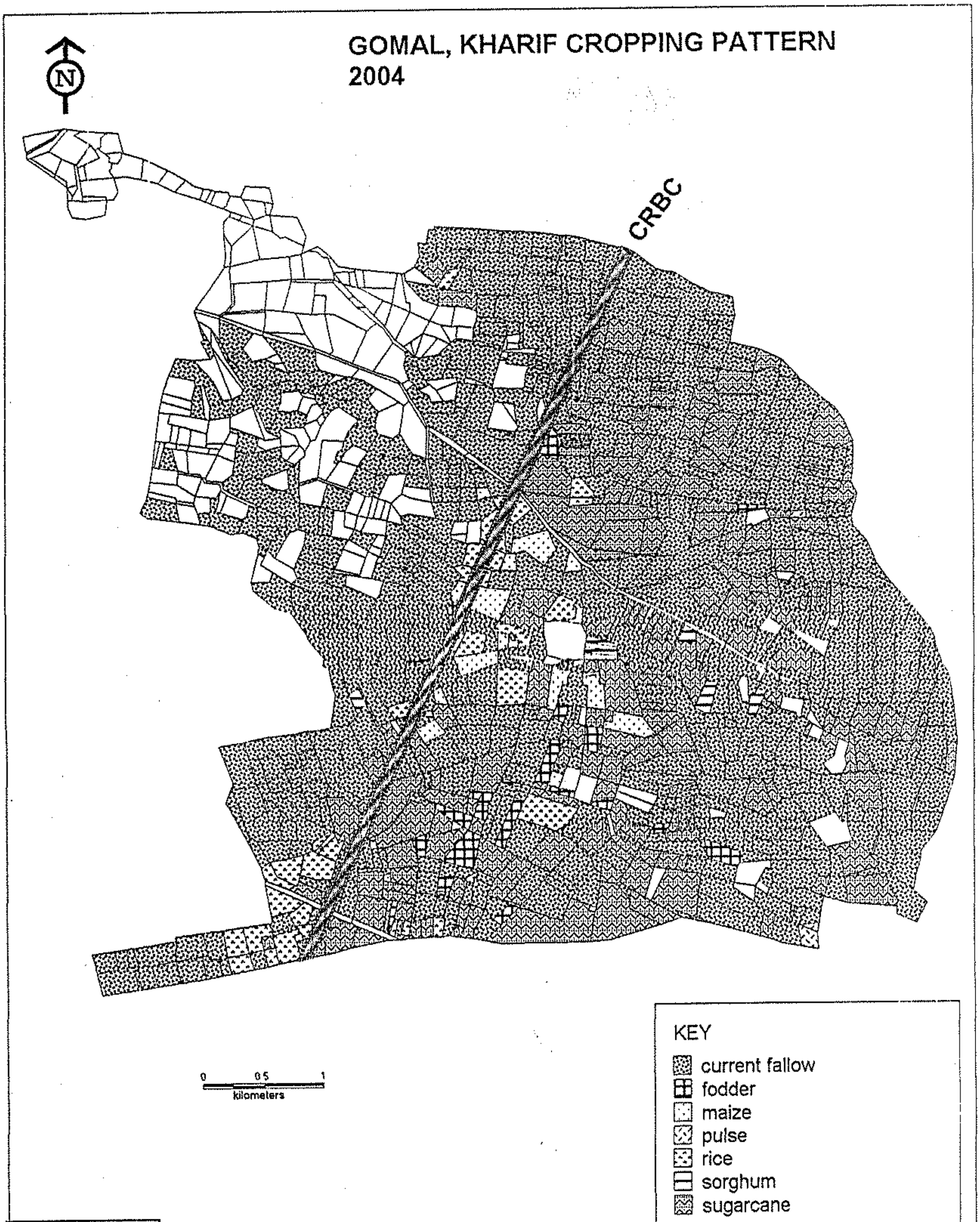
Figure VII-7

ii. GOMAL

Gomal is one of the largest Mouza in the district. Here the cultivated area is irrigated through canals, Rod Kohi and well-irrigated in addition to rainfed cultivation. Therefore, numerous crops are grown since long. Prior to CRBC, net sown area varied from season to season, depending upon the climatic conditions. Favourable climatic condition has accelerated the cultivated area in certain years, whereas harsh climate adversely affected the cultivated land. Important Kharif crops are sugarcane, cotton, rice, maize, sorghum, millet, fodder, oilseed, vegetables and pulses. Before CRBC from 1967-70, sugarcane, sorghum and millet dominated the Kharif cropping season but from 1975 to 1987 the lead was taken by rice and fodder. After CRBC from 1988 to 2004, the two water loving crops remained the principal contributors in Kharif season. The analysis further reveals that before CRBC only one water-loving crop i.e. rice dominated the whole scene but after CRBC, the two water loving crops retained the leading share. Besides this, in Kharif season, cotton, maize, millet, oilseed, pulse and sorghum were also grown but on small acreage and of little significance. The table VII-4 shows that prior to CRBC area under Kharif crops varied from 66 to 587 ha indicating wide uncertainty in the cropped area (Map VII-3 and 4). During post CRBC from 1988 to 2004, area under Kharif crops increased from 89 to 811 ha (Figure VII-8). The figure VII-9 further elaborates that during the study period negative changes have reported only in sorghum. After CRBC positive changes have occurred in almost all


GOMAL, KHARIF CROPPING PATTERN
1987
N
0
0.5
1
kilometers
KEY
current fallow
fodder
maize
millet
rice
sorghum
sugarcane

Map VII-3


GOMAL, KHARIF CROPPING PATTERN
2004
N
CRBC
0 0.5 1
kilometers
KEY
current fallow
fodder
maize
pulse
rice
sorghum
sugarcane

Map VII-4

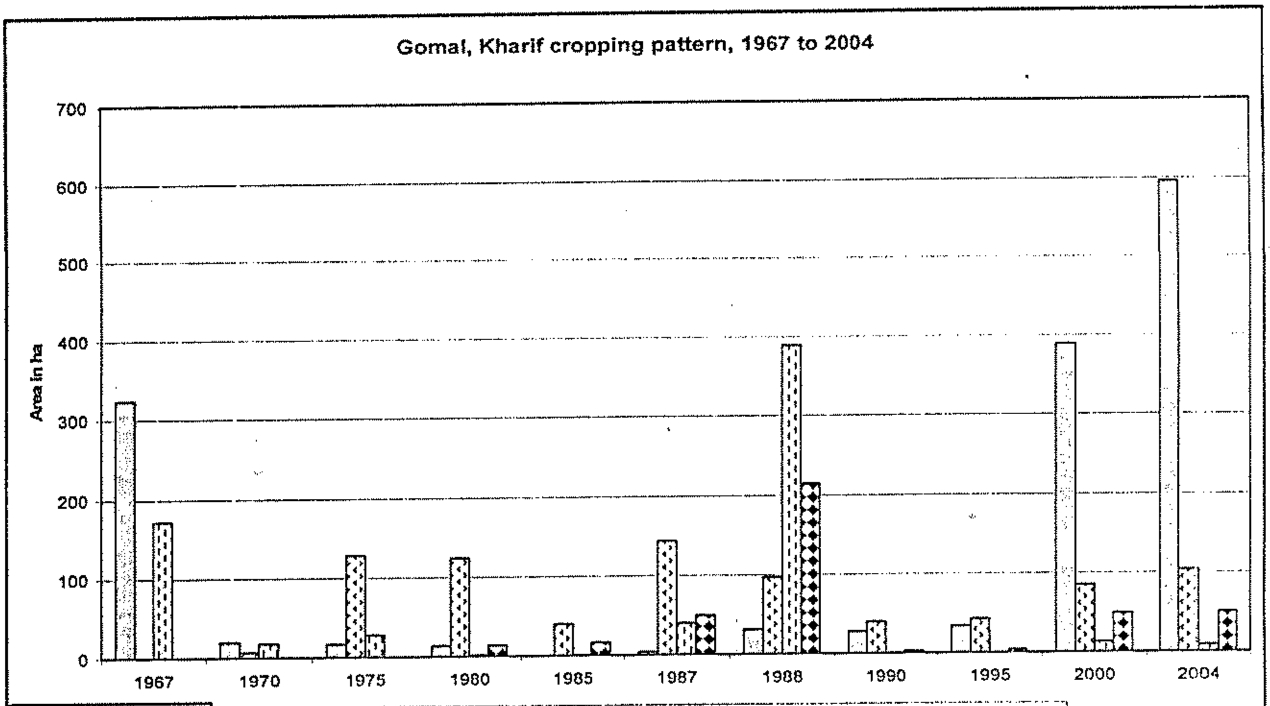


Figure VII-8

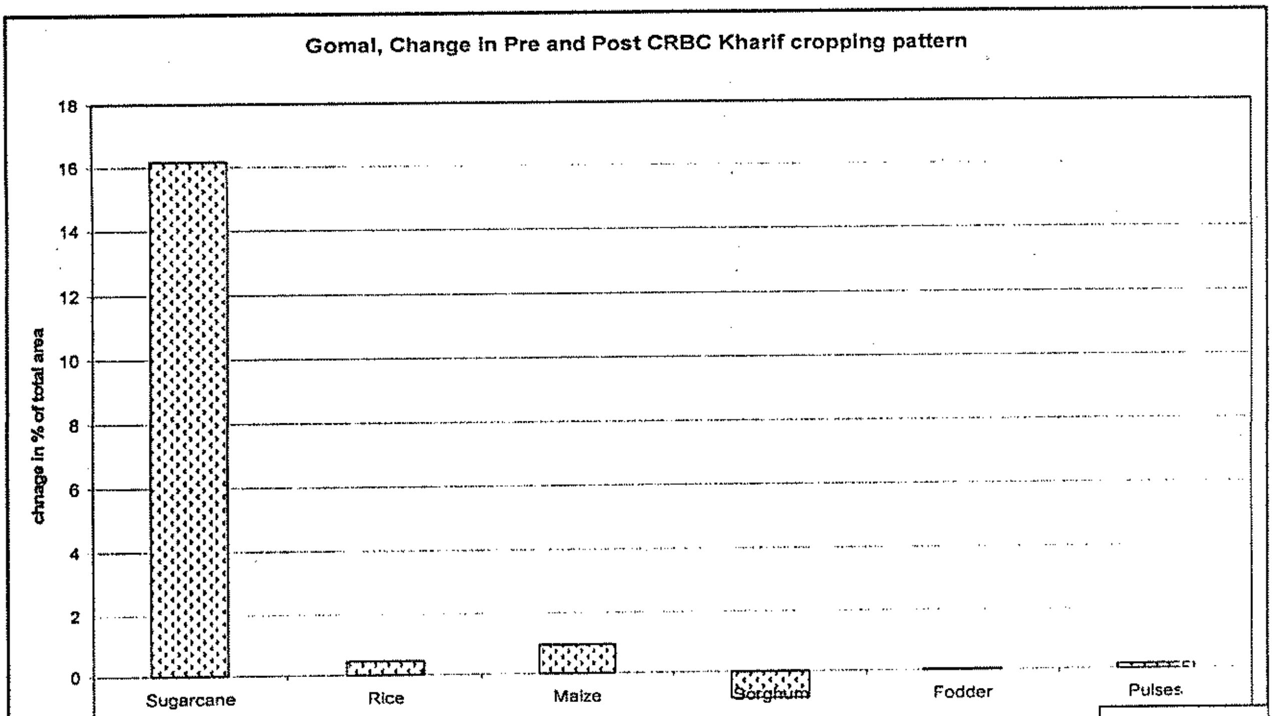


Figure VII-9

the Kharif crops. The analysis reveals that after advent of CRBC large-scale cultivable waste has been brought under cultivation.

Table VII-4

Gomal, Kharif cropping pattern, 1967-2004 (Area in ha)

Period	*Year*	*Sugarcane*	*Cotton*	*Rice*	*Maize*	*Sorghum*	*Millet*	*Fodder*	*Oilseed*	*Pulse*	*Total*
Pre CRBC	1967	324	14	0	0	172	74	0	4	0	587
	1970	20	4	7	5	18	11	0	0	1	66
	1975	17	0	128	6	28	1	0	1	1	183
	1980	14	7	124	0	2	0	14	0	13	174
	1985	0	0	40	6	1	0	17	0	0	66
	1987	4	0	144	12	40	1	50	0	0	251
Post CRBC	1988	32	0	97	12	389	13	215	0	0	759
	1990	28	0	40	0	0	0	3	0	17	89
	1995	34	0	43	0	0	0	4	0	17	98
	2000	389	0	85	0	13	0	50	0	15	551
	2004	596	0	104	46	9	0	51	0	5	811

Source: Revenue record (Lal Kitab of Mouza Gomal), 1967-2004

iii. BUCHARI

Prior to CRBC, the cultivated area of Buchari was entirely dependent on rainfall or Rod Kohi irrigation. The table VII-5 indicates that prior to CRBC area under Kharif crop varied from zero (1985) to maximum 25 ha (1967). Moreover, after CRBC from 1994 to 2004, it increased from minimum 11 ha (1994) to highest figure of 256 ha in 2004 (Figure VII-10). It means that after CRBC the Kharif acreage has increased. The analysis further reveals that positive changes have been recorded in all the Kharif crops (Figure VII-11). However, highest positive changes registered for sugarcane and rice, respectively.

Before CRBC, during Kharif cropping season only sorghum and millet were grown. Similarly, there was uncertainty in Kharif acreage due to non availability of water. During Kharif 1985, not even a single plot was cultivated because of dry climatic condition. However, after commissioning of CRBC in 1994, drastic changes have occurred in cropped area (Figure VII-10). Besides this, new water loving crops were also introduced. The table VII-5 indicates that after CRBC area under new water loving crops, cereal crops and pulses has been largely increased. The table VII-3 shows that after CRBC, there has been overwhelming increase in the area under sugarcane and rice. In Buchari, after CRBC, area under sugarcane was 4 ha in 1994, which increased to 118 ha (2004) in span of only ten years (Figure VII-10). Similarly, rice was also introduced after CRBC. During initial phase of CRBC commissioning, rice was grown on 4 ha in 1994, which constantly increased to 79 ha in 2004 (Map VII- 5 and 6). The high increase in the acreage of sugarcane and rice is attributed to the assured water supply through CRBC. Prior to CRBC, melon was also grown but on limited scale as it was the crop of Rod Kohi system. However, after CRBC, no significant fruits cultivation is reported. Mung bean (*mong*) and lentil (*masoor*) are the two important pulses grown in the sample village. Trend towards pulses started after CRBC. The table VII-5 clearly shows pre and post CRBC changes in the Kharif cropping pattern. It shows that area under sorghum and millet is gradually decreasing, because of trend towards new water loving and high return crops.

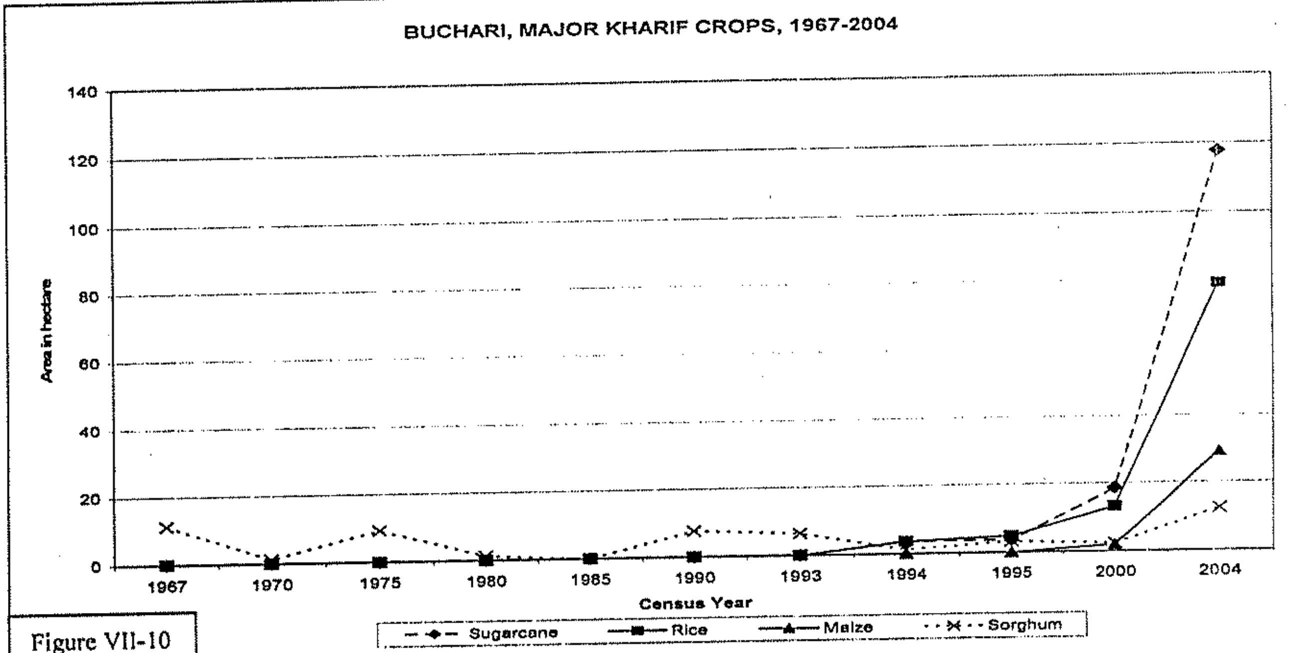


Figure VII-10

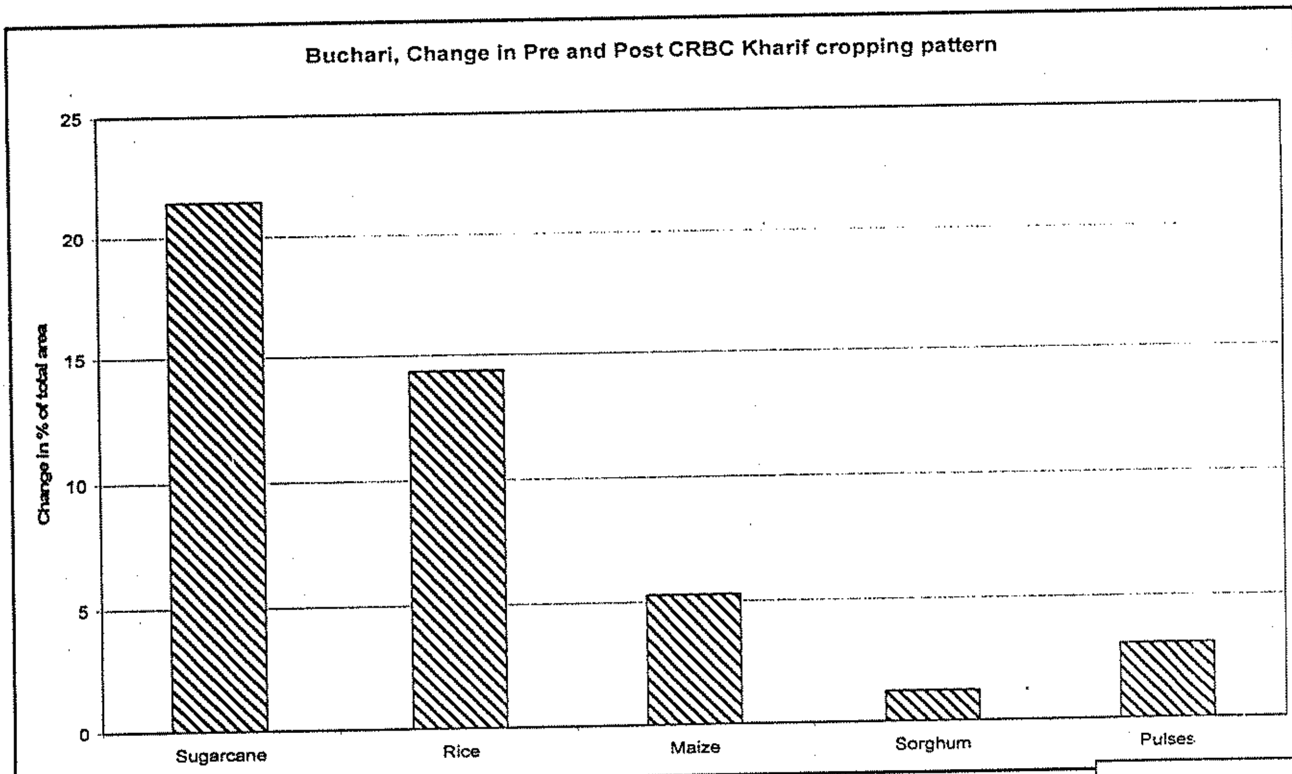
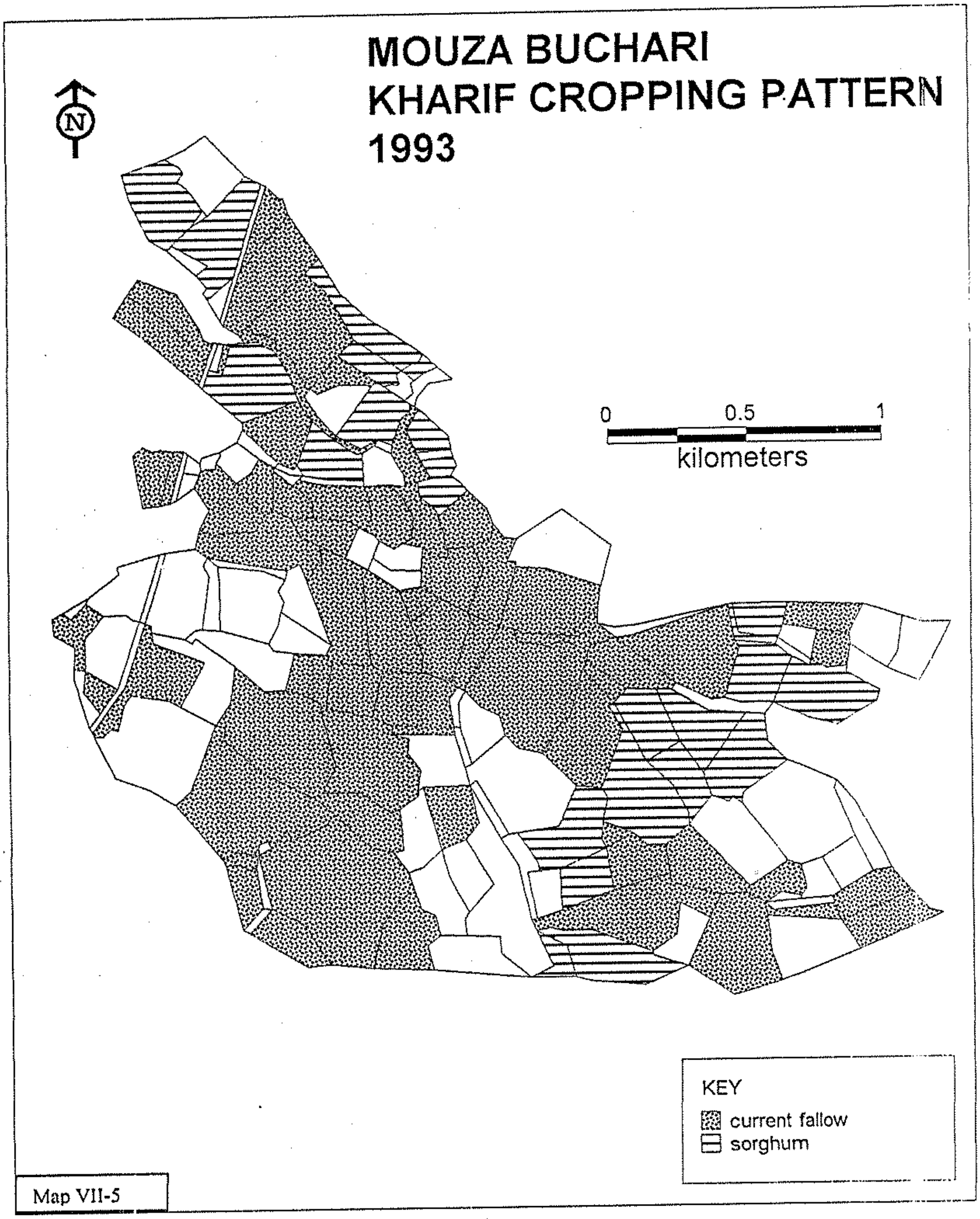


Figure VII-11


MOUZA BUCHARI
KHARIF CROPPING PATTERN
1993
N
0
0.5
1
kilometers
KEY
current fallow
sorghum
Map VII-5

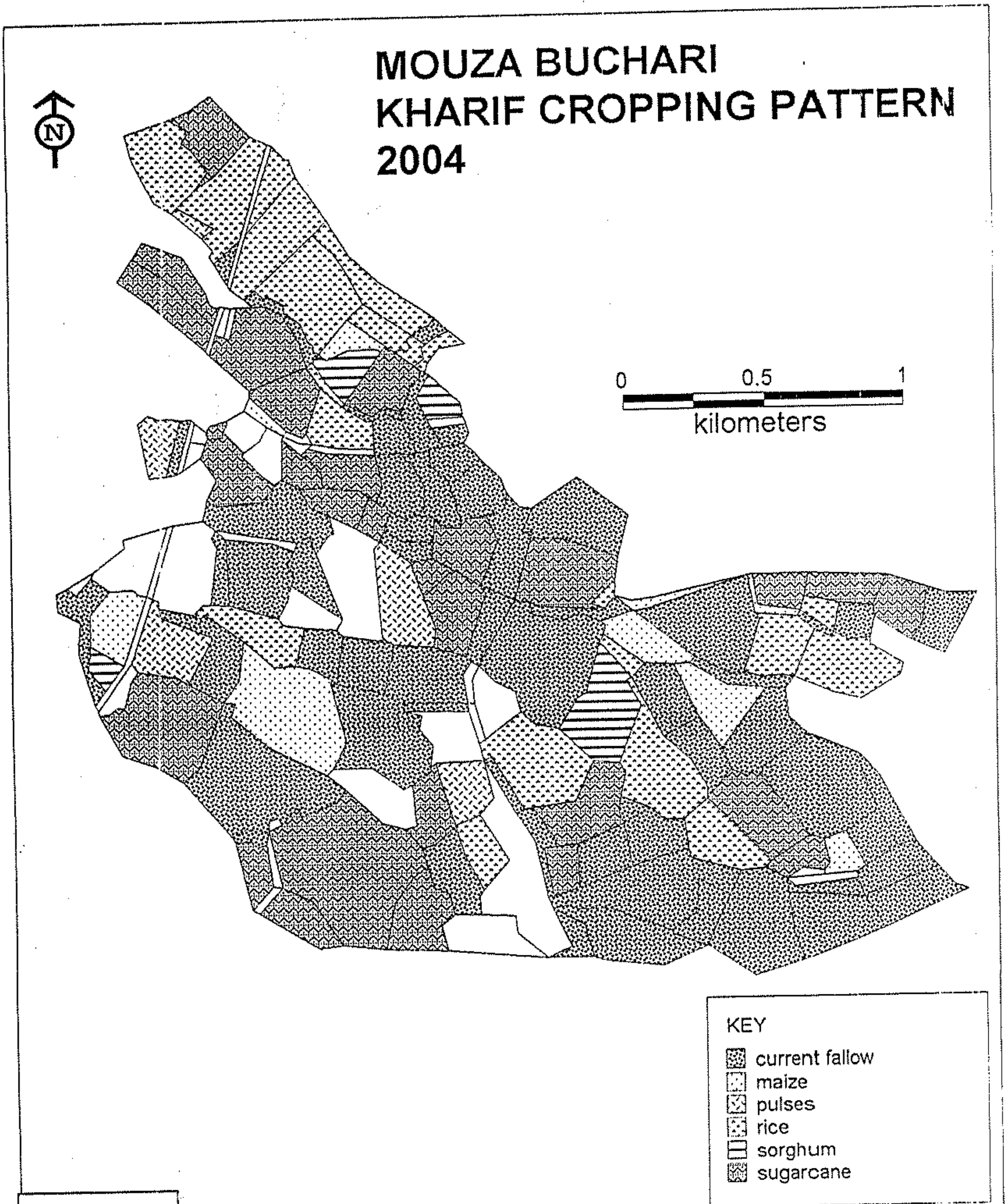

MOUZA BUCHARI
KHARIF CROPPING PATTERN
2004
N
0
0.5
1
kilometers
KEY
current fallow
maize
pulses
rice
sorghum
sugarcane
Map VII-6

Table VII-5

Buchari, Kharif cropping pattern, 1967-2004 (Area in ha)

Period	Year	Sugarcane	Rice	Maize	Sorghum	Millet	Pulses	Fruit	Total
Pre CRBC	1967	0	0	0	11	14	0	0	25
	1970	0	0	0	1	2	0	0	3
	1975	0	0	0	9	10	0	0	19
	1980	0	0	0	1	0	0	1	2
	1985	0	0	0	0	0	0	0	0
	1990	0	0	0	8	3	0	0	11
	1993	0	0	0	6	0	0	0	6
Post CRBC	1994	4	4	0	1	1	1	0	11
	1995	4	5	0	3	2	4	0	18
	2000	19	13	2	2	3	15	0	54
	2004	118	79	29	13	0	17	0	256

Source: Revenue record (Lal Kitab of Mouza Buchari), 1967-2004

iv. CHERA

In Chera prior to CRBC major sources of water supply was Rod Kohi in addition to rainfed cultivation. In Chera, before CRBC, area under Kharif crops varied from year to years. The table VII-6 shows that prior to CRBC minimum (zero) Kharif acreage was recorded in 1995, whereas maximum (160 ha) reported in 1990. This variation is mainly due to the dependency of cultivated area on the prevailing uncertain climatic condition in the area. The analysis reveals that there has been gradual increase in the Kharif acreage. In Chera, prior to CRBC, important Kharif crops were sorghum, millet, oilseed, fodder and fruit but after CRBC cultivation of sugarcane and pulses was also started. Field survey (2005) revealed that in Chera rice has been introduced, after commissioning of CRBC.

It is clear from the figure VII-12 that before CRBC i.e. from 1967 to 2000, sorghum and millet was the leading Kharif crops. However, after CRBC i.e. from 2001 to 2004 cultivation of sugarcane and pulses has also started as Kharif crops. While comparing pre and post CRBC Kharif cropping pattern, a positive changes were recorded in sugarcane and pulses, whereas negative changes occurred in sorghum, millet, oilseed, fodder and fruit. The figure VII-13 elaborates that area under pulses and sorghum has increased, whereas area under millet has largely decreased. Similarly, after CRBC, sugarcane has been introduced in the Kharif cropping pattern of Chera. Amongst the pulses, mung bean and urd bean are the dominant pulses of Kharif season. Beside this, prior to CRBC fodder was also cultivated.

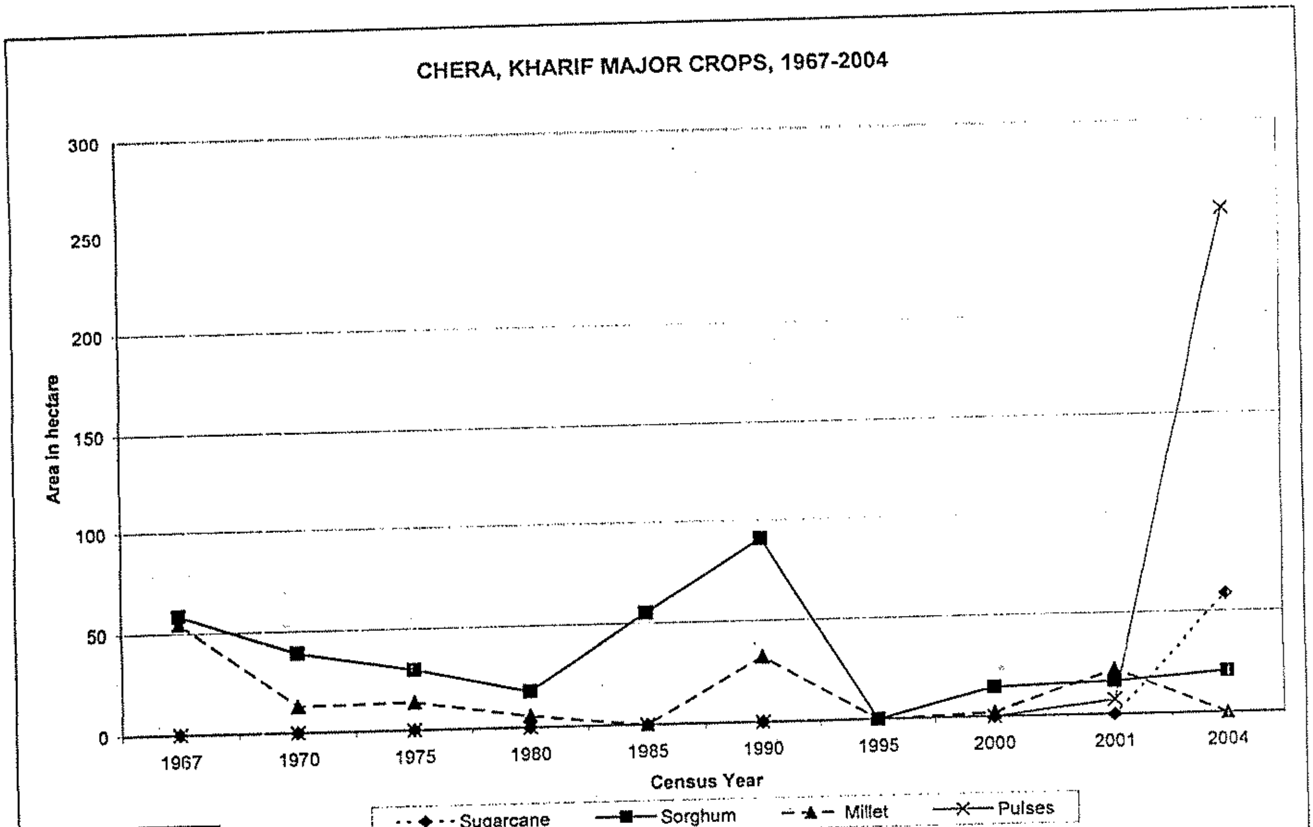


Figure VII-12

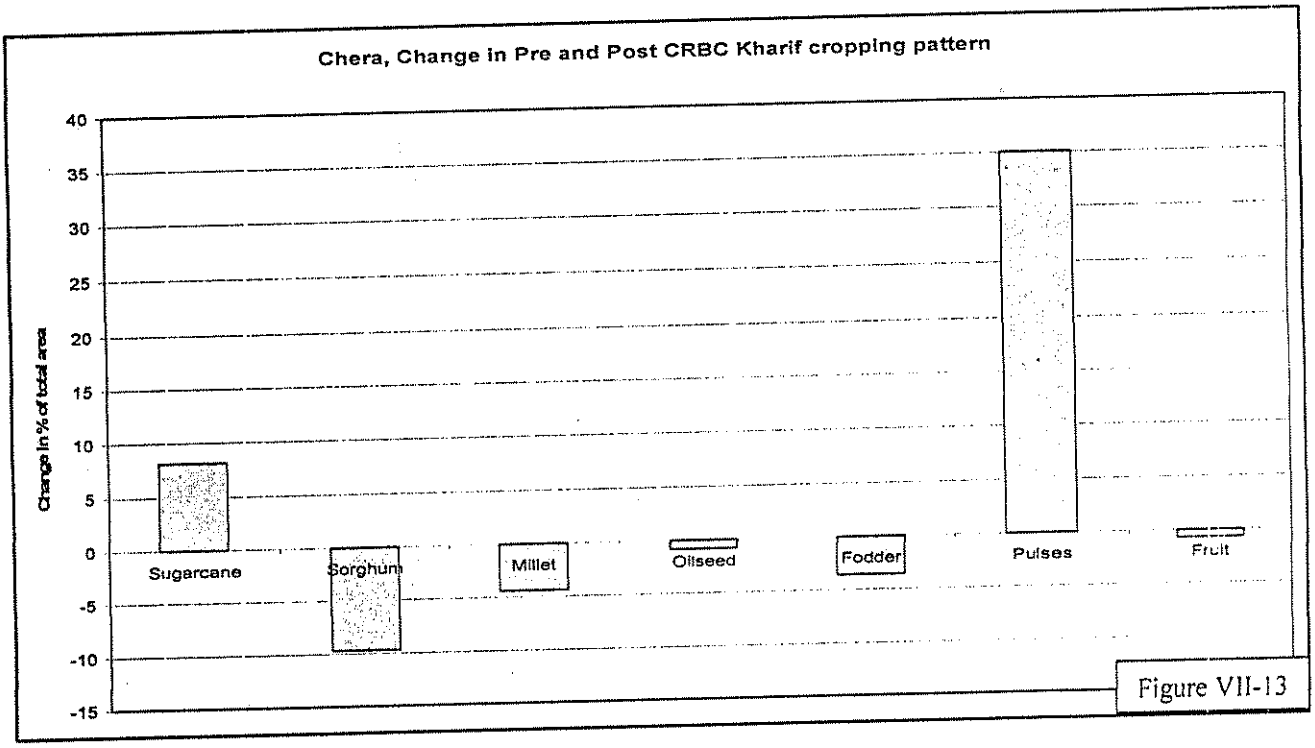
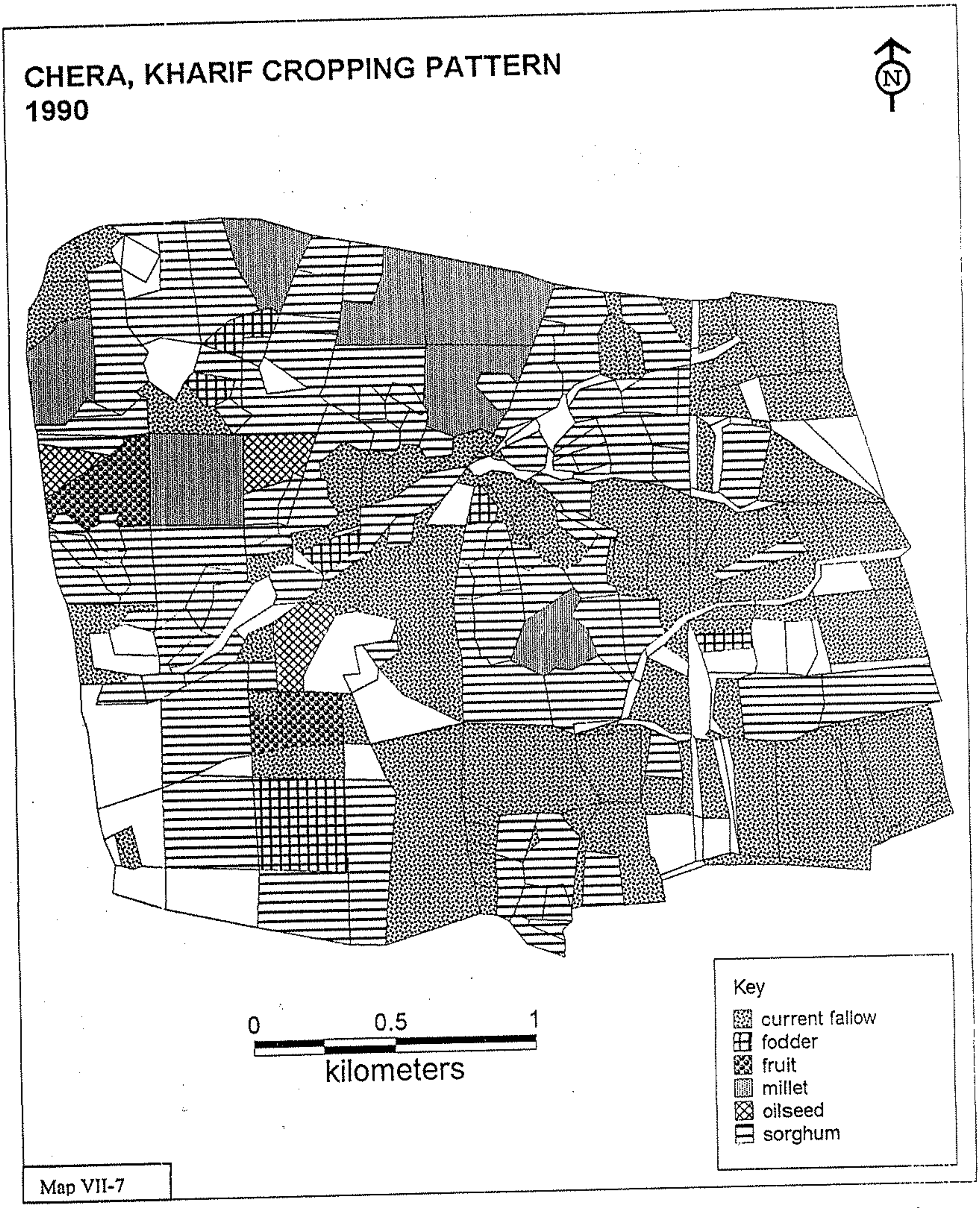
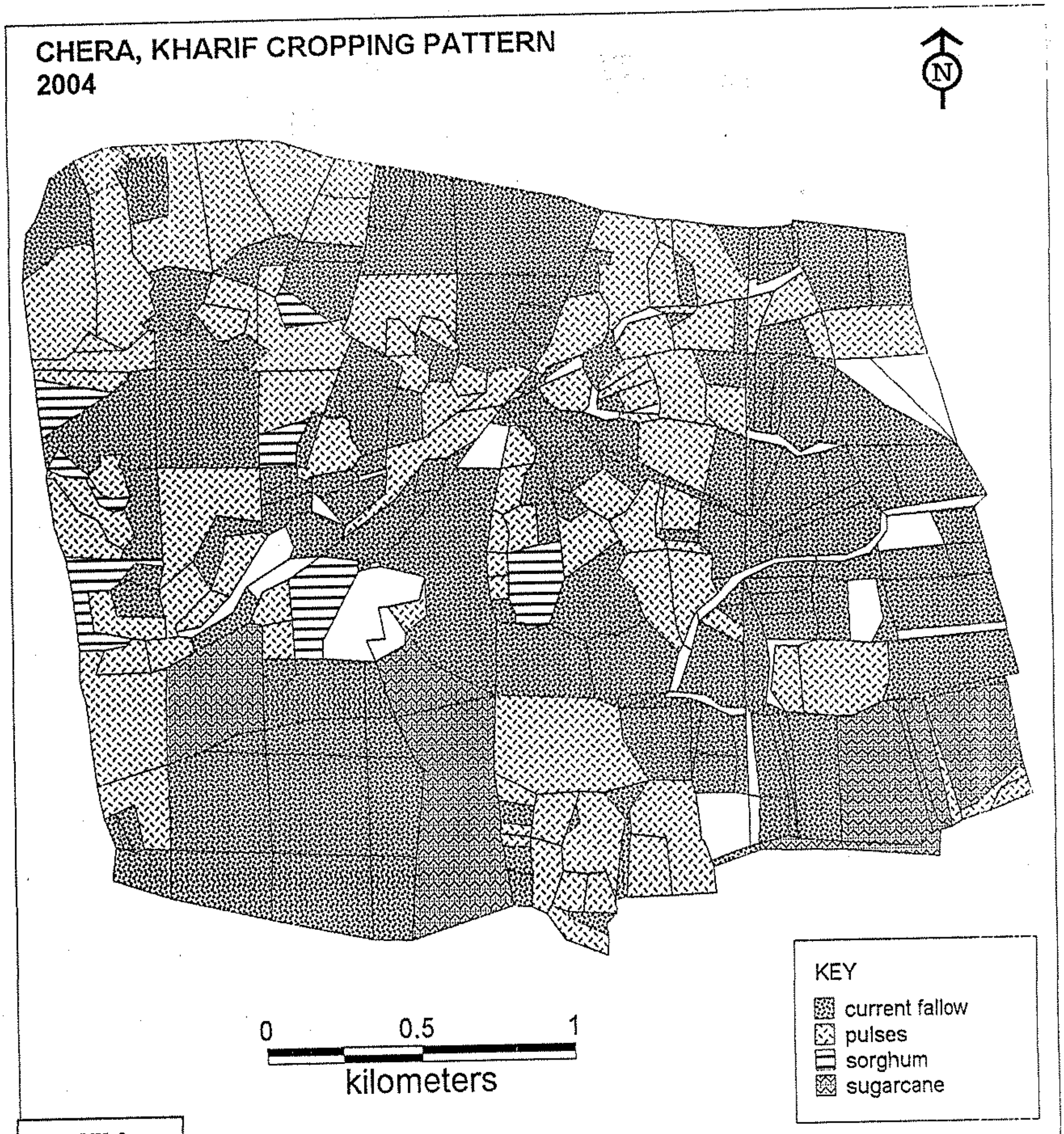


Figure VII-13


CHERA, KHARIF CROPPING PATTERN
1990
N
0
0.5
1
kilometers
Key
current fallow
fodder
fruit
millet
oilseed
sorghum
Map VII-7


CHERA, KHARIF CROPPING PATTERN
2004
N
0
0.5
1
kilometers
KEY
current fallow
pulses
sorghum
sugarcane

Map VII-8

Table VII-6
Chera, Kharif cropping pattern, 1967-2004 (Area in ha)

Period	*Year*	*Sugarcane*	*Sorghum*	*Millet*	*Oilseed*	*Fodder*	*Pulse*	*Fruit*	*Total*
Pre CRBC	1967	0	58	55	0	0	0	0	113
	1970	0	39	13	0	0	0	0	52
	1975	0	30	14	0	0	0	0	44
	1980	0	18	6	0	2	0	0	26
	1985	0	55	0	0	4	0	1	60
	1990	0	91	32	6	26	0	5	160
	1995	0	0	0	0	0	0	0	0
	2000	0	15	2	0	1	0	0	18
Post CRBC	2001	0	17	22	0	8	7	0	54
	2004	59	21	0	0	0	254	0	334

Source: Revenue record (Lal Kitab of Mouza Chera*), 1967-2004*

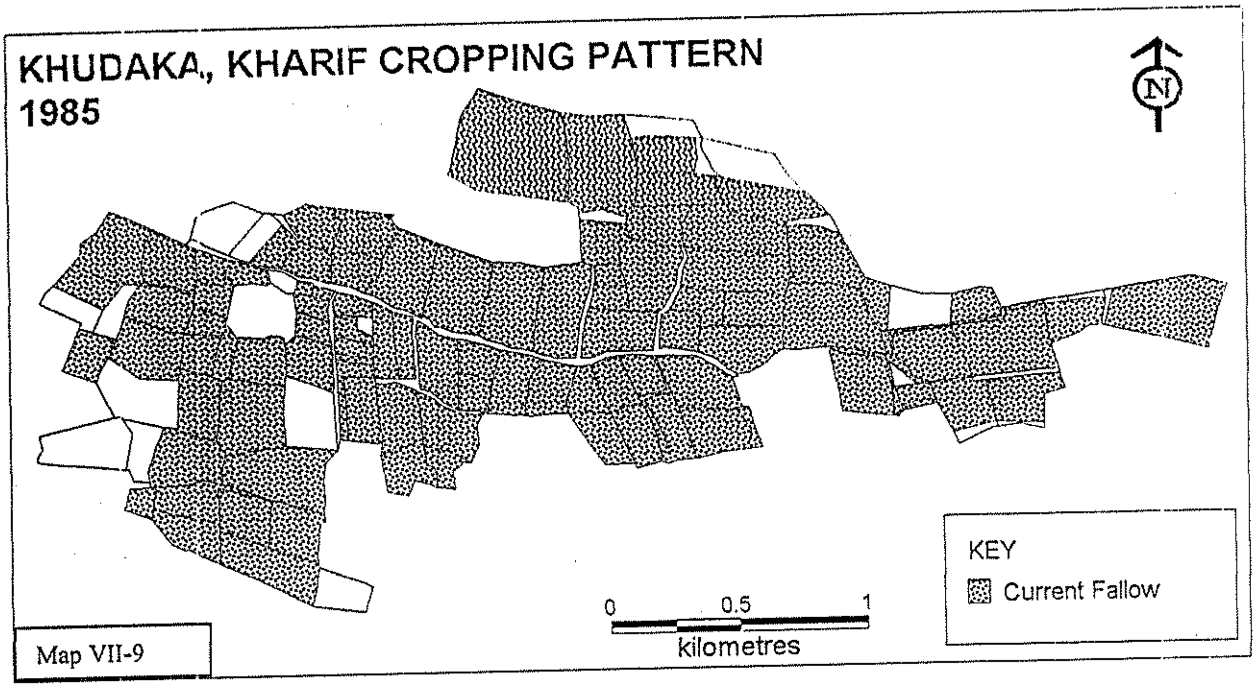
v. KHUDAKA

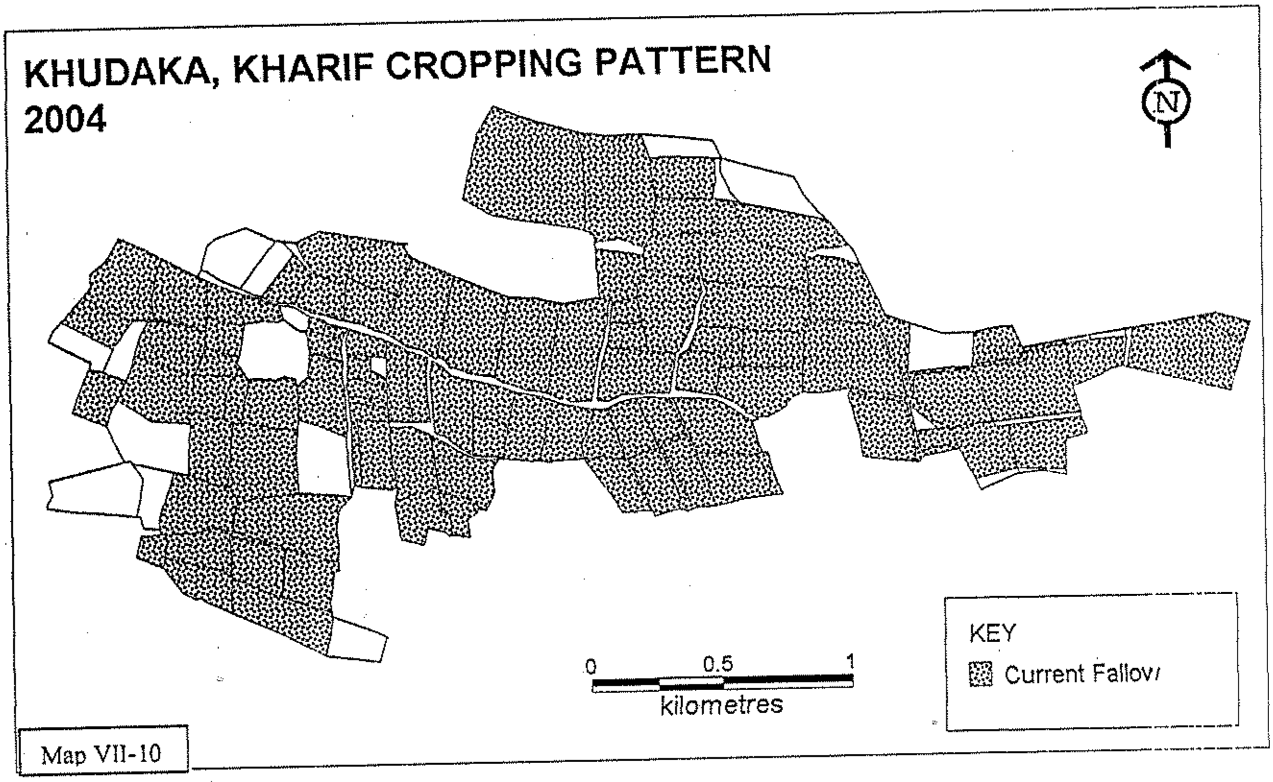
In the sampled village Khudaka, cultivated area is entirely dependent upon the centuries old Rod Kohi irrigation system. In Khudaka, throughout the study period, sorghum and millet were the two dominant Kharif crops. These crops have been competing in terms of area from 1967 to 2004 and are considered as drought resistant Kharif crops (Figure VII-14). However, there are certain spells, when none of these crops were grown in the area (Table VII-7). The last lengthy period was due to long spell of drought over the western part of Pakistan (1997-2003) (Sheikh, 2004). The table VII-7 indicates that certain dry spells has adversely affected the Kharif acreage. Revenue record reveals that besides sorghum and millet no other crop is reported from this sample village. To sum up the Kharif acreage it was found that as Khudaka lies outside the CRBC command area hence no impact of CRBC was detected during the study period.

Table VII-7
Khudaka, Kharif cropping pattern, 1967-2004 (Area in ha)

Year	*Sorghum*	*Millet*	*Total*
1966	125	40	165
1970	76	29	105
1975	0	0	0
1980	24	31	55
1985	0	0	0
1990	0	0	0
1995	0	0	0
2000	0	0	0
2004	0	0	0

Source: Revenue record (Lal Kitab of Mouza Khudaka) 1966-2004


KHUDAKA, KHARIF CROPPING PATTERN
1985
N
KEY
Current Fallow
0
0.5
1
kilometres
Map VII-9


KHUDAKA, KHARIF CROPPING PATTERN
2004
N
KEY
Current Fallow
0
0.5
1
kilometres
Map VII-10

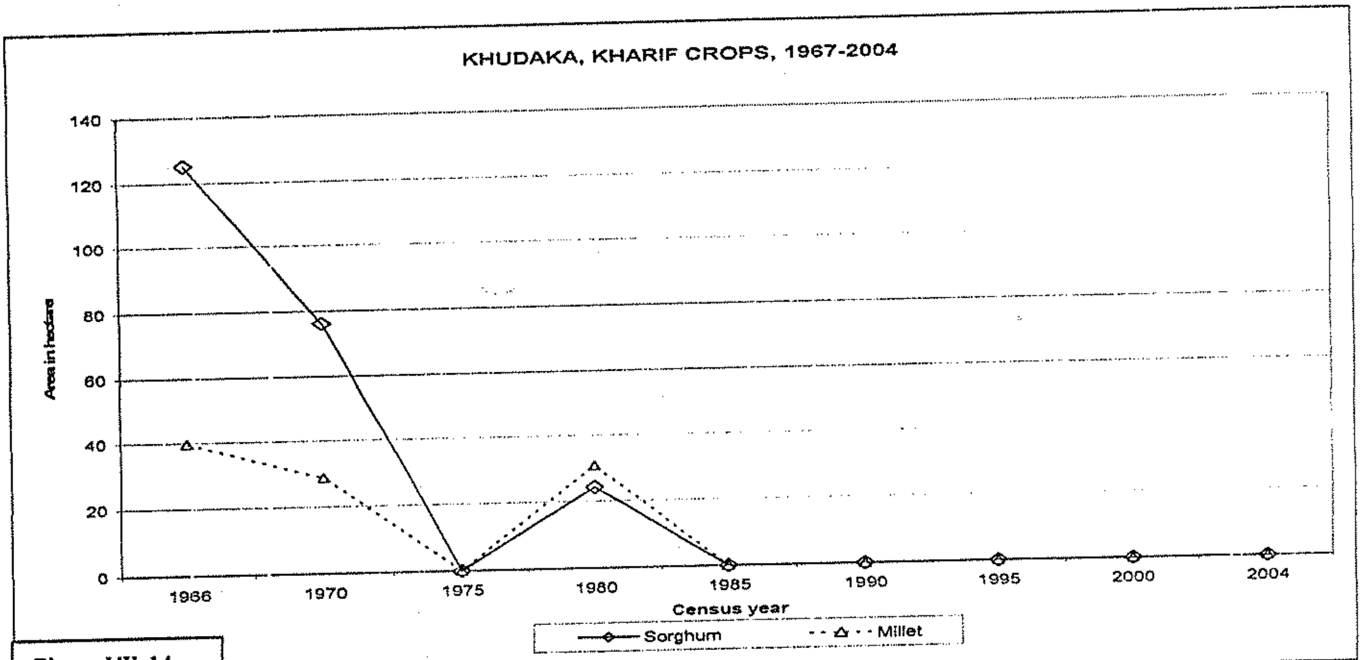


Figure VII-14

B. Rabi cropping pattern

In Rabi cropping season, wheat, gram, barely, oilseed (mustered, sunflower, soybean), Rabi vegetables and fruits are grown. In some places single crop dominates the system, whereas in others complex combinations of many crops. The analysis reveals that after CRBC the cropped area has been largely increased and farmers have mostly switched over to more productive crops. The detailed analysis of five sample villages is discussed as follows:

i. JARRA

In Jarra, wheat, barley, pulses, oilseed, fodder and fruits were grown during Rabi cropping season. After comparing pre and post CRBC condition, the cropping pattern in the mouza is not much different. It is clear from the figure VII-15 that after commissioning of CRBC, a lot of productive land has been reduced and adversely affected by waterlogging and salinity. As a result there is declining trend in the Rabi acreage from 1994-1995 to 1999-2000. However, after the introduction of SCARP, the wasteland has been gradually brought under cultivation. The table VII-8 shows that before and after CRBC wheat remained the predominant Rabi crop followed by fodder. Before CRBC, pulses were grown on large area, but after CRBC, it was replaced by orchards (Map VII-11 and 12). Presently, the area under orchards is consistently increasing. During field survey, it was found that farmers are in favour of mix cropping (orchard and crops). This of course seems more profitable cropping pattern. The figure VII-16 reveals that after comparing pre and post CRBC, positive changes have been recorded in wheat, fodder and fruit, whereas negative changes have occurred in barley, pulses and oilseed.

Table VII-8

Jarra, Rabi cropping pattern, 1987-2004 (area in ha)

Period	*Year*	*Wheat*	*Barley*	*Pulses*	*Oilseed*	*Fodder*	*Orchard*	*Total*
Pre CRBC	1987-88	261	2	16	1	20	0	300
Post CRBC	1994-95	100	1	0	0	5	0	106
	1999-2000	102	2	0	1	5	1	110
	2003-04	273	0	0	0	26	13	312

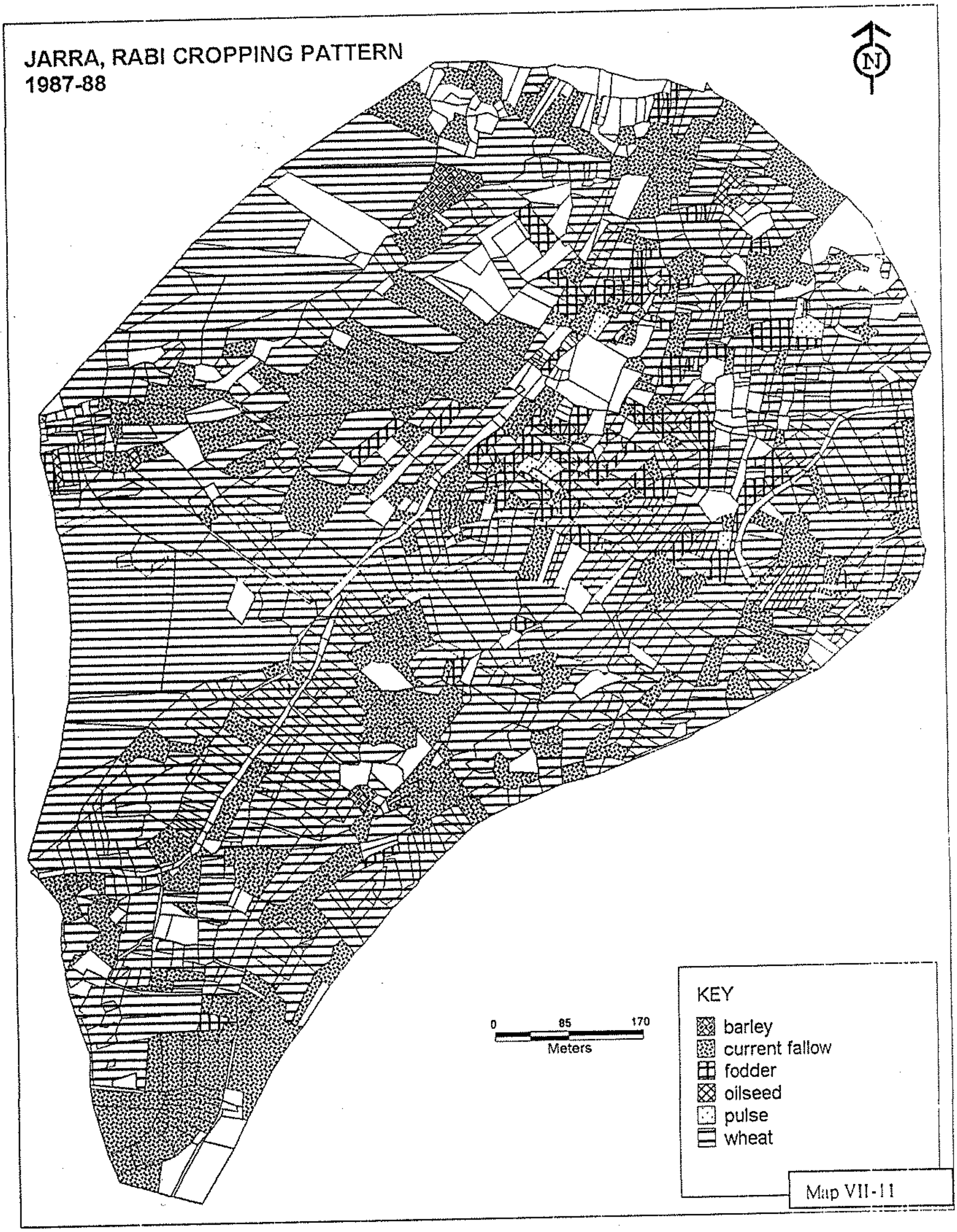
Source: Revenue record (Lal Kitab of Mouza Jarra), 1987-2004

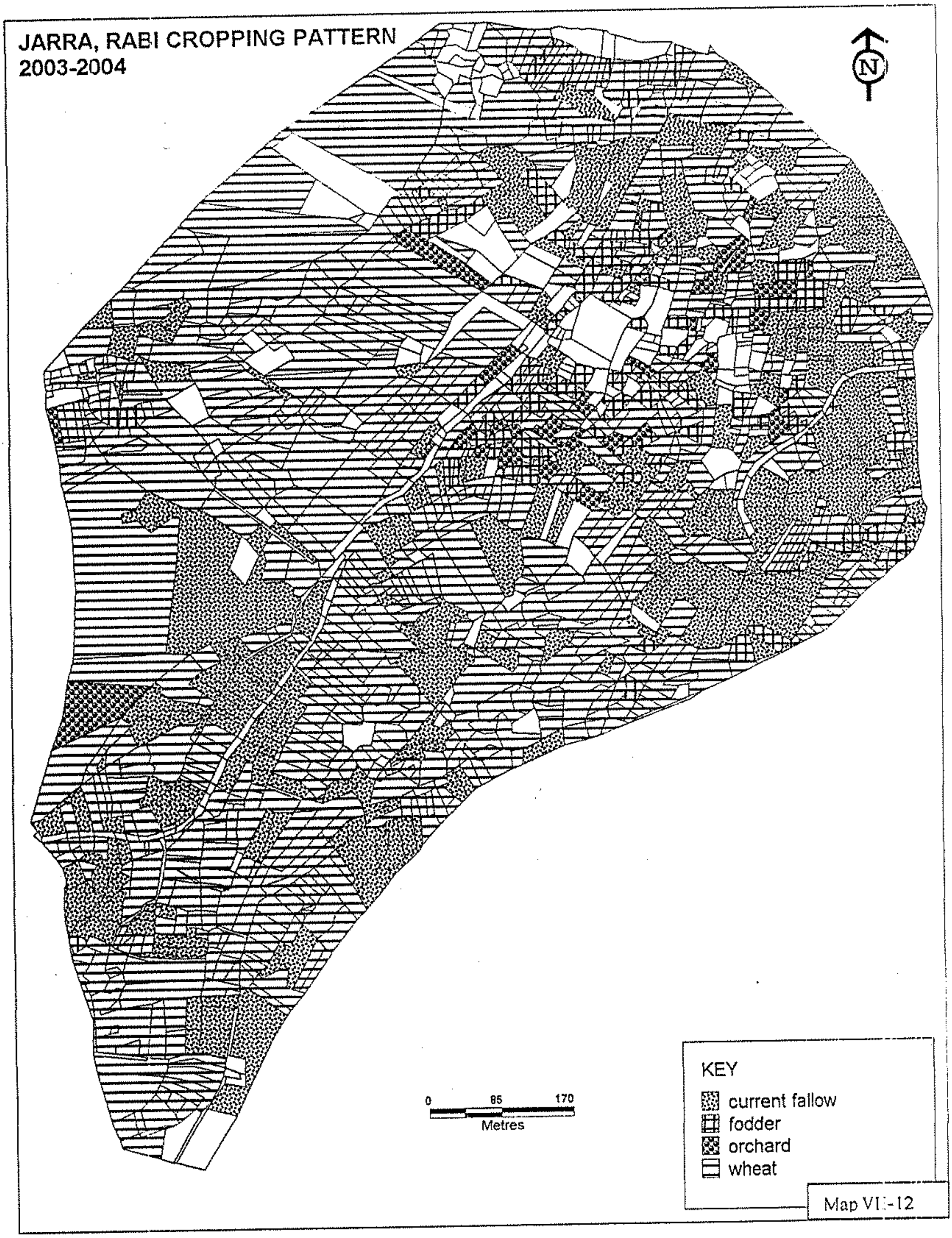
Table VII-9

Change in Rabi cropping pattern of sample villages

Mouza	*Period*	*Wheat*	*Barley*	*Pulses*	*Oilseed*	*Fodder*	*Fruit*
Jarra	Pre CRBC	261	2	16	1	20	0
	% of total area	50.386	0.386	3.089	0.193	3.861	0.000
	Post CRBC	273	0	0	0	26	13
	% of total area	52.703	0.000	0.000	0.000	5.019	2.510.
	Change in %age	2.317	-0.386	-3.089	-0.193	1.158	2.510
Gomal	Pre CRBC	666	3	2	2	43	0
	% of total area	18.192	0.082	0.055	0.055	1.175	0.000
	Post CRBC	1,077	7	120	22	83	2
	% of total area	29.418	0.191	3.278	0.601	2.267	0.055
	Change in %age	11.226	0.109	3.223	0.546	1.093	0.055
Buchari	Pre CRBC	20	1	0	3	0	0
	% of total area	3.636	0.182	0.000	0.545	0.000	0.000
	Post CRBC	270	0	40	0	16	0
	% of total area	49.091	0.000	7.273	0.000	2.909	0.000
	Change in %age	45.455	-0.182	7.273	-0.545	2.909	0.000
Chera	Pre CRBC	30	0	9	25	0	0
	% of total area	4.138	0.000	1.241	3.448	0.000	0.000
	Post CRBC	349	0	65	4	0	0
	% of total area	48.138	0.000	8.966	0.552	0.000	0.000
	Change in %age	44.000	0.000	7.724	-2.897	0.000	0.000
Khudaka	Pre CRBC	113	8	32	32	0	0
	% of total area	35.313	2.500	10.000	10.000	0.000	0.000
	Post CRBC	0	0	0	0	0	0
	% of total area	0	0	0	0	0	0
	Change in %age	-35.313	-2.500	-10.000	-10.000	0	0

Source: Revenue record of the sample villages


JARRA, RABI CROPPING PATTERN
1987-88
N
0
85
170
Meters
KEY
barley
current fallow
fodder
oilseed
pulse
wheat
Map VII-11


JARRA, RABI CROPPING PATTERN
2003-2004
N
0 85 170
Metres
KEY
current fallow
fodder
orchard
wheat
Map VII-12

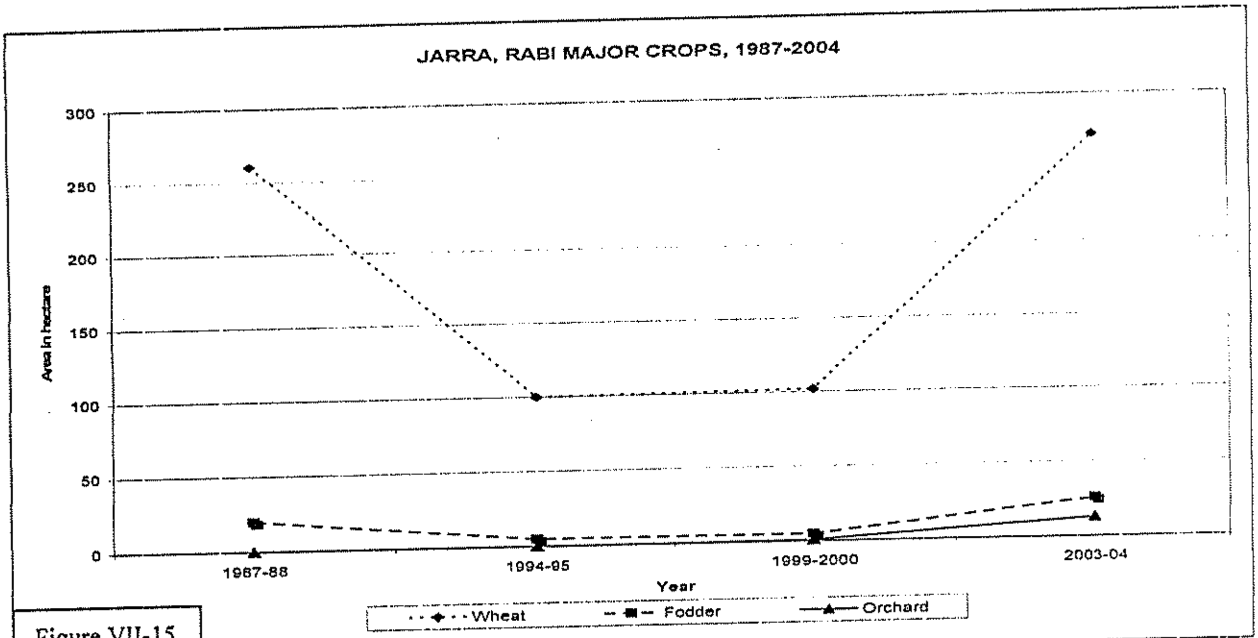


Figure VII-15

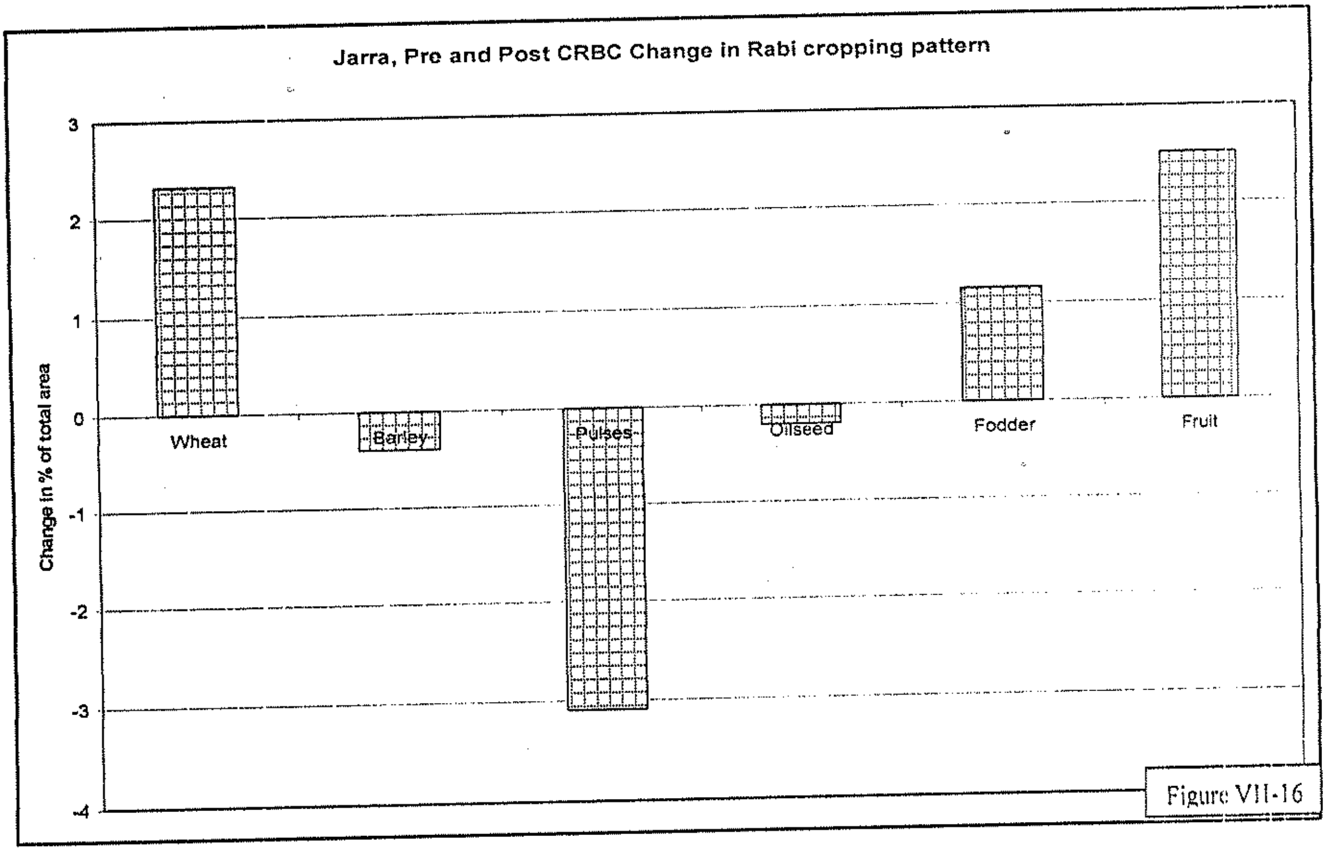


Figure VII-16

ii. GOMAL

In mouza Gomal wheat, barley, pulse, oilseed, fodder and fruits are important Rabi crops. The table VII-10 indicates that after CRBC, Rabi cropped area has been increased as against post CRBC acreage. During Rabi cropping season, prior to CRBC highest acreage was found in 1979-80 (1,093 ha) and lowest acreage reported in 1969-70, when 385 ha was cultivated (Figure VII-17). Before CRBC, in Gomal wheat, fodder and oilseed predominantly grown over the Rod Kohi, well irrigated and rainfed areas (Map VII-13). The table VII-10 indicates that wheat dominates the Rabi cropping pattern both before and after CRBC followed by the fodder and oilseed, competing for second and third rank. The Figure VII-17 shows that prior to CRBC, there were uncertainty in the wheat acreage but after CRBC, a regular increase has been noted in the area under wheat crop, which constitute more than 80% of the Rabi acreage (Map VII-14). This indicates the impact of CRBC intervention in the agricultural eco-system. However, the acreage varies from year to year but during the year 2003-2004, the highest area under wheat was recorded (Table VII-10). Barley and pulse are also reported but from a limited area. Amongst the pulses, gram is the major contributor.

Comparing both pre and post CRBC condition, area under barley, pulses, oilseed and fodder has been gradually increased after inception of CRBC. The figure VII-18 reveals that positive changes have been recorded in all the Rabi crops and no negative change occurred, when pre and post CRBC situation was compared.

Table VII-10

Gomal, Rabi cropping pattern, 1967-2004 (area in ha)

Period	*Year*	*Wheat*	*Barley*	*pulse*	*Oilseed*	*Fodder*	*Fruit*	*Total*
Pre CRBC	1967-68	640	7	41	249	34	0	972
	1969-70	298	2	3	40	42	0	385
	1974-75	453	1	2	9	22	0	488
	1979-80	1042	7	1	19	24	0	1093
	1984-85	617	2	2	6	34	0	661
	1987-88	666	3	2	2	43	0	716
Post CRBC	1989-90	798	5	5	39	59	205	1111
	1994-95	832	5	6	1	17	0	862
	1999-00	915	2	8	8	72	0	1004
	2003-04	1077	7	120	22	83	2	1311

Source: Revenue record (Lal Kitab of Mouza Gomal), 1967-2004

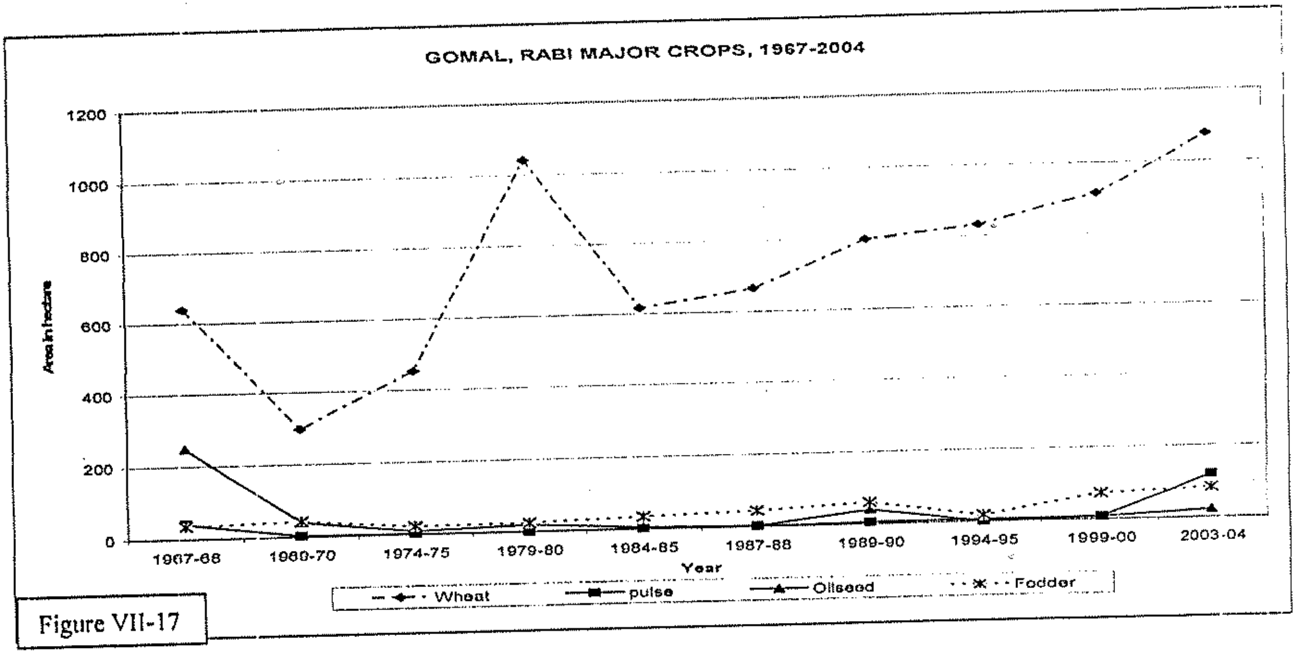


Figure VII-17

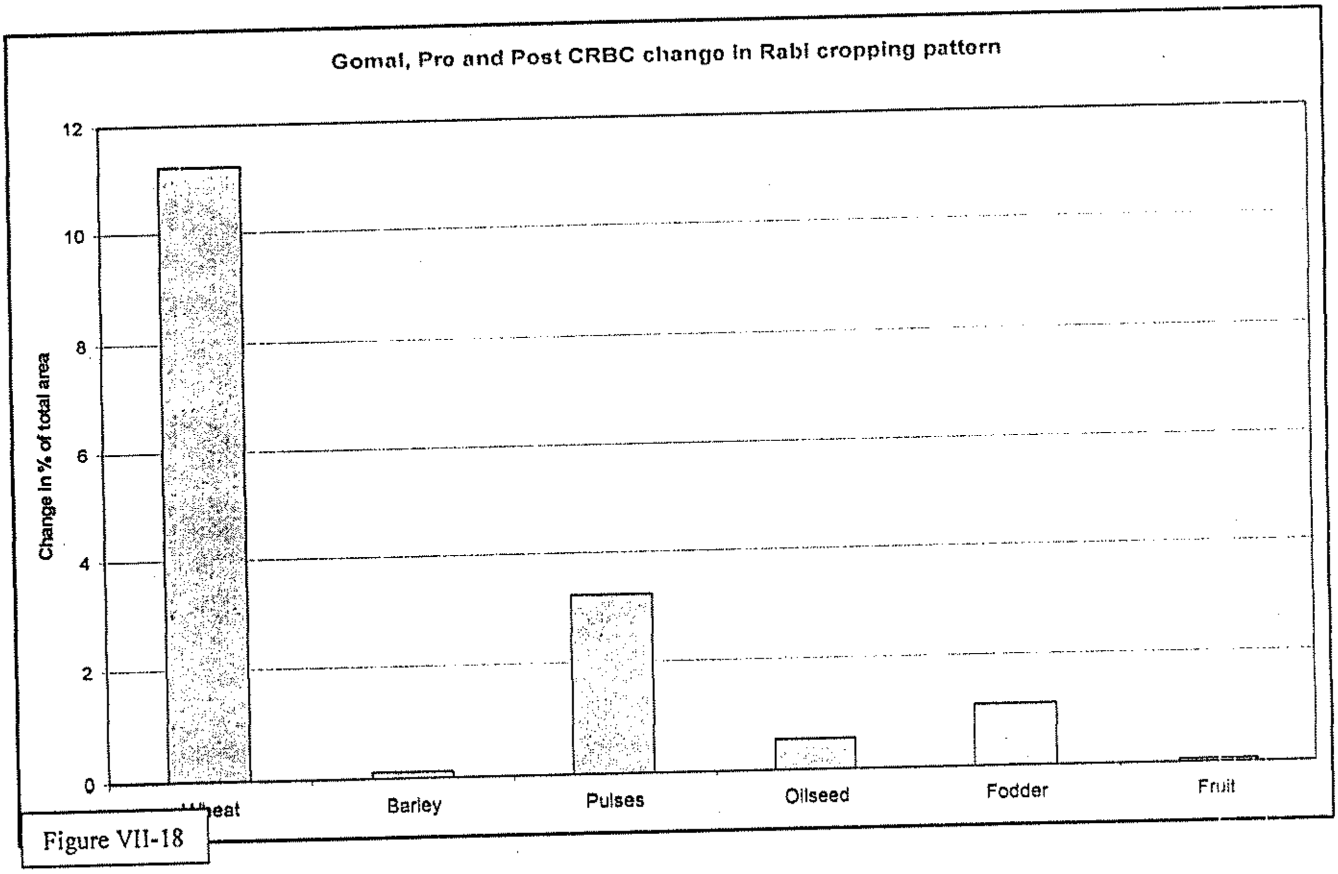
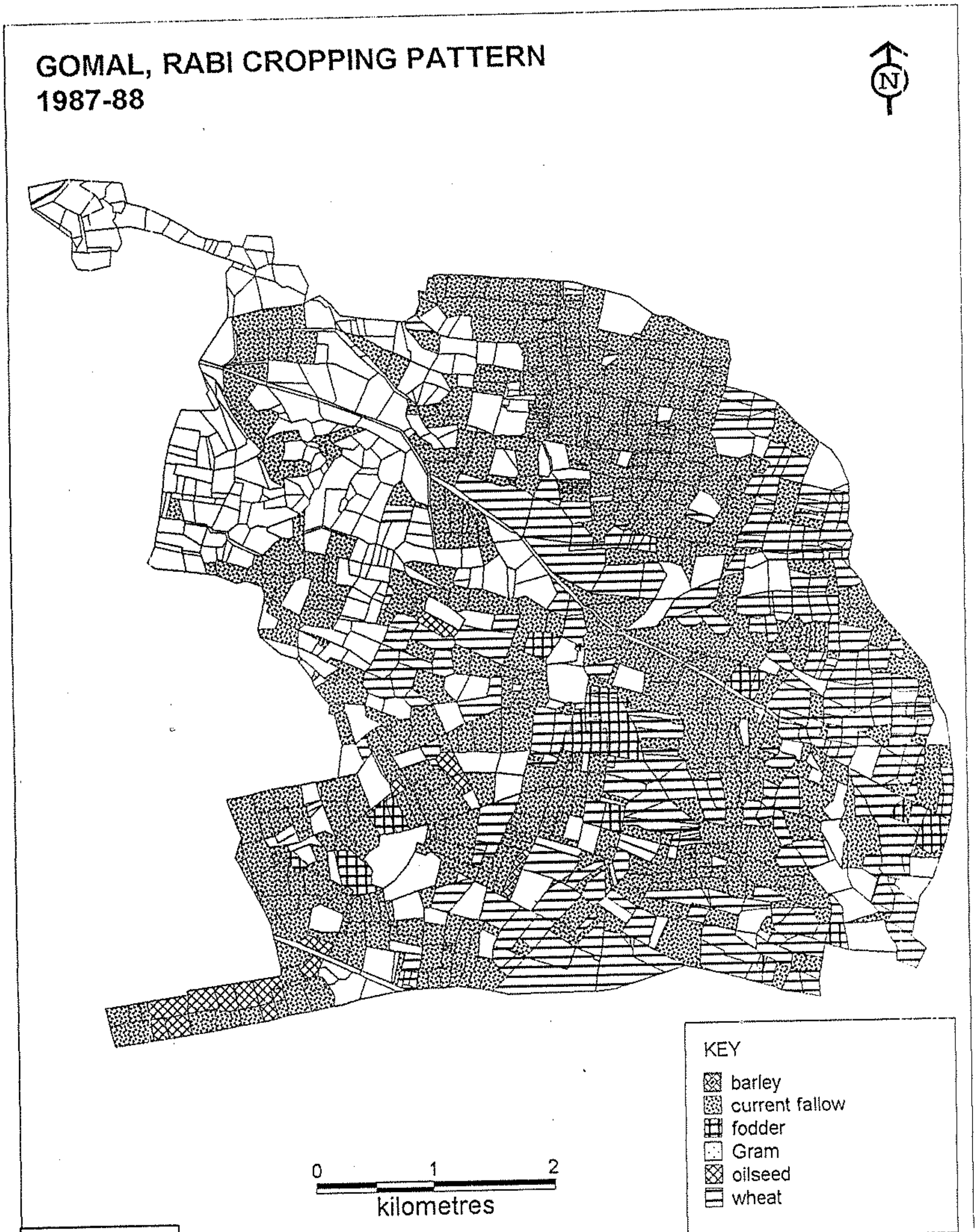
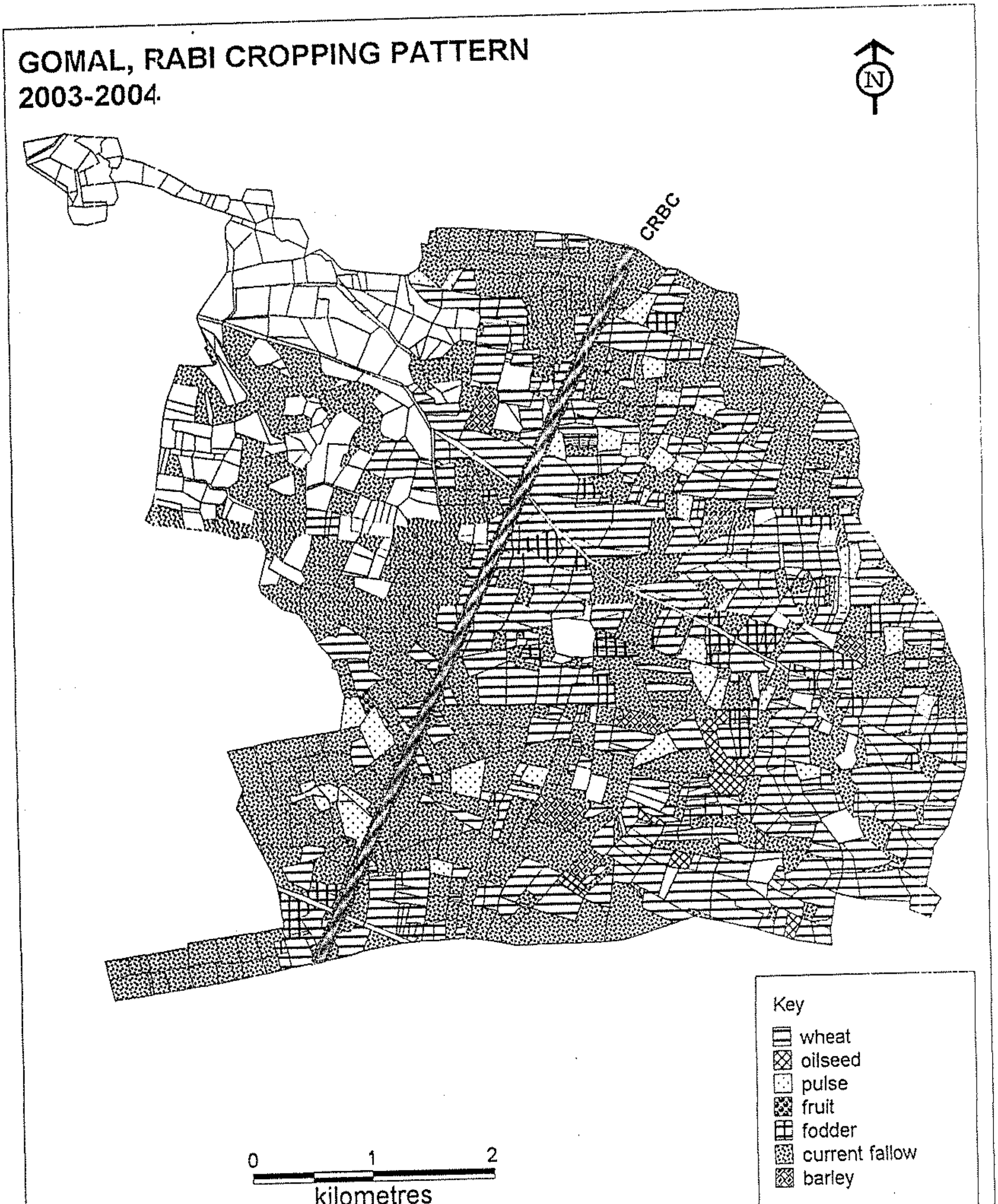


Figure VII-18


GOMAL, RABI CROPPING PATTERN
1987-88
N
KEY
barley
current fallow
fodder
Gram
oilseed
wheat
0
1
2
kilometres

Map VII-13


GOMAL, RABI CROPPING PATTERN
2003-2004
N
CRBC
Key
wheat
oilseed
pulse
fruit
fodder
current fallow
barley
0
1
2
kilometres
Map VII-14

iii. BUCHARI

In Buchari, major Rabi crops include wheat, barley, gram, oilseed, fodder and fruits. Before CRBC, in Buchari agricultural land was entirely dependent upon the sporadic rainfall and Rod Kohi irrigation system. The table VII-11 indicates that prior to CRBC, area under Rabi crops varied from zero in 1969-70 and in 1989-90 to maximum 95 ha in 1979-80. This indicates wide uncertainty before CRBC in the Rabi cropped area. However, after CRBC, large proportion of cultivable waste was brought under the command of CRBC. The figure VII-19 elaborates that during the study period there has been gradual increase in the Rabi cropped area, which marked the highest recorded figure of 326 ha in 2003-2004.

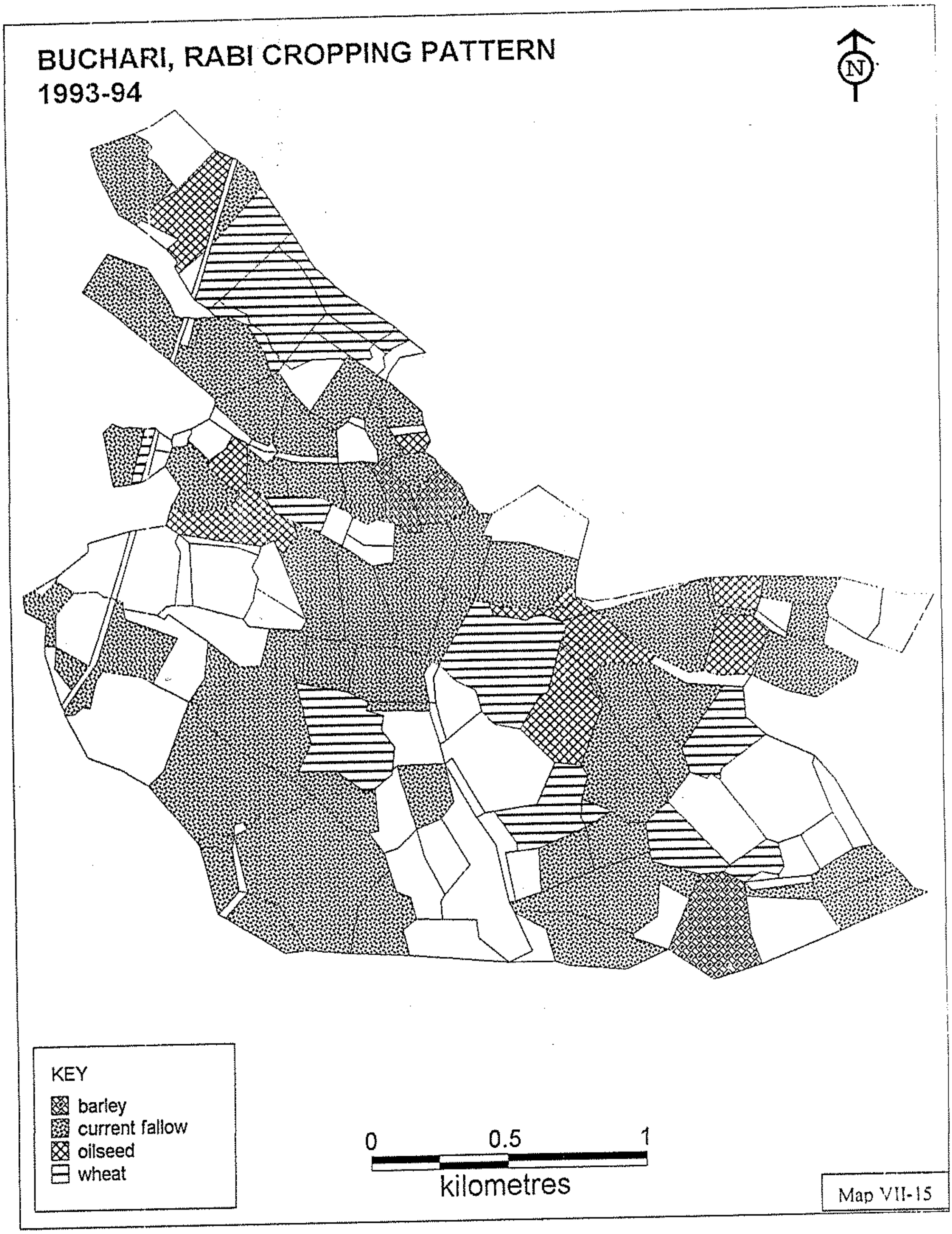
The analysis reveals that throughout the study period from 1967-68 to 2003-04, wheat remained the dominant crop (Map VII-15 and 16). The table VII-11 shows that before CRBC, area under wheat crop varied from season to season, mainly due to non-availability of water. Field survey together with the revenue record reveals that before CRBC, wasteland was mostly used as a grazing land. Therefore area under fodder crop is not reported. However, after CRBC, wasteland has been converted into cultivated land and farmer switched-over to fodder, in order to feed their livestock. Beside this, Rabi oilseed is also reported both before and after CRBC. The important oilseeds are *Ussan* (*Brassica Napus*) and *sarshaf* (*Brassica campestris*); of these *Ussan* is by far the most important and occupied about 80% of the area under oilseed. Oilseed is predominantly grown on the Rod Kohi and rainfed areas. However, after CRBC oilseed is also reported but from limited area (Map VII-16). The figure VII-20 reveals that after comparing pre and post CRBC positive changes have been recorded in wheat, pulses and fodder, which is also similar to macro level changes. However, negative changes have been recorded in barley and oilseed, which is also identical to macro level changes.

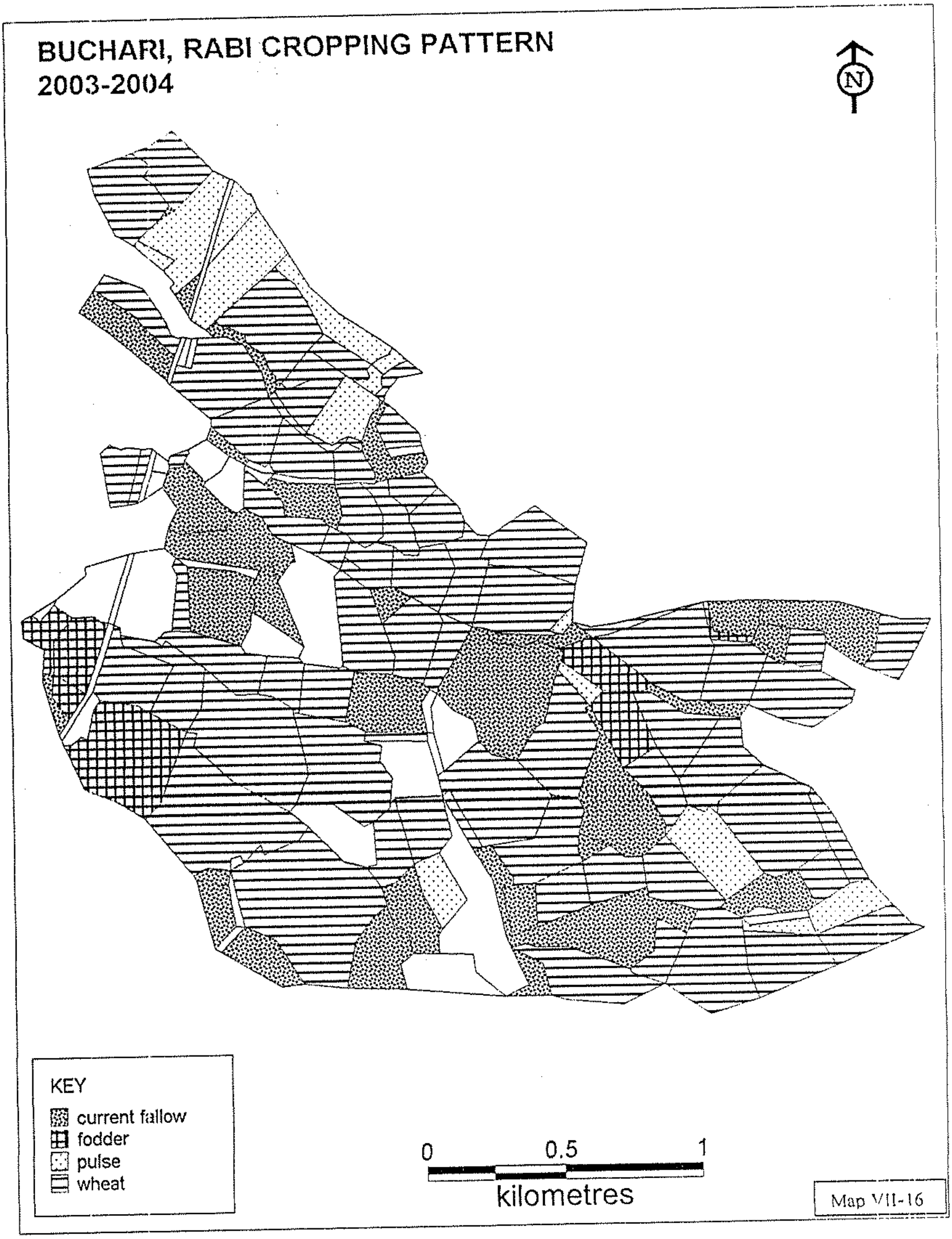
Table VII-11

Buchari, Rabi cropping pattern, 1967-2004 (area in ha)

Period	*Year*	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Fodder*	*Fruit*	*Vegetable*	*Total*
Post CRBC	1967-68	13	1	0	2	0	21	0	37
	1969-70	0	0	0	0	0	0	0	0
	1974-75	6	2	0	7	0	0	0	15
	1979-80	39	2	1	53	0	0	0	95
	1984-85	15	4	0	14	0	0	2	35
	1989-90	0	0	0	0	0	0	0	0
	1993-94	20	1	0	3	0	0	0	24
Post CRBC	1994-95	30	5	6	4	1	0	0	46
	1999-00	30	2	0	4	2	0	0	38
	2003-04	270	0	40	0	16	0	0	326

Source: Revenue record (Lal Kitab of Mouza Buchari), 1967-2004


BUCHARI, RABI CROPPING PATTERN
1993-94
N
KEY
barley
current fallow
oilseed
wheat
0
0.5
1
kilometres
Map VII-15



BUCHARI, RABI CROPPING PATTERN
2003-2004
N
KEY
current fallow
fodder
pulse
wheat
0
0.5
1
kilometres
Map VII-16

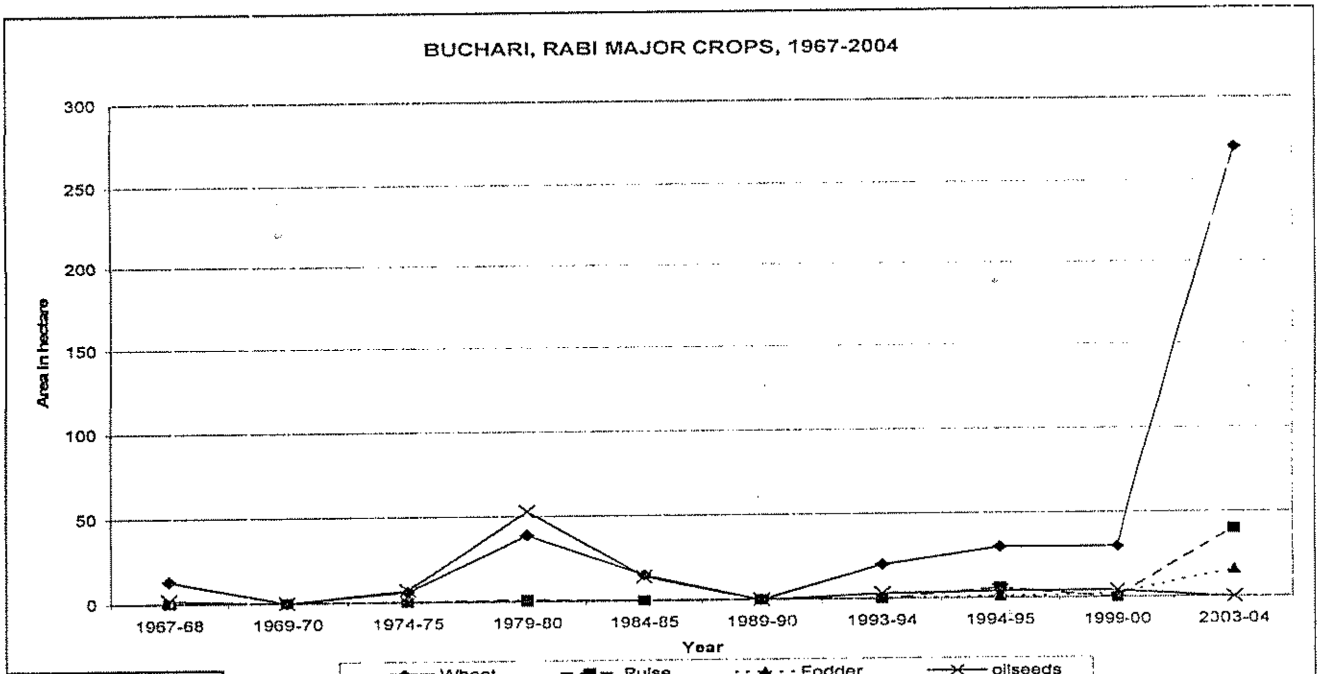


Figure VII-19

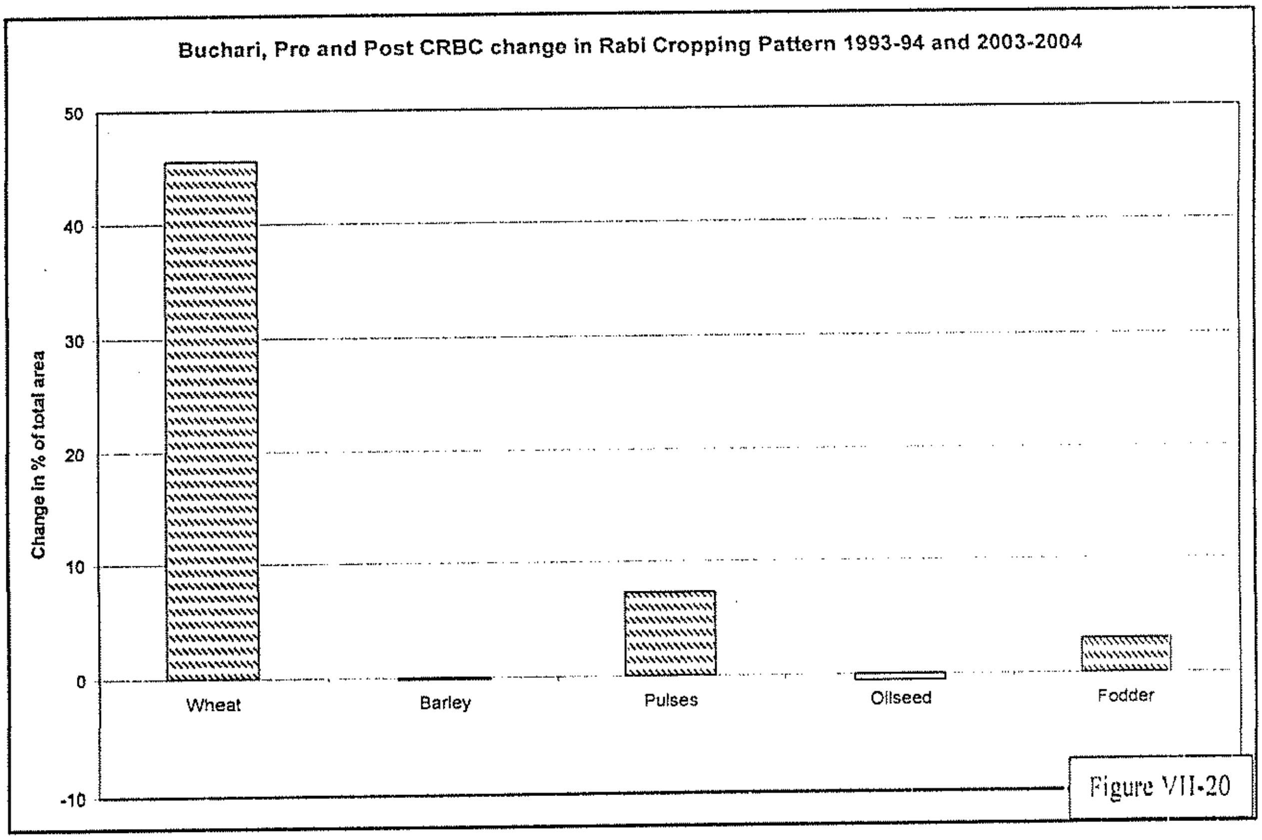


Figure VII-20

vi. CHERA

In Chera, prior to CRBC, the cultivated area was entirely dependent on the Rod Kohi irrigation system. Map VII-17 shows that before CRBC current fallow was the dominant category. The table VII-12 indicates that before CRBC, there were uncertainty in the Rabi acreage but after CRBC a constant increase in the Rabi acreage was recorded. It is clear from the figure VII-21 that before CRBC after a gap of a few years there is a dry spell, which adversely affected the Rabi cropped area. The analysis shows that during pre CRBC from 1967-68 to 1999-2000, the sown area varied from zero to maximum 106 ha (1984-85). There were certain dry spells, when even a single plot was not cultivated (Table VII-12). Comparative analysis of Map VII-17 and Map VII-18 reveal that current fallow was the dominant land use. Because of limited irrigation more crops were not cultivated, whereas after CRBC, current fallow has decreased to greater extent. This single land use clearly indicates positive change after CRBC.

In Chera, important Rabi crops include wheat, barley, pulse and oilseed. Wheat and barley are the major cereal crops grown in the area. However, wheat does best in both the rainfed and Rod Kohi lands. Therefore, area under wheat remained dominant both before and after CRBC (Map VII-17 and 18). Prior to CRBC, there was uncertainty in the cropped area due to the prevailing climatic condition. Whenever, the climatic condition was found favourable, farmers have switched over to wheat, pulse and oilseed. After CRBC, there has been constant increase in the area under Rabi crops. It is clear from the Map VII-18 that after CRBC, wheat is extensively grown followed by pulses and oilseed. This is mainly due to the assured water supply through canal irrigation and bringing of large scale cultivable waste under cultivation. The figure VII-22 reveals that after CRBC major positive changes have been occurred in wheat and pulses, whereas negative changes recorded for oilseed. This indicates that changes in the micro level Rabi cropping pattern is similar to that of macro level.

Table VII-12
Chera, Rabi cropping pattern, 1967-2004 (area in ha)

Period	*Year*	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Total*
Pre CRBC	1967-68	0	0	3	8	11
	1969-70	0	0	0	2	2
	1974-75	0	0	0	0	0
	1979-80	22	0	23	16	61
	1984-85	31	0	33	42	106
	1989-90	30	0	9	25	64
	1994-95	14	5	9	0	28
	1999-00	0	0	0	0	0
Post CRBC	2000-01	46	0	0	3	49
	2003-04	349	0	65	4	418

Source: Revenue record (Lal Kitab of Mouza Chera), 1967-2004

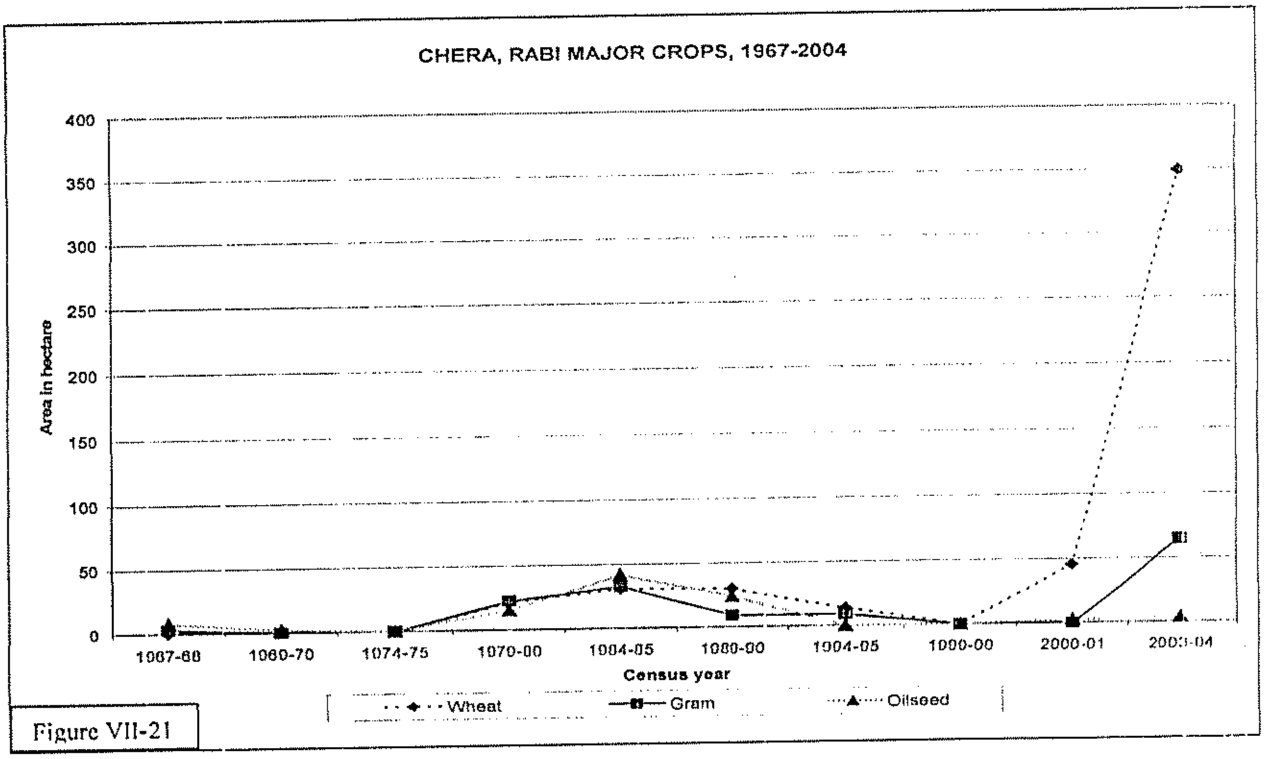


Figure VII-21

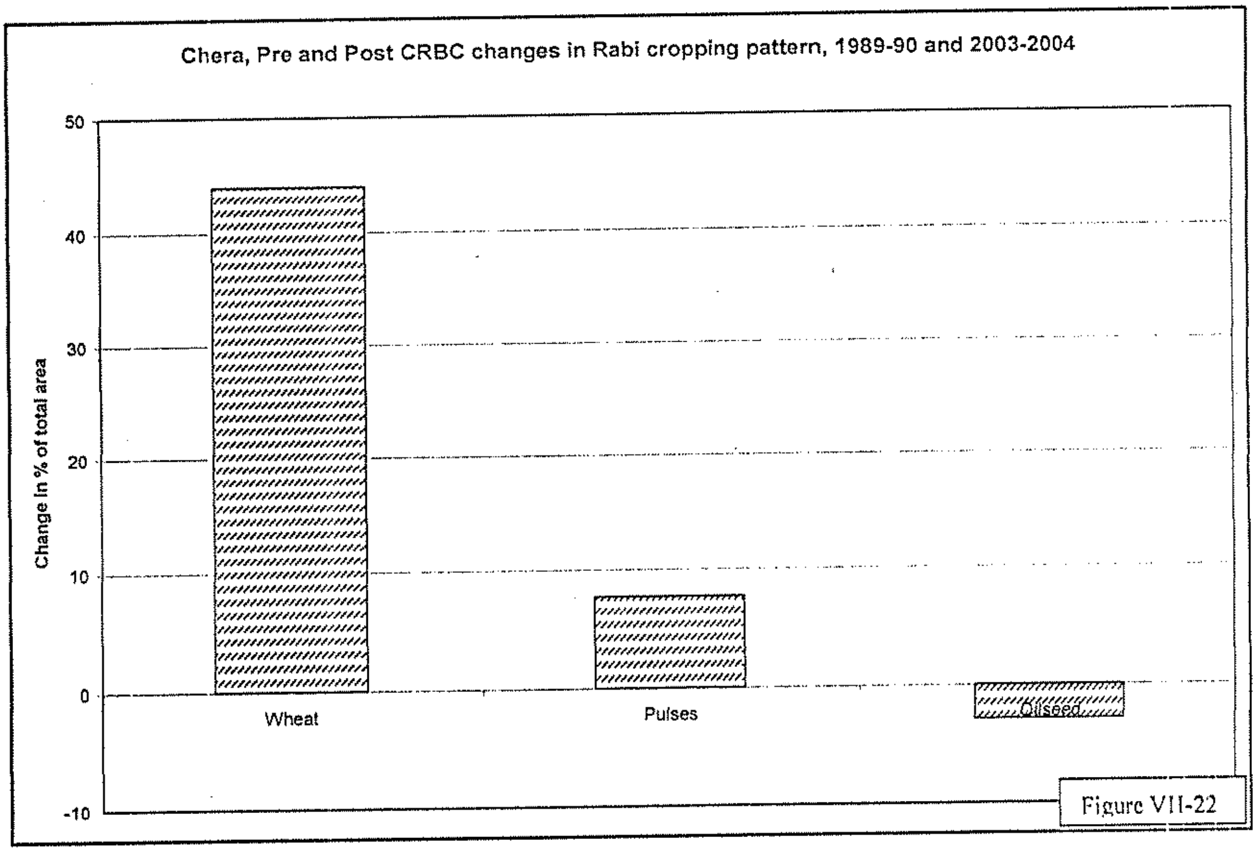
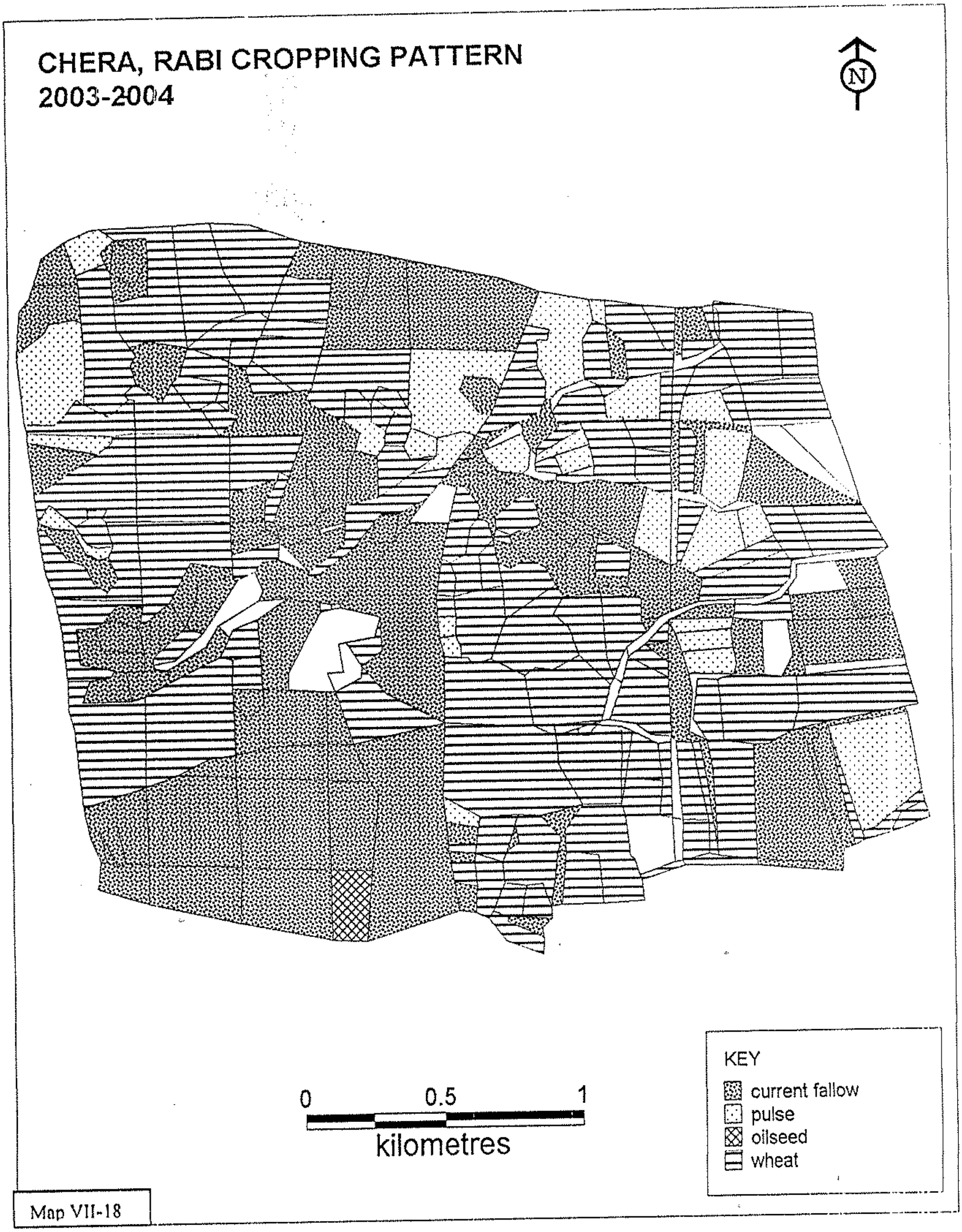


Figure VII-22


CHERA, RABI CROPPING PATTERN
1989-90
N
KEY
current fallow
pulse
oilseed
wheat
0
0.5
1
kilometres
Map VII-17


CHERA, RABI CROPPING PATTERN
2003-2004
N
0
0.5
1
kilometres
KEY
current fallow
pulse
oilseed
wheat

Map VII-18

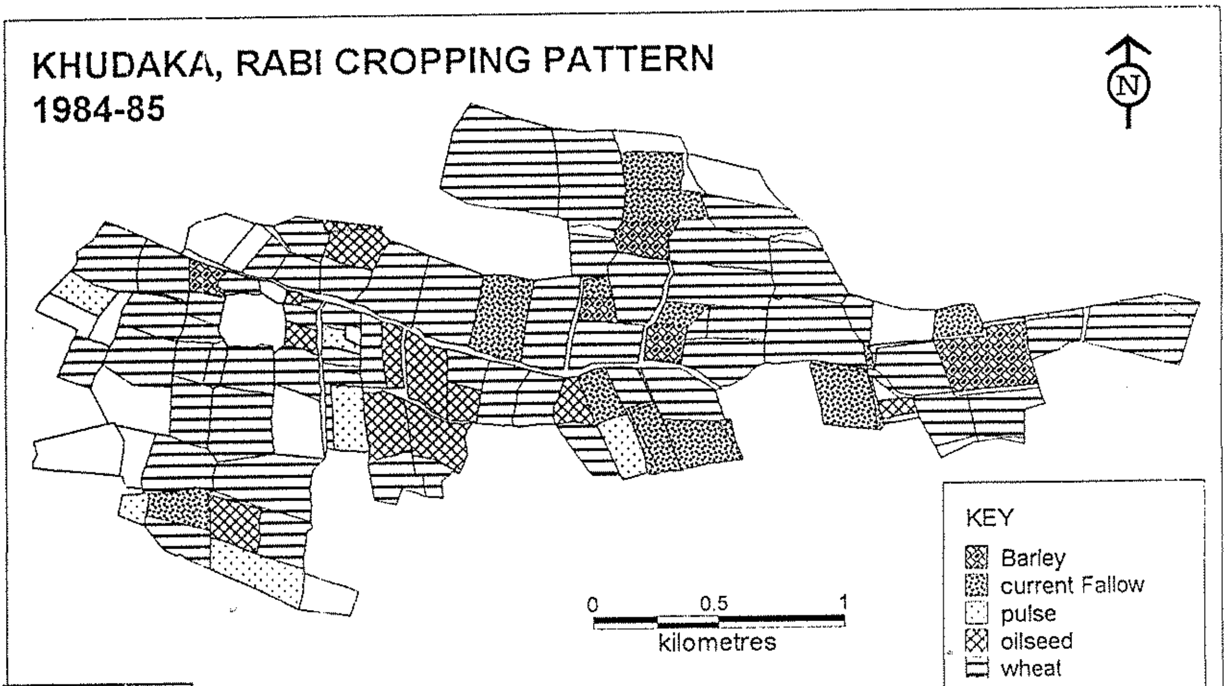
v. KHUDAKA

The analysis reveals that in Khudaka Rabi acreage is uncertain and varied from year to year. The comparative analysis of map VII-19 and 20 indicates that during 1984-1985 large area was found under Rabi crops as against nil in 2003-2004. It is mainly due to the uncertain climatic condition in 2003-2004. In Khudaka, during Rabi season, wheat, barley, gram and oilseed are grown. Wheat is the dominant Rabi crop and grown extensively. In the sample village Khudaka, wheat is grown both over rainfed and Rod Kohi areas, but due to limiting physical factors small acreage reaches the maturity. In 1979-80, wheat was grown on 150 ha as against zero in 1969-70, 1989-90, 1999-2000, 2000-2001 and 2003-2004 (Table VII-13). Beside wheat, barley and gram are also grown but over a limited area. The important oilseed crops are *ussan* (*Brassica Napus*), *Sarshaf* (*Brassica Campestris*) and *Taramira* (*Eruca Sativa*); of these *ussan* is by far the most important and occupies 70-90% of the area under oilseed (Figure VII-23). Ussan is predominantly a crop of dry land, whereas, *sarshaf* and *Taramira* are the crops of rainfed areas (Map VII-19 and 20). Like Kharif cropping pattern, there are certain dry spells due to which cultivation of oilseeds is not reported. Due to limiting climatic factors, fruits, fodder and vegetables are not cultivated. The figure VII-24 reveals that during the study period negative changes have been recorded in all the Rabi crops. This is mainly due to the facts that since 1999 not even a single plot was cultivated.

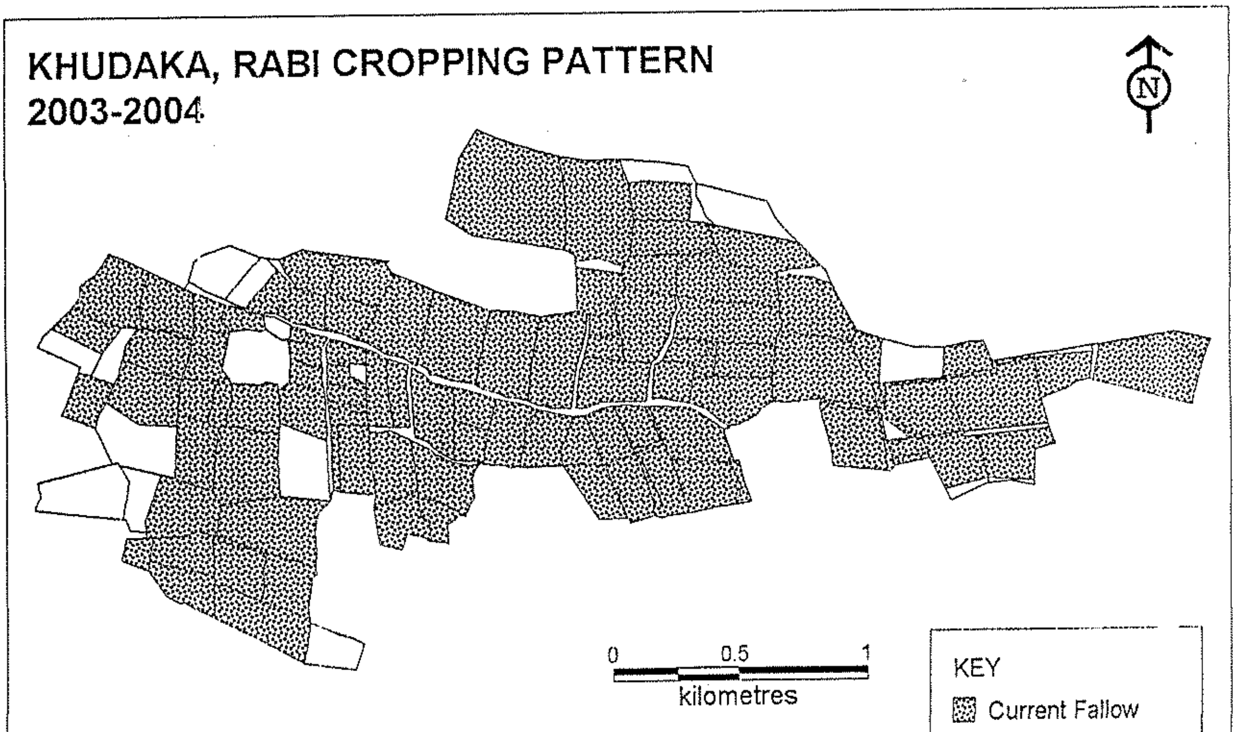
Table VII-13
Khudaka, Rabi cropping pattern, 1967-2004 (area in ha)

Year	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Total*
1966-67	77	0	3	34	114
1969-70	0	0	0	0	0
1974-75	6	0	2	13	21
1979-80	150	7	3	77	237
1984-85	113	8	32	32	185
1989-90	0	0	0	0	0
1994-95	105	54	0	0	159
1999-00	0	0	0	0	0
2000-01	0	0	0	0	0
2003-04	0	0	0	0	0

Source: Revenue record (Lal Kitab of Mouza Khudaka), 1967-2004



Map VII-19



Map VII-20

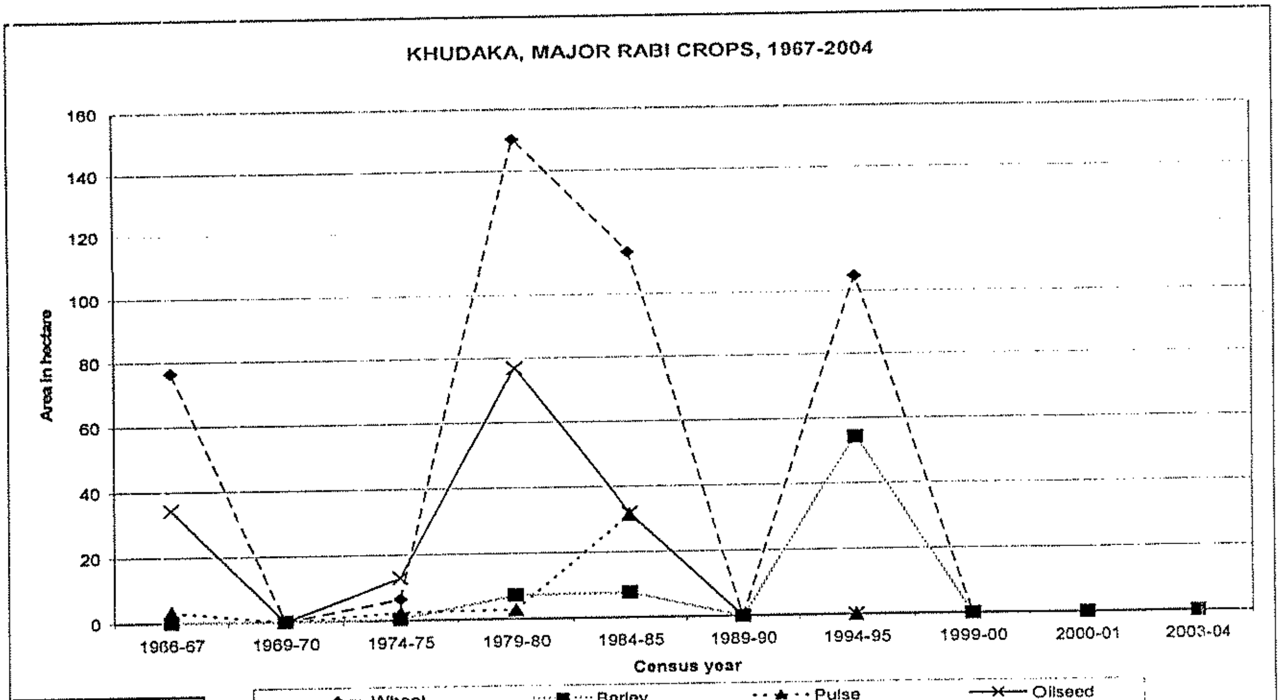


Figure VII-23

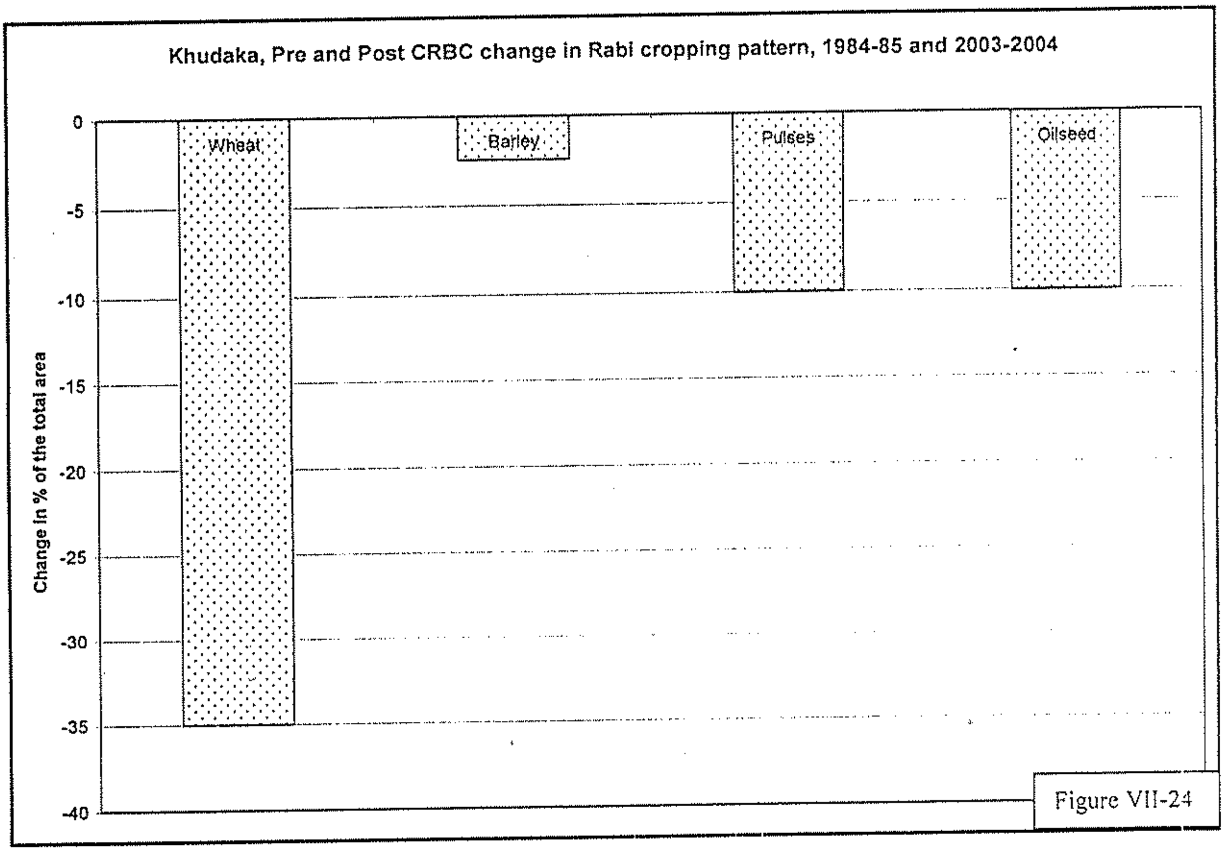


Figure VII-24

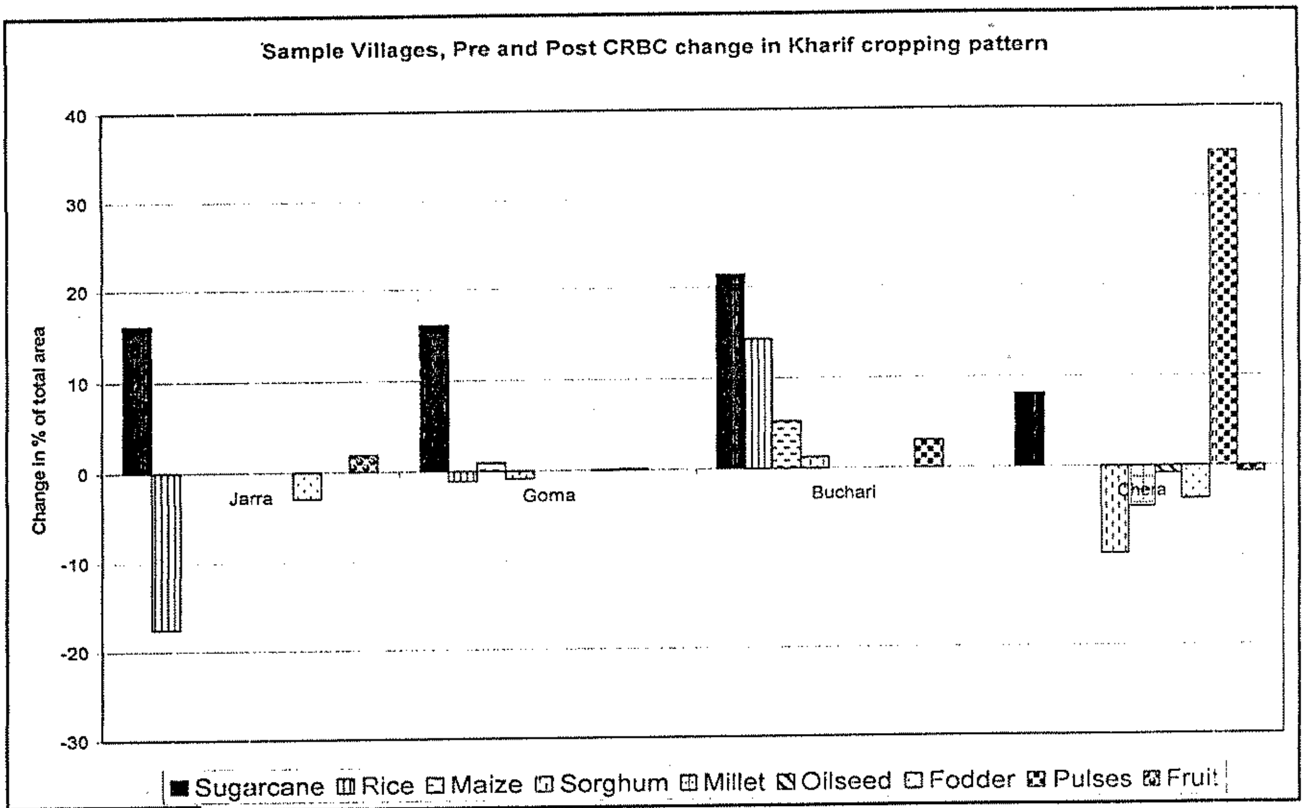


Figure VII-25

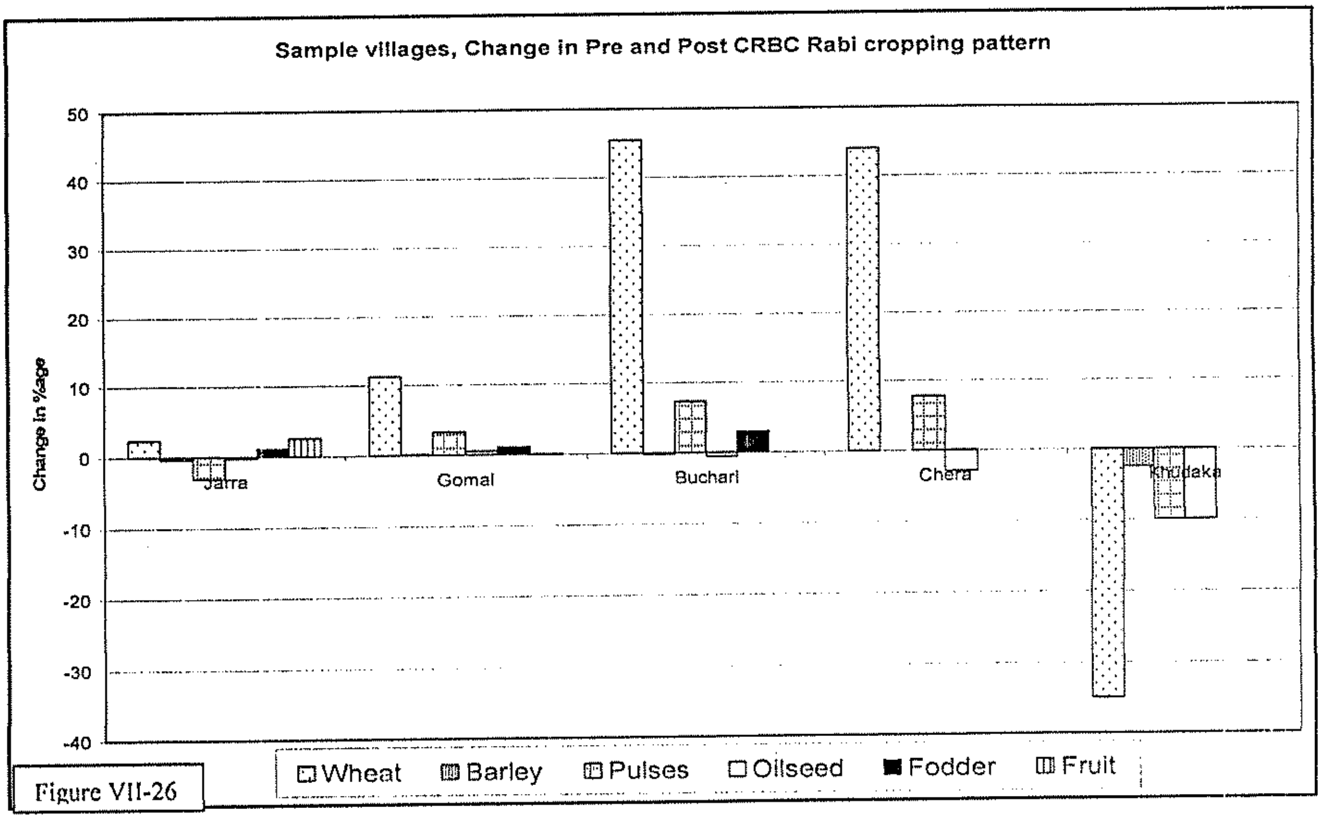


Figure VII-26

7.2 ENVIRONMENTAL IMPACTS OF CRBC ON THE CROPPING INTENSITY

The analysis reveals that since the inception of CRBC, there has been constant increase in the cropping intensity particularly in the CRBC command area. The following discussion explains both the cropping intensity of D.I.Khan district as a whole (macro-level) and cropping intensity of sample villages (micro-level).

7.2.1 Environmental impact of CRBC on the cropping intensity of D.I.Khan district (Macro-level analysis)

Before the introduction of canal irrigation, the cropping intensity in D.I.Khan district was very low. This was mainly due to limited supply of water for agricultural land. Rod Kohi and rainfed cultivation was practiced with uncertainty in maturing crops. However, CRBC has brought an immense change in the cropping intensity. Pre CRBC, small area was under irrigation, but after CRBC, rapid increase in the canal irrigated area occurred mainly due to the inception of Chashma Right Bank Canal.

The table VII-14 indicates that before CRBC in 1969-70, total cultivated land in D.I.Khan district was 232,036 ha. Out of this cultivated land, area under Kharif crops was 20,864 ha, making Kharif cropping intensity of only 9.0%. Similarly, area under Rabi crops in 1969-70 was 58,375 ha, which has resulted Rabi cropping intensity of 25.15% (Table VII-14). The over all picture shows that the annual cropping intensity was 34.15% during 1969-70.

The table VII-14 shows that after the construction of CRBC in 1989-90, total cultivated area was increased to 238,678 ha. Out of this cultivated land 47,724 ha was under Kharif crop, making cropping intensity of 20%, whereas during the same year, Rabi crops were grown over 93,879 ha, giving Rabi cropping intensity of 39%. It means that after inception of CRBC in 1989-1990, the annual cropping intensity of D.I.Khan district has been increased to 49% (Table VII-14).

In 1999-2000, total cultivated area of D.I.Khan district was 233,100 ha (31.9% of the total reported area), out of which 42,150 ha were under Kharif crop, making Kharif cropping intensity of only 18% and that of Rabi (65,407 ha) 28% (Table VII-14). Hence, the annual cropping intensity of D.I.Khan district during 1999-2000 reached to 46% as against 49% in 1989-90. The prevailing low cropping intensity was mainly due to dependence on uncertain rainfall, Rod Kohi irrigation together with the drought period (1997 to 2003) but as a whole in D.I.Khan district, the cropping intensity has been gradually increased mainly due to the extension of CRBC.

The analysis further reveals that after CRBC in 2003-2004, the total cultivated land of D.I.Khan district was 236,371 ha, out of which 40,807 ha were under Kharif crops, which has resulted Kharif cropping intensity of 17.2%, whereas Rabi crops were grown on 70,878 ha showing cropping intensity of 30%. Hence, the annual cropping intensity of D.I.Khan district was registered 47.2% during 2003-2004 as against 46%, during 1999-2000 (Table VII-14). The figure VII-27 shows comparison of pre and post CRBC cropping intensity. It reveals that in the cropping intensity positive changes have occurred, which is an indication that after CRBC cropping intensity has been increased to a greater extent.

TableVII-14
Cropping intensity, D.I.Khan district, 1969-2005

Type of area	*Pre CRBC*		*Post CRBC*		
	1969-70	*1979-80*	*1989-90*	*1999-2000*	*2003-2004*
Cropping intensity	34.15%	DNA	49%	46%	47.2%
Cultivated land	232,036	232,108	238,678	233,100	236,371
Kharif cropped area	20,864 (9.0%)	DNA	47,724 (20%)	42,150 (18%)	40,807 (17.2%)
Rabi cropped area	58,375 (25.15%)	DNA	93,879 (39%)	65,407 (28%)	70,878 (30%)

Source: GoNWFP, 1970; 1980; 1991; 2000c and 2004

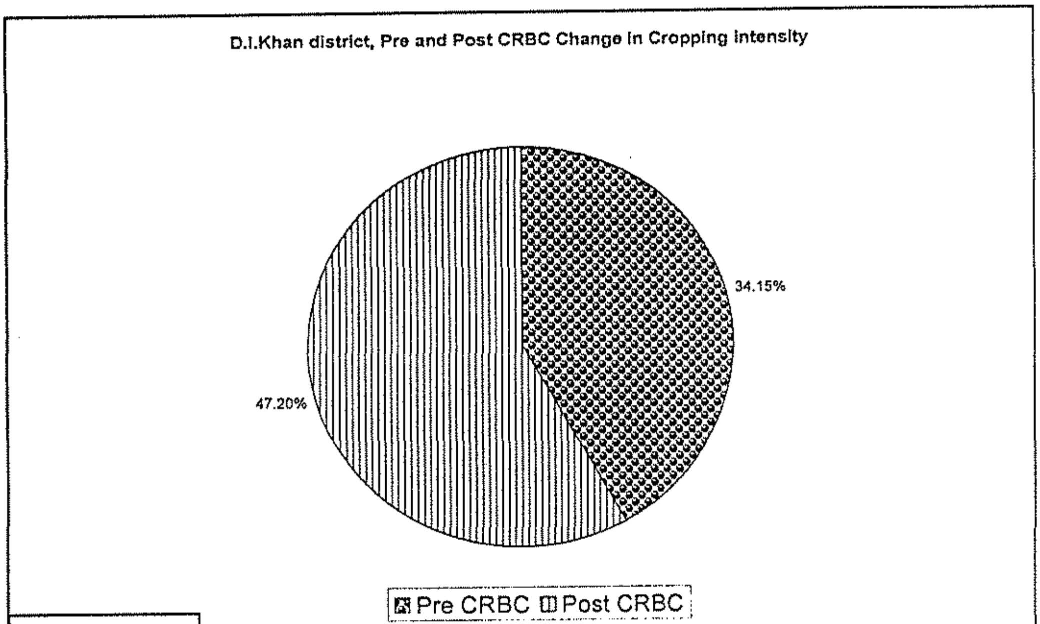


Figure VII-27

7.2.2 Environmental impact of CRBC on the cropping intensity of sample villages (Micro-level analysis)

The cropping intensity of the sample villages varies from one another. The analysis reveals that after CRBC the cropping intensity of CRBC command sample villages have been increased, whereas that of off commands area no impacts of CRBC on the cropping intensity was detected. In Jarra, prior to CRBC (1987-88), total cultivated land was 389 ha. Out of this cultivated area 147 ha was under Kharif crop making cropping intensity of 38% (Table VII-15). During the same year, area under Rabi crops was 300 ha, which gives Rabi cropping intensity of 77%. The figure VII-28 reveals that pre CRBC the annual cropping intensity was 115%. After inception of CRBC this intensity has been reduced to 109%. This high intensity during pre CRBC is mainly because of the fact that Jarra was under the command of old Paharpur canal. However, after CRBC, the annual cropping intensity was reduced to 55% during 1999-2000, but once again in 2003-04, the annual cropping intensity was improved to a level of 109%. This increase in the cropping intensity, from 1999-2000 is attributed to the reclamation of waterlogged and saline area.

Table VII-15
Jarra, cropping intensity and area, 1987-2004 (Area in ha)

Type of area	*Pre CRBC*	*Post CRBC*	
	1987-88	*1999-2000*	*2003-04*
Cropping intensity	115%	55%	109%
Cultivated land	389	248	410
Kharif cropped area	147	28	135
Rabi cropped area	300	110	312

Source: Revenue record (Lal Kitab of Mouza Jarra), 1987-2004

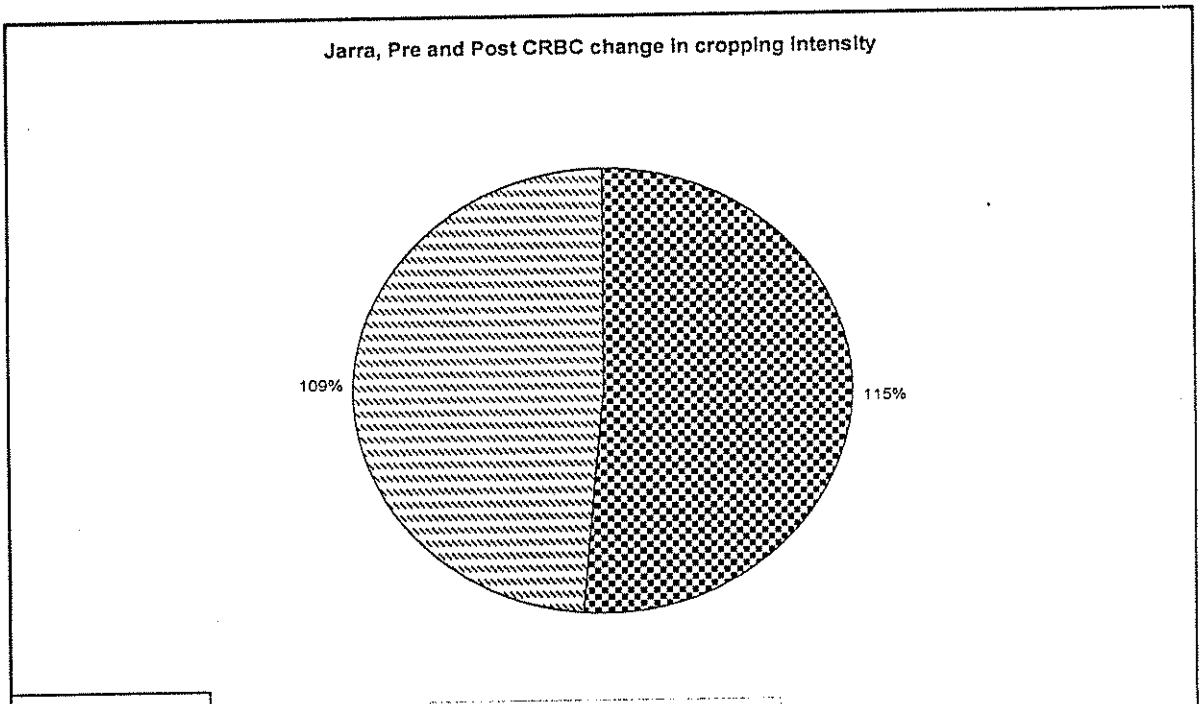


Figure VII-28

In Gomal, prior to CRBC cropping intensity was 78%, which after CRBC increased to 88%.The table VII-16 indicates that before CRBC in 1969-70, Kharif cropping intensity was 6% and that of Rabi 36%. Hence, the annual cropping intensity has marked the figure of 42%, which was further increased to 95% during 1979-80. This increase was due to large-scale availability of water from Rod Kohi that has accelerated the Rabi cropping intensity. However, after CRBC, the annual cropping intensity has shown a consistent increase i.e. 51% in 1989-90, 66% in 1999-2000 and 88% during 2003-04. The table VII-16 indicates that after CRBC both cultivated land and cropped area is gradually increasing due to availability of canal water. It is expected that if this trend continue, the cropping intensity will further enhance in the future.

Table VII-16

Gomal, cropping intensity, 1969-2004 (Area in ha)

Type of area	*Pre CRBC*			*Post CRBC*		
	1969-70	*1979-80*	*1987-88*	*1989-90*	*1999-2000*	*2003-2004*
Cropping intensity	42%	95%	78%	51%	66%	88%
Cultivated land	1,053	1,330	1237	2,381	2,392	2,417
Kharif cropped area	66	174	251	89	551	811
Rabi cropped area	385	1,093	716	1,111	1,004	1,311

Source: Revenue record (Lal Kitab of Mouza Gomal), 1969-2004

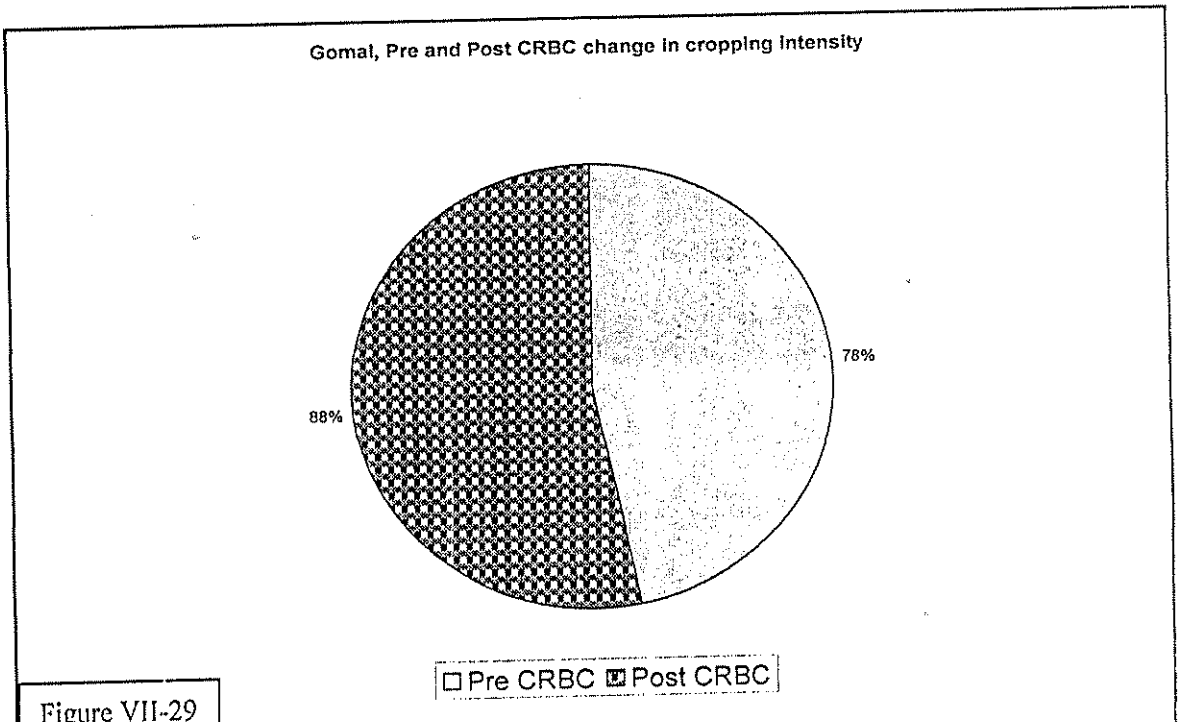


Figure VII-29

In Buchari, before CRBC (during 1969-1970), the total cultivated land was only 3 ha. Almost all this area was under Kharif crop, which makes cropping intensity of 100% as against zero in Rabi (Table VII-17). Hence, before CRBC in 1969-70, the annual cropping intensity was 100%. Nevertheless, during 1979-80, the annual cropping intensity was reduced to 75% as against 15% during 1989-90. The figure VII-30 reveals that prior to CRBC cropping intensity was 44%, which after inception of CRBC has increased to 169%. The analysis reveals that after CRBC, in 1999-2000, the cropping intensity has marked the figure of 38%, which gradually increased to 169% during 2003-04. It is the highest recorded cropping intensity amongst the sample villages. It is expected that it will further boost-up in the preceding years. This steady increase in the cropping intensity is attributed to irrigation facility through CRBC.

Table VII-17

Buchari, cropping intensity and area, 1969-2004 (Area in ha)

Type of area	*Pre CRBC*				*Post CRBC*	
	1969-70	*1979-80*	*1989-90*	*1993-94*	*1999-2000*	*2003-2004*
Cropping intensity	100%	75%	15%	44%	38%	169%
Cultivated land	3	128	74	68	245	345
Kharif cropped area	3	2	11	6	54	256
Rabi cropped area	-	95	-	24	38	326

Source: Revenue record (Lal Kitab of Mouza Buchari), 1969-2004 *- means negligible*

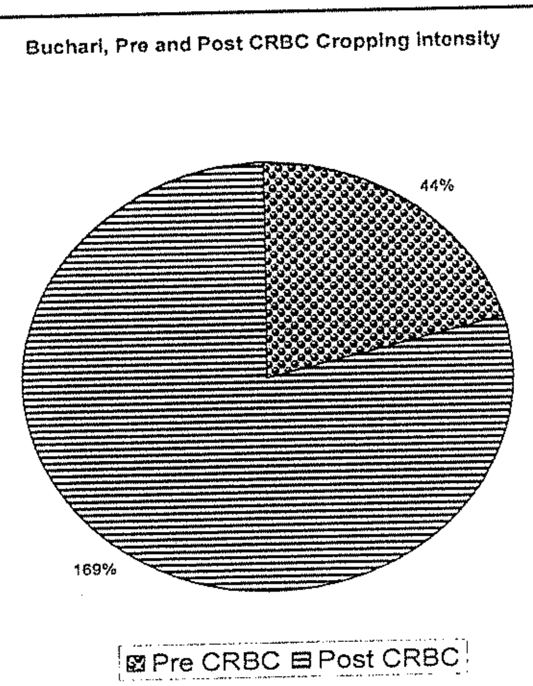


Figure VII-30

The table VII-18 shows that in Chera, prior to CRBC in 1969-70, the cultivated area was 356 ha. Out of this cultivated area 52 ha was under Kharif crops and 2 ha under Rabi (Table VII-18). It means that before CRBC the annual cropping intensity was 16% in 1969-70, 24% in 1979-80, 91% during 1989-90 and 50% in 1999-2000. However, after the inception of CRBC, it has increased to 120% (Figure VII-31). Subsequently, after CRBC both the cultivated area and cropped area were enhanced, which positively affected the cropping intensity. The table VII-18 indicates that after CRBC in 2003-2004, annual cropping intensity marked the figure of 120% with almost equal share from both Rabi and Kharif. This is the highest recorded cropping intensity during the study period and is expected to increase further in the future. The analysis reveals that there has been constant increase in the cropping intensity as a result of CRBC.

Table VII-18

Chera, cropping intensity and area, 1969-2004 (Area in ha)

Type of area	*Pre CRBC*				*Post CRBC*
	1969-70	*1979-80*	*1989-90*	*1999-2000*	*2003-04*
Cropping intensity	16%	24%	91%	50%	120%
Cultivated land	356	369	246	36	627
Kharif cropped area	52	26	160	18	334
Rabi cropped area	2	61	64	-	418

Source: Revenue record (Lal Kitab of Mouza Chera), 1969-2004 *- means negligible*

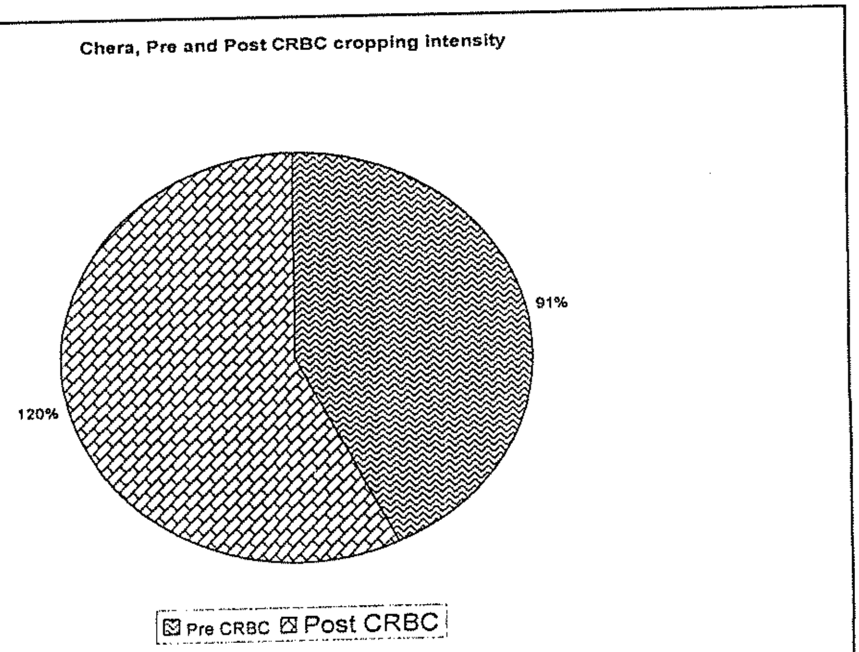


Figure VII-31

Khudaka lies off the CRBC command area and therefore presents quite a different picture as far as cropping intensity is concerned. Here, the cultivated land is entirely dependent on Rod Kohi irrigation system. The table VII-19 indicates that during 1969-70, the annual cropping intensity was 45%, whereas 114% recorded in 1979-80. However, after 1979-80 even a single plot was not cultivated due to non-availability of Rod Kohi water, therefore impact of CRBC on the cropping intensity was not detected.

Table VII-19
Khudaka, cropping intensity and area, 1969-2004 (Area in ha)

Type of area	*1969-70*	*1979-80*	*1989-90*	*1999-2000*	*2003-04*
Cropping intensity	45%	114%	-	-	-
Cultivated land	234	256	-	-	-
Kharif cropped area	105	55	-	-	-
Rabi cropped area	-	237	-	-	-

Source: Revenue record (Lal Kitab of Mouza Khudaka), 1969-2004 *- means negligible*

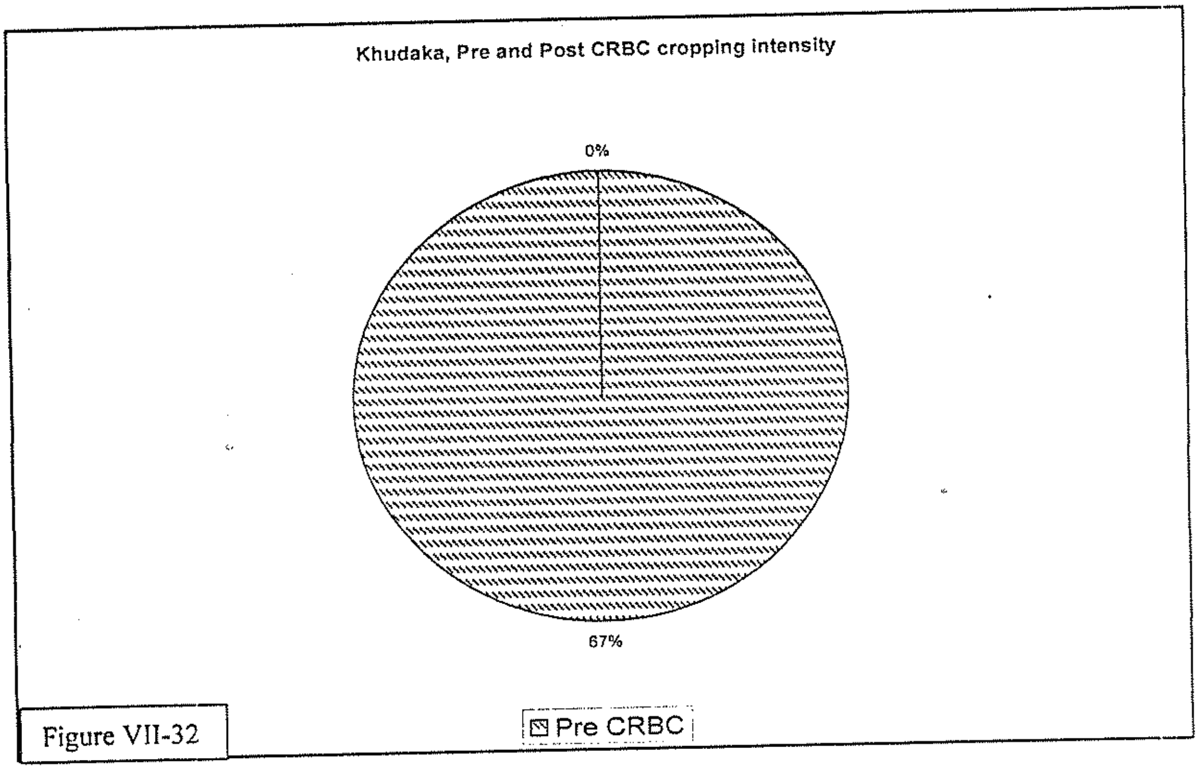


Figure VII-32

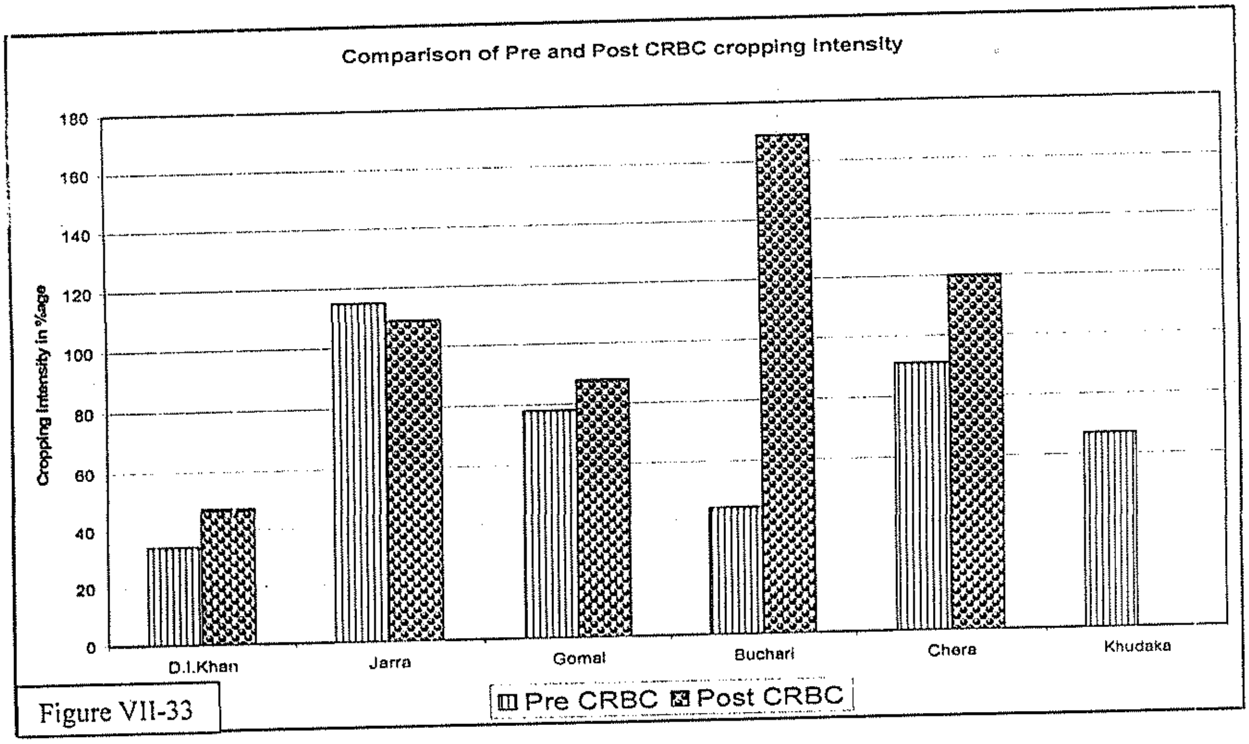


Figure VII-33

Table VII-20

Pre and Post CRBC Macro and micro level cropping intensity

Level	*Area*	*Pre CRBC %*	*Post CRBC %*	*Change in %age*
Macro	D.I.Khan	34.15	47.2	13.05
Micro	Jarra	115	109	-6
	Gomal	78	88	10
	Buchari	44	169	125
	Chera	91	120	29
	Khudaka	67	0	-67

Source: Revenue record (Lal Kitab of Mouza Khudaka), 1969-2004

7.3. CONCLUSION

The macro analysis of Kharif cropping pattern revealed that after CRBC net positive changes were reported in rice, sugarcane, pulses, orchards and vegetables. These positive changes are attributed to the advent of canal irrigation in the form of CRBC. The analysis revealed that after CRBC the farmer switched over to water loving crops. In the present cropping system new crops such as rice, sugarcane and orchards have been introduced. Contrary to this negative changes were registered in sorghum, millet, oilseed, barley and maize. These are the crops, which respond better if water supplied accordingly. However, prior to CRBC due to limited assured water supply drought resistant crops were preferred by the farmers, whereas after CRBC the farmer switched over to more productive crops. The analysis further revealed that there had been increase in the Rabi acreage from 72,490 ha pre CRBC to 80,863 ha post CRBC. Prior to the inception of CRBC wheat, barley, pulses and fruits were the dominant crops grown in the district. Acreage-wise wheat, pulses and oilseed had a highest share as against the fruit. However, after CRBC a positive change had been recorded in wheat, pulses and fruit, whereas negative changes occurred in barley and oilseed.

The micro level analysis of Kharif cropping pattern revealed that after comparing pre and post CRBC condition, it was found that positive changes have been recorded in sugarcane, rice, pulses and fruit, whereas negative changes were occurred in maize, sorghum, oilseed and fodder. Moreover, it was found from the comparative analysis that in both the cases area under sugarcane, rice, pulses and fruit considerably increased, whereas area under sorghum, millet, oilseed and fodder drastically reduced. The micro level analysis outside the CRBC command area was quite different than the CRBC commands villages. In Khudaka both pre and post of CRBC, even a single plot was not cultivated during Kharif cropping season. The micro and macro level analysis confirmed that changes in the Kharif cropping pattern was largely found identical. The micro level analysis of Rabi cropping pattern revealed that positive changes have occurred in wheat, pulses, fodder and fruit, after CRBC. However, negative changes were recorded in barley and oilseed. The comparative analysis of micro and macro level revealed that similar positive changes were recorded for wheat, pulses and fruit, while negative changes were also found identical. Hence, it can be concluded that after CRBC trend towards new water loving crops such as sugarcane, rice and orchard were increased.

The analysis revealed that after CRBC the cropping intensity has been increased considerably. In D.I.Khan district, after comparing pre and post CRBC cropping intensity, a positive change of 13.05% of the total area has taken place. The micro level analysis revealed that in Jarra, a negative change of 6% has occurred, which is mainly due to the problem of waterlogging and salinity. However, in rest of the CRBC command sample villages, the cropping intensity has improved. In Gomal 10%, Buchari 125% and Chera 29% positive changes in the cropping intensity have been registered. This clearly indicates that after inception of CRBC the cropping intensity has enhanced both at micro and macro level. On the other hand, outside the CRBC command area (Khudaka) no impact of CRBC on the cropping intensity was detected.

ENVIRONMENTAL IMPACTS OF CRBC ON THE AGRICULTURAL PRODUCTION, MECHANIZATION, LAND VALUES AND WATER-TABLE

Introduction

The previous chapter discussed the environmental impacts of CRBC on the cropping pattern and cropping intensity of D.I.Khan district, while this chapter assesses the environmental impacts of CRBC on the agricultural production, mechanization, land values and water-table. This chapter is divided into five sections. Section one deals with the environmental impacts of CRBC on the agricultural production. Section two describes the impacts of CRBC on the mechanization, whereas section three assesses environmental impacts of CRBC on the land values. Section four describes the impacts of CRBC on the ground water-table, whereas conclusion is given in the final section.

8.1 ENVIRONMENTAL IMPACTS OF CRBC ON THE AGRICULTURAL PRODUCTION

Agricultural (crop) production is directly related to yield per hectare that gives the productivity of the land. It followed that higher the yield, higher would be the production and consequently increase in the gross value of crop production would occur. As such, average yield is an important indicator of the production process. In the following paragraphs, the environmental impact of CRBC on the agricultural production is discussed both at macro and micro level, respectively.

8.1.1 Impacts of CRBC on the agricultural production of D.I.Khan district (Macro level analysis)

This section analyses the agricultural production both before and after the inception of CRBC (from 1970 to 2005). The agricultural production is also discussed with special reference to irrigated and un-irrigated areas. The production value for all the (pre and post CRBC) crops has been calculated at market price, 2006, to get clear picture of change in crops production value. The discussion is based on two broad categories i.e. Kharif and Rabi.

A. Kharif crops

It was found that after inception of CRBC, the production of almost all the Kharif crops have been improved (Table VIII-1). The increase in agricultural production has been recorded in rice, sugarcane, cotton, maize and pulses, whereas negative change in agricultural production has occurred in millet, sorghum and oilseed (Figure VIII-1). It was found that after CRBC the yield in kg per ha of all the Kharif crops has been improved. The production value of Kharif crops has estimated at market price 2006. The comparison of pre and post CRBC conditions shows positive changes for rice, sugarcane, cotton, maize, pulses and fruit, whereas negative production value has been registered for millet, sorghum and oilseed. The positive changes in sugarcane and rice production is mainly due to the farmer's trends to high return crops after CRBC.

Table VIII-1

D.I.Khan district, Pre and Post CRBC Kharif Production

Period	Indicators	Rice	Sugarcane	Cotton	Maize	Millet	Sorghum	Pulse	Oilseed	K.Fruit
Pre CRBC	Yield in Kg/ha	1,495	29,871	1,243	988	349	308	457	230	-
	Production in tones	2,800	95,500	2,676	1,600	2,900	4,300	54	56	-
	Value in million rupees	112	200.5	107	16	29	43	1.6	1.7	57
Post CRBC	Yield in Kg/ha	2,815	42,440	2,519	1,847	635	616	647	333	-
	Production in tones	18,374	490,819	5,143	2,197	924	1,798	2,734	0.4	-
	Value in million rupees	734.9	1030.8	205.7	22	9.3	18	82	0.01	1971
Change	Change in value (in million rupees)	622.9	830.3	98.7	6	-19.7	-25	80.4	-1.69	1914

Source: GoNWFP, 1975; 1980; and 2005 *Value is estimated at market price, 2006*

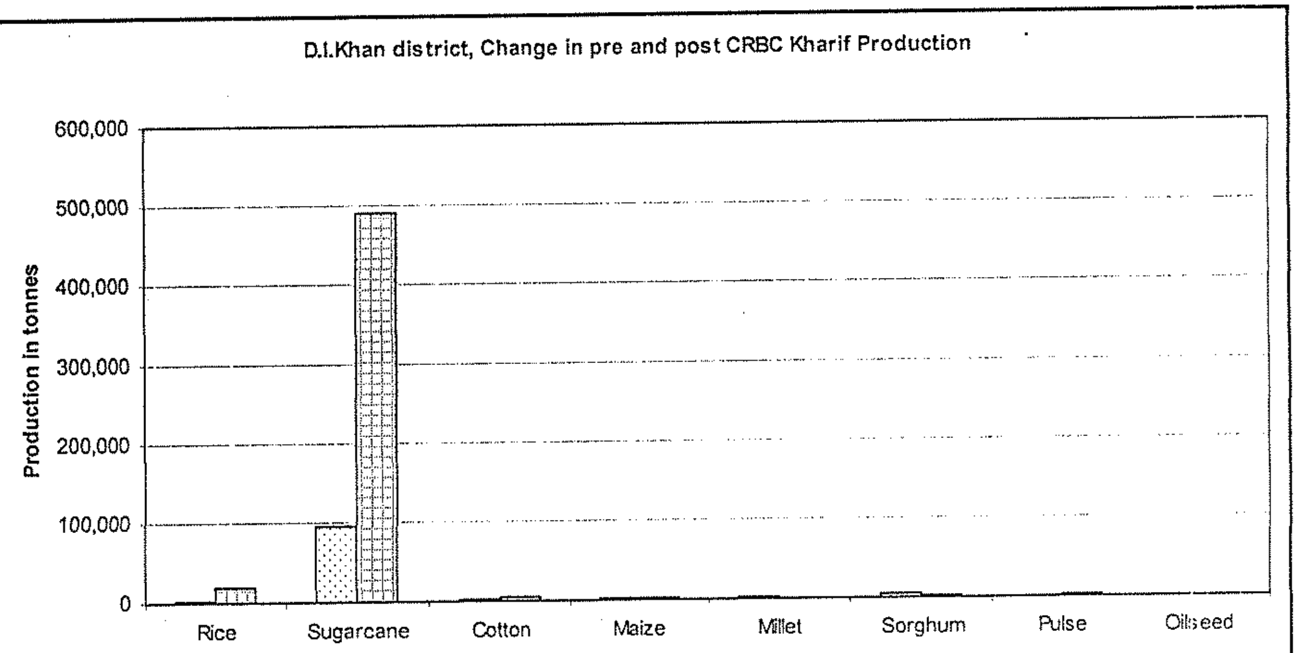


Figure VIII-1

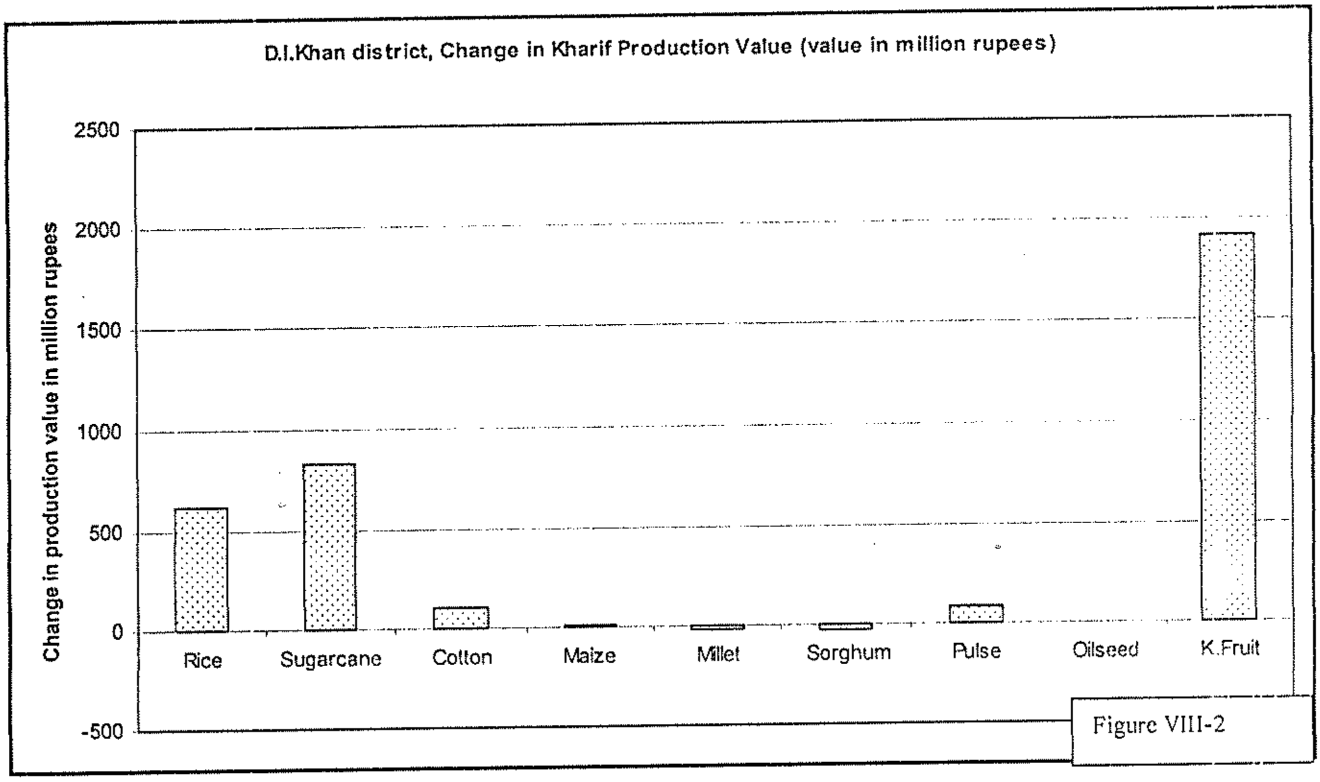


Figure VIII-2

The analysis further reveals that there has been constant increase in the rice production after CRBC. Prior to the inception of CRBC, total rice production was 2,800 tonnes in 1970, which after CRBC increased to 18,374 tonnes in 2005 (Table VIII-1). It is pertinent to note that rice production is only reported from the irrigated areas, as rice requires plenty of water. It was found during field survey that two important varieties are very common among the farmers i.e. IRRI and Ks-282. The figure VIII-2 reveals that after CRBC a positive change in production value has occurred. The increase in production and yield per hectare is attributed to the introduction of canal irrigation in the form of CRBC.

The table VIII-1 indicates that in D.I.Khan district, there has been gradual increase in the sugarcane production. Prior to CRBC, sugarcane production was 95,500 tonnes in 1970, which increased to 490,819 tonnes after CRBC in 2005 (Figure VIII-1). As sugarcane is a water-loving crop, therefore it is predominantly reported from the irrigated areas. The analysis further reveals that the increasing production is predominantly because of canal irrigation. In D.I.Khan district, before CRBC yield in Kg per ha was 29,871 during 1970, whereas after CRBC it marked the figure of 42,440 in the year 2005. The figure VIII-2 reveals that a positive change in production value has occurred.

The analysis reveals that after CRBC the production of cotton has been increased in the last twenty years. Prior to CRBC, cotton production was 2,676 tonnes in the year 1985, which was increased to 5,143 tonnes after CRBC in 2005 (Figure VIII-1). However, the cotton production was found maximum over the irrigated areas as against un-irrigated areas. The figure VIII-2 reveals that a positive change in production value has been occurred. Likewise, there has been an increase in the yield after commissioning of CRBC. On the average before CRBC, the yield in Kg per ha was 1,243 in 1985, which after CRBC has been increased more than two fold (2,519 kg/ha) in 2005. This increase is attributed to the enhancement of canal irrigation.

The analysis reveals that the production of maize has gradually increased during the study period. The table VIII-1 shows that after CRBC in 2005, the total production was 2,197 tonnes as against 1,600 tonnes before CRBC in 1970. The analysis further elaborates that the maize production does best over the irrigated land. Therefore prior to CRBC yield in kg per ha was 988 (1970), which was increased to 1,847 after CRBC (2005). This indicates that the introduction of canal irrigation system has accelerated the yield per ha. The figure VIII-2 reveals that a positive change in production value of maize has been recorded.

In D.I.Khan district, millet is predominantly a crop of un-irrigated area. However, it is grown over irrigated area as well. The analysis reveals that area under millet has been gradually reducing. Before CRBC, millet production was 2,900 tonnes, which after inception of CRBC has gradually reduced to 924 tonnes in 2005. The decrease in production is mainly due to the reduction in area under millet. As a result more area came under canal irrigation. This canal irrigated area was given to more productive crops as compared to millet. The table VIII-1 indicates that yield in Kg per ha is gradually increasing both over irrigated as well as on un-irrigated land. Before CRBC, in 1970 yield in Kg per ha was 349, whereas, after CRBC the yield has increased to 635 kg/ha. The figure VIII-2 reveals that a negative change in production value of millet has been recorded.

The Table VIII-1 elaborates that there has been constant decrease in the production under sorghum, whereas yield per ha is encouraging. Before CRBC, in 1970 total production of sorghum was 4,300 tonnes, but after CRBC in 2005, the production was reduced to 1,798 tonnes. The reduction in sorghum production is mainly due to the allocation of land to other high return crops. The figure VIII-2 reveals that a negative change in production value has been recorded. However, the yield in kg per ha is improving (Table VIII-1). Before CRBC, in 1970, the yield in Kg per ha was 308, which after CRBC has increased to 616 kg per ha in 2005. The analysis reveals that yield in Kg per ha is encouraging over the irrigated areas as against un-irrigated land. This is mainly due to the advent of canal irrigation.

In Kharif pulses mung bean is the predominant pulse grown in D.I.Khan district. The table VIII-1 indicates that after CRBC both production and yield of Kharif pulses has been increased. Before CRBC, production of Kharif pulses was 54 tonnes, which has been rapidly enhanced to 2,734 tonnes after CRBC. The increase in the pulses production is attributed to the increasing acreage as a result of CRBC. The figure VIII-2 reveals that after CRBC a positive change in production value has been recorded. As far as yield per ha is concerned, it is also improving. Before CRBC, yield in Kg per ha was 457 as against 647 after CRBC. The increase in production and yield per ha is because of canal irrigation.

In D.I.Khan district, important Kharif fruits are watermelon, muskmelon, dates, apple and mango. The table VIII-2 indicates that there has been consistent increase in the production and yield per hectare of Kharif fruits particularly after CRBC. Similarly, with increasing production yield in Kg per ha was also improved from 11,756 pre CRBC (1980) to 12,974 after CRBC in 2000. The table VIII-2 reveals that since the inception of CRBC, the production of almost all Kharif fruits has increased. A comparison of pre and post CRBC conditions of Kharif fruits indicates that a positive change in production value has been recorded (figure VIII-2).

Table VIII-2

Kharif Fruits, acreage, production and yield, 1980 and 2000

Fruit	*Pre CRBC 1980*			*Post CRBC 2000*		
	Area (In ha)	*Production (in tonnes)*	*Yield in Kg/ha*	*Area (in ha)*	*Production (in tonnes)*	*Yield in Kg/ ha*
Watermelon	1	60	60,000	305	18,442	61,269
Muskmelons	291	3,421	11,756	8,521	110,550	12,974
Dates	9	54	6,000	462	2,772	6,000
Apple	7	63	9,000	40	360	9,000
Mango	8	88	11,000	105	1,155	11,000
Total	316	-	-	9,433	-	-

Source: GoNWFP, 1981and 2000c

B. Rabi crops

The table VIII-3 reveals that after the inception of CRBC, the production of almost all the Rabi crops have increased. The improvement in the agricultural production has been recorded in wheat, pulses and fruits, whereas negative change in agricultural production has occurred in barley and oilseed (Figure VIII-3). The figure VIII-4 reveals that after comparing pre and post CRBC condition positive changes in production value has been recorded for wheat, pulses and fruit, whereas negative production value has been registered for barley and oilseed. The analysis also reveals that after the inception of CRBC, the yield in kg per ha of all the Rabi crops has been enhanced.

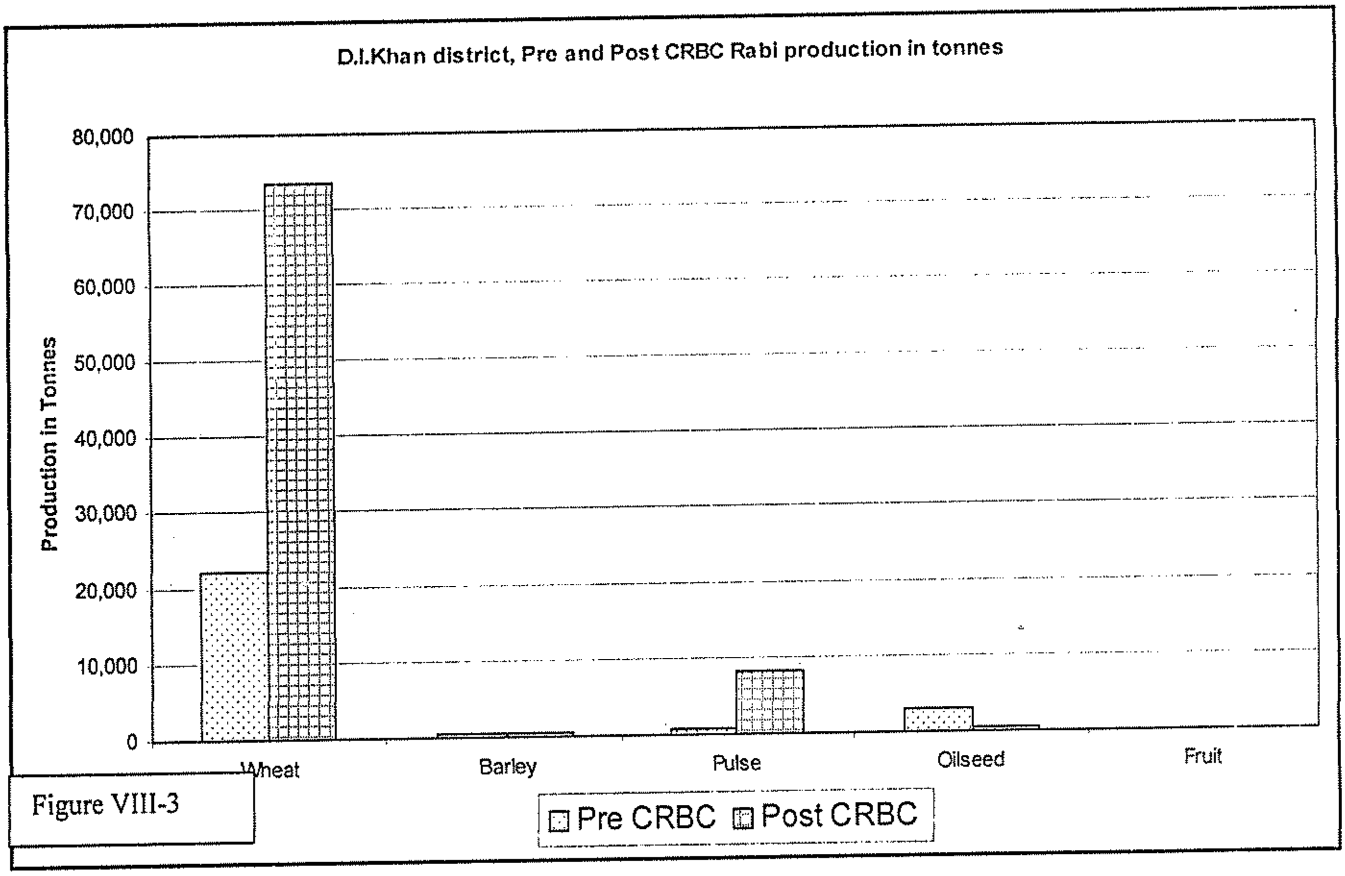


Figure VIII-3

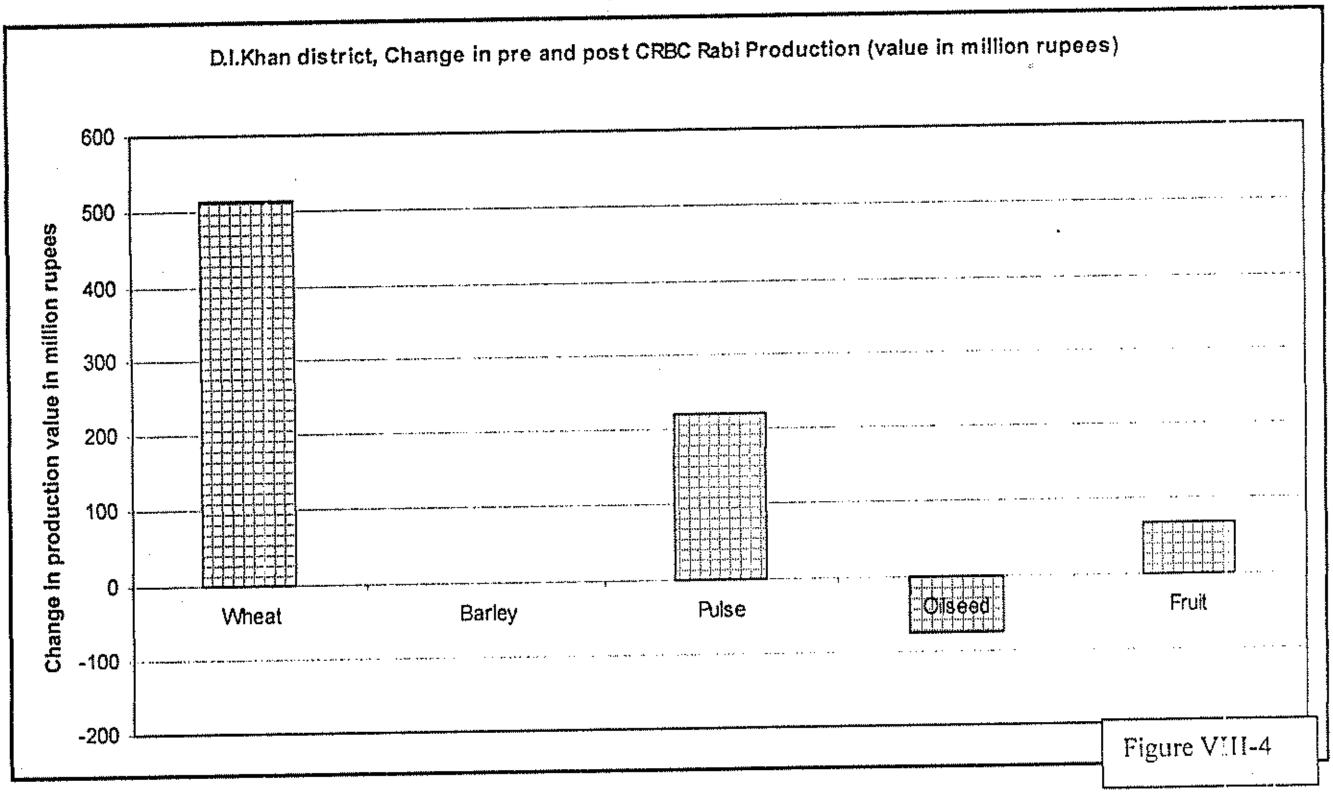


Figure VIII-4

Table VIII-3
D.I.Khan district, Pre and Post CRBC Rabi Production

Period	**Indicators**	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Fruit*
Pre CRBC	Yield in Kg/ha	416	322	90	370	-
	Production in tones	22,200	600	800	3,100	-
	Value in million rupees	222	1.8	24	93	2.44
Post CRBC	Yield in Kg/ha	1,531	692	408	354	-
	Production in tones	73,544	557	8,184	576	-
	Value in million rupees	735.4	1.67	245.5	17.2	69.4
Change	Change in value (in million rupees)	513.4	-0.13	221.5	-75.8	66.96

Source: GoNWFP, 1975; 1980; 1991; 2000c; 2004 and 2005 *Value is estimated at market price, 2006*

The table VIII-3 reveals that after the inception of CRBC there has been constant increase in the wheat production. Before CRBC, wheat production was 22,200 tonnes as against 73,544 tonnes after CRBC. The analysis reveals that after CRBC there has been 331% enhancement in the wheat production. This indicates positive impact of CRBC on the wheat production. The analysis reveals that after CRBC both production and yield per ha is increasing (figure VIII-4).

In D.I.Khan district before CRBC, barley production was 600 tonnes, which after CRBC has been reduced to 557 tonnes (Figure VIII-3). The figure VIII-4 reveals that after comparing pre and post CRBC production value a negative change of 0.13 million rupees has been recorded. Consequently, the acreage is gradually shrinking but the production and yield per ha is improving. This is mainly due to the introduction of canal irrigation.

Prior to CRBC, production of Rabi pulses was 800 tonnes as against 8,184 tonnes (almost ten fold increase) after inception of CRBC (Figure VIII-3). The analysis reveals that after comparing pre and post CRBC production value a net positive change of 221.5 million rupees has been recorded. As a result of CRBC, the pulse production was greatly increased. Likewise, the yield in Kg per ha has been improved from pre CRBC 90 Kg to post CRBC 408 kg per ha.

The table VIII-3 indicates that prior to CRBC, the production of Rabi oilseed was 3,100 tonnes, which was reduced to 576 tonnes after CRBC. The figure VIII-4 reveals that after CRBC, a negative change of 75.8 million rupees has been recorded in production value of oilseed.

In D.I.Khan district, important Rabi fruits are citrus, guava and banana. The yield in Kg per ha was improved from 11,000 Kg per ha pre CRBC in 1979-80 to 15,000 Kg after CRBC (Table VIII-4). This indicates farmer trend towards horticulture and awareness as a result of CRBC. After inception of CRBC, banana was found on 19 ha as against nil before CRBC. The overall Rabi fruits acreage, production and yield in Kg per ha has shown positive changes. After comparing pre and post CRBC production value a positive change of 66.96 million rupees has been recorded in Rabi fruits (Figure VIII-4).

TableVIII-4

Rabi Fruits, acreage, production and yield, 1979-80 and 1999-2000

Fruit	*Pre CRBC 1979-80*			*Post CRBC 1999-2000*		
	Area (In ha)	*Production (in tonnes)*	*Yield in Kg/ha*	*Area (in ha)*	*Production (in tonnes)*	*Yield in Kg/ ha*
Citrus	19	202	10,631	211	2,236	10,597
Guava	2	22	11,000	140	2,100	15,000
Banana	-	-	-	19	342	18,000

Source: GoNWFP, 1981 and 2000c - means negligible

8.1.2 Impacts of CRBC on the agricultural production of sample villages (Micro level analysis)

A. Kharif Production

i. JARRA

The table VIII-5 reveals that the production of all Kharif crops has increased after inception of CRBC. The analysis reveals that the yield per ha also improved after CRBC. The figure VIII-5 shows that positive changes in production have been recorded in sugarcane, maize, sorghum and Kharif fruit, whereas negative changes have occurred in rice. It is also clear from the figure that production value of sugarcane has increased several folds after CRBC and that of rice has been reduced.

Table VIII-5

Jarra, Pre and Post CRBC change in Kharif production and value

Period	***Indicators***	*Rice*	*Sugarcane*	*Maize*	*Sorghum*	*K. Fruit*
Pre CRBC (1987)	Yield in Kg/ha	1,536	38,400	1,000	300	6,000
	Production in tones	153.6	883.2	1	0.3	18
	Value in million rupees	6.1	1.85	0.01	0.003	0.54
Post CRBC (2004)	Yield in Kg/ha	3,840	48,000	2,000	800	6,000
	Production in tones	34.56	5,136	2	0.8	78
	Value in million rupees	1.4	10.8	0.02	0.008	2.34
Change	Change in production (Tones)	-119.04	4252.8	1	0.5	60
	Change in value (in million rupees)	-4.7	8.95	0.01	0.005	1.8

Source: Field survey 2005 and revenue record of mouza Jarra *Value is estimated at market price, 2006*

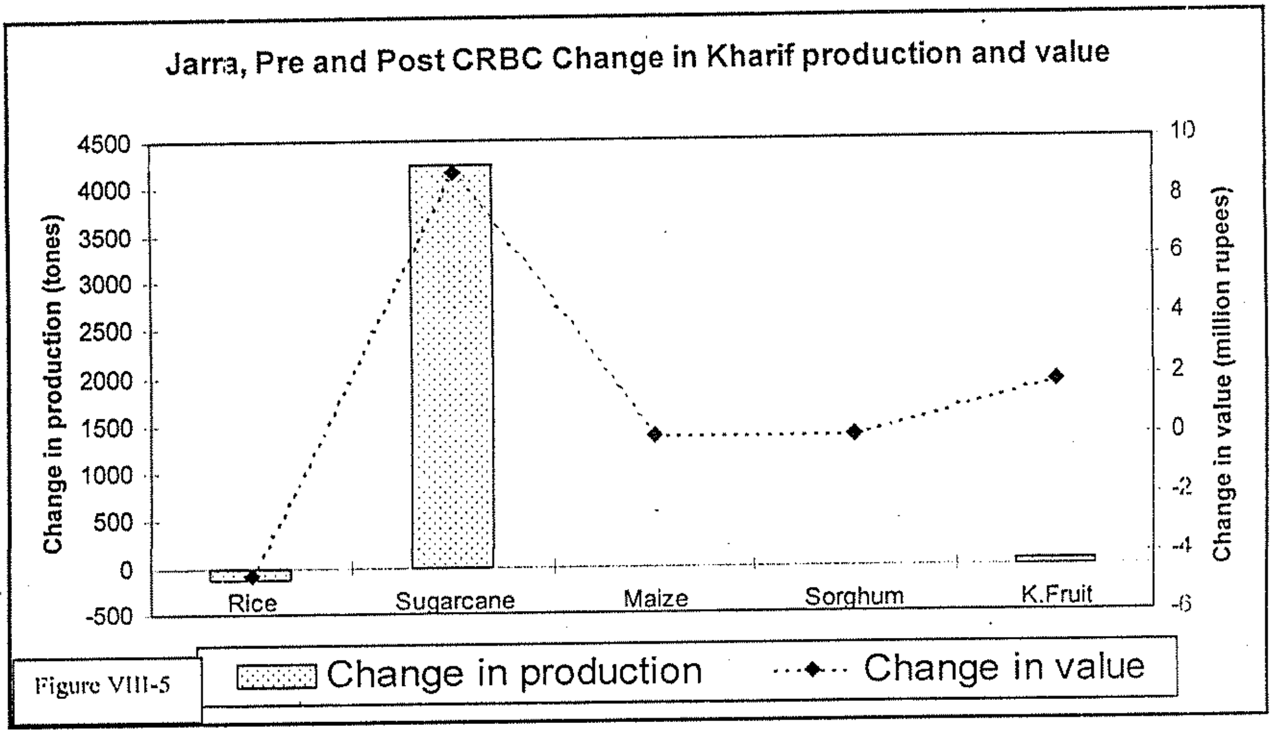


Figure VIII-5

ii. GOMAL

The analysis reveals that the production of almost all the Kharif crops has been increased after inception of canal irrigation in the form of CRBC. The figure VIII-6 reveals that after CRBC a positive change in production has been recorded for rice, sugarcane, maize and pulse, whereas negative changes has occurred in the production of millet and sorghum. It is also clear from table VIII-6 that positive change in production value has been registered for rice, sugarcane, maize and pulse, whereas negative changes have been recorded for millet and sorghum.

Table VIII-6

Gomal, Pre and Post CRBC Kharif Production and value

Period	*Indicators*	*Rice*	*Sugarcane*	*Maize*	*Millet*	*Sorghum*	*Pulse*
Pre CRBC (1987)	Yield in Kg/ha	1,495	96,000	988	349	308	-
	Production in tones	215	384	11.8	0.349	12.3	-
	Value in million rupees	8.6	0.8	0.12	0.003	0.12	-
Post CRBC (2004)	Yield in Kg/ha	3,840	192,000	1,847	-	616	647
	Production in tones	399.4	19,968	85	-	5.5	3.2
	Value in million rupees	16	42	0.85	-	0.055	0.097
Change	Change in Production (in tones)	184.4	19,584	73.2	-0.349	-6.8	3.2
	Change in value (in million rupees)	7.4	41.2	0.73	-0.003	-0.065	0.097

Source: Field survey 2005 and revenue record of mouza Gomal *Value is estimated at market price, 2006*

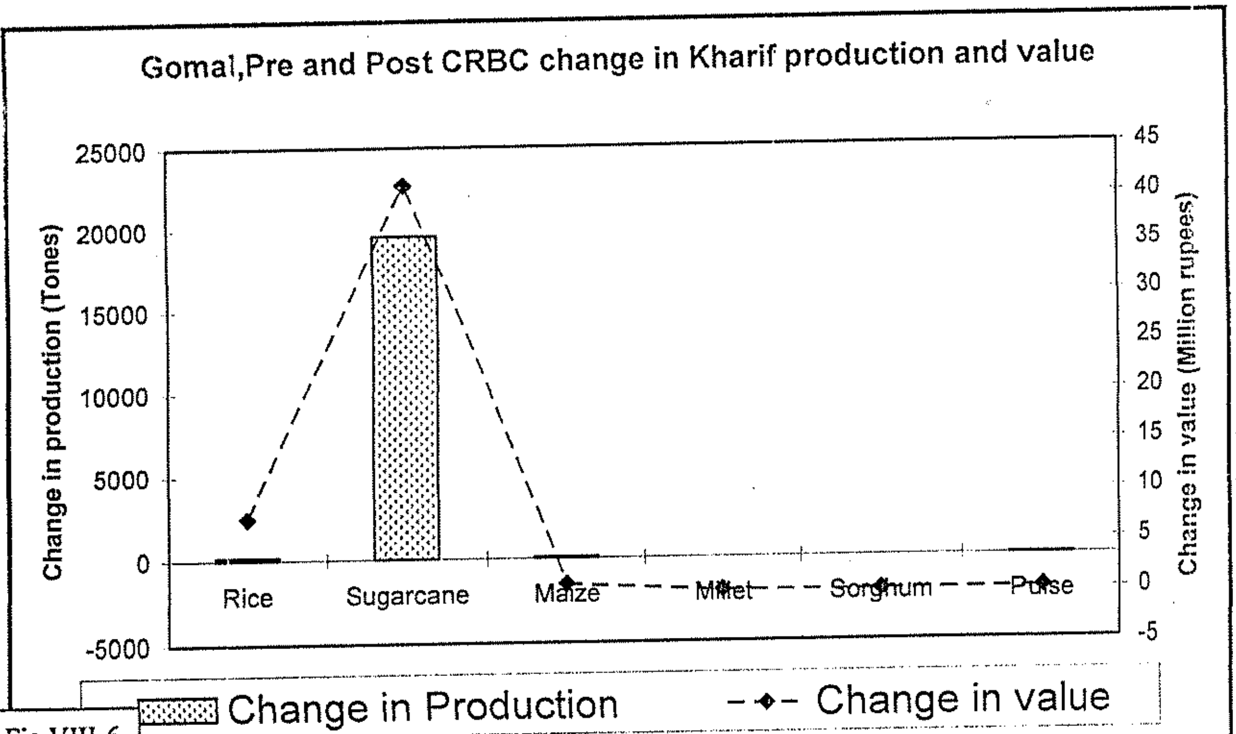


Fig VIII-6

iii. BUCHARI

It was found from the analysis that after inception of CRBC positive changes in production has been recorded for all Kharif crops (Table VIII-7). It was found that prior to CRBC rice, sugarcane, maize and pulses were not cultivated, however after CRBC rice, sugarcane, maize, sorghum and pulses have been cultivated in the mouza. The figure VIII-7 reveals that after CRBC, maximum production changes have been recorded for rice followed by maize, sugarcane, pulse and sorghum. The analysis indicates that large-scale production value has been recorded for sugarcane followed by rice, maize, pulse and sorghum.

Table VIII-7
Buchari, Pre and Post CRBC Kharif Production and value

Period	*Indicators*	*Rice*	*Sugarcane*	*Maize*	*Sorghum*	*Pulse*
Pre CRBC (1993)	Yield in Kg/ha	-	-	-	308	-
	Production in tones	-	-	-	1.84	-
	Value in million rupees	-	-	-	0.018	-
Post CRBC (2004)	Yield in Kg/ha	3,840	96,000	1,847	616	647
	Production in tones	303.3	11.33	53.5	8	11
	Value in million rupees	21.1	23.8	0.53	0.08	0.33
Change	Change in Production (in tones)	303.3	11.33	53.5	6.16	11
	Change in value (in million rupees)	21.1	23.8	0.53	0.062	0.33

Source: Field survey 2005 and revenue record of mouza Buchari Value is estimated at market price, 2006

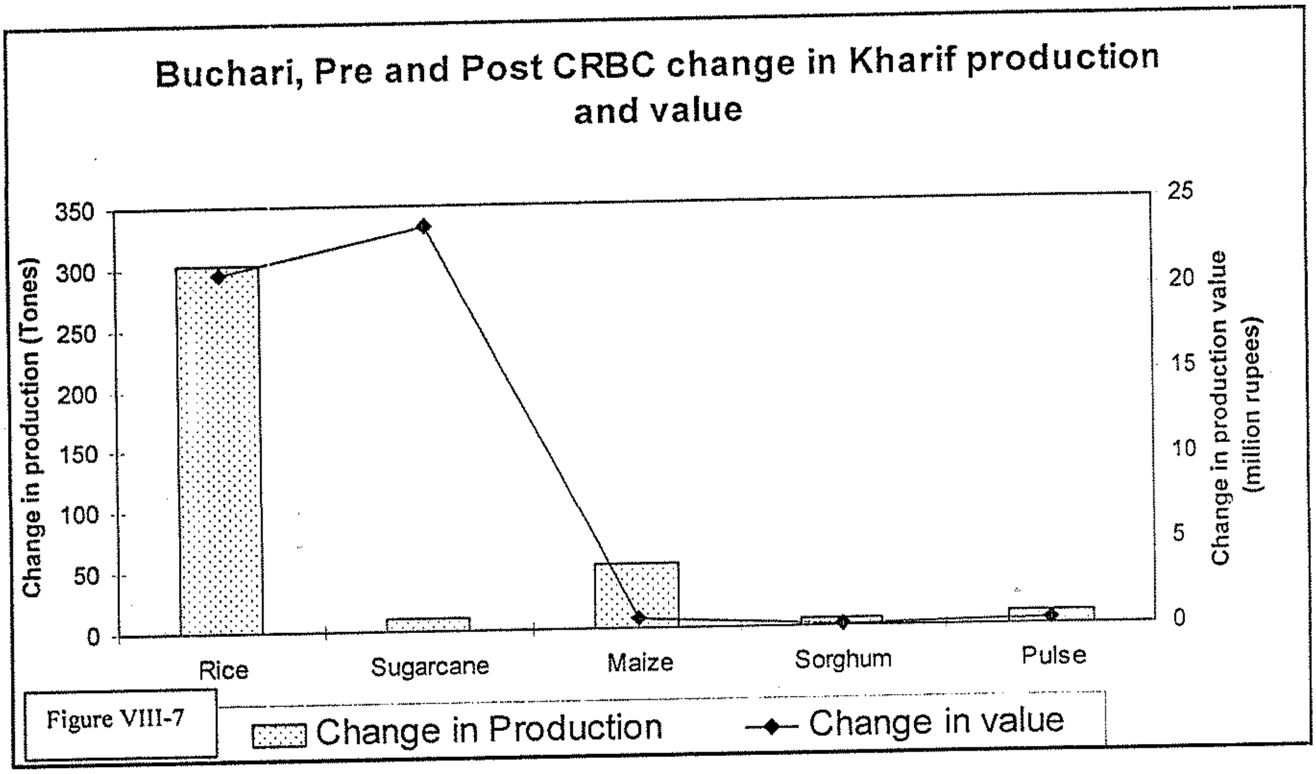


Figure VIII-7

iv. CHERA

The figure VIII-8 reveals that after CRBC the Kharif production of majority crops has been increased in Chera. The analysis reveals that positive production changes have been recorded for sugarcane and pulses, whereas negative changes have occurred in oilseed, millet, sorghum and fruit. The table VIII-8 indicates that the yield in kg per hectare of majority of crops have been increased after CRBC. It is also clear from figure VIII-8 that after CRBC, positive changes in production value have been recorded for sugarcane and pulse, whereas negative changes have occurred in oilseed, millet, sorghum and fruit.

v. KHUDAKA

As discussed earlier Khudaka is one of the sample village located off the CRBC command area. The analysis reveals that both pre and post CRBC the Kharif production was found zero. Therefore, no changes have been detected after comparing pre and post CRBC conditions.

Table VIII-8

Chera, Pre and Post CRBC Kharif Production and value

Period	*Indicators*	*Sugarcane*	*Oilseed*	*Millet*	*Sorghum*	*Pulse*	*Fruit*
Pre CRBC (1990)	Yield in Kg/ha	-	1,920	349	308	-	10,000
	Production in tones	-	11.5	11.16	28	-	50
	Value in million rupees	-	0.345	0.11	0.28	-	10
Post CRBC (2004)	Yield in Kg/ha	192,000	-	-	616	647	-
	Production in tones	11,328	-	-	13	164	-
	Value in million rupees	23.8	-	-	0.129	5	-
Change	Change in Production (in tones)	11,328	-11.5	-11.16	-15	164	-50
	Change in value (in million rupees)	23.8	-0.345	-0.11	-0.151	5	-10

Source: Field survey 2005 and revenue record of mouza Chera   Value is estimated at market price, 2006

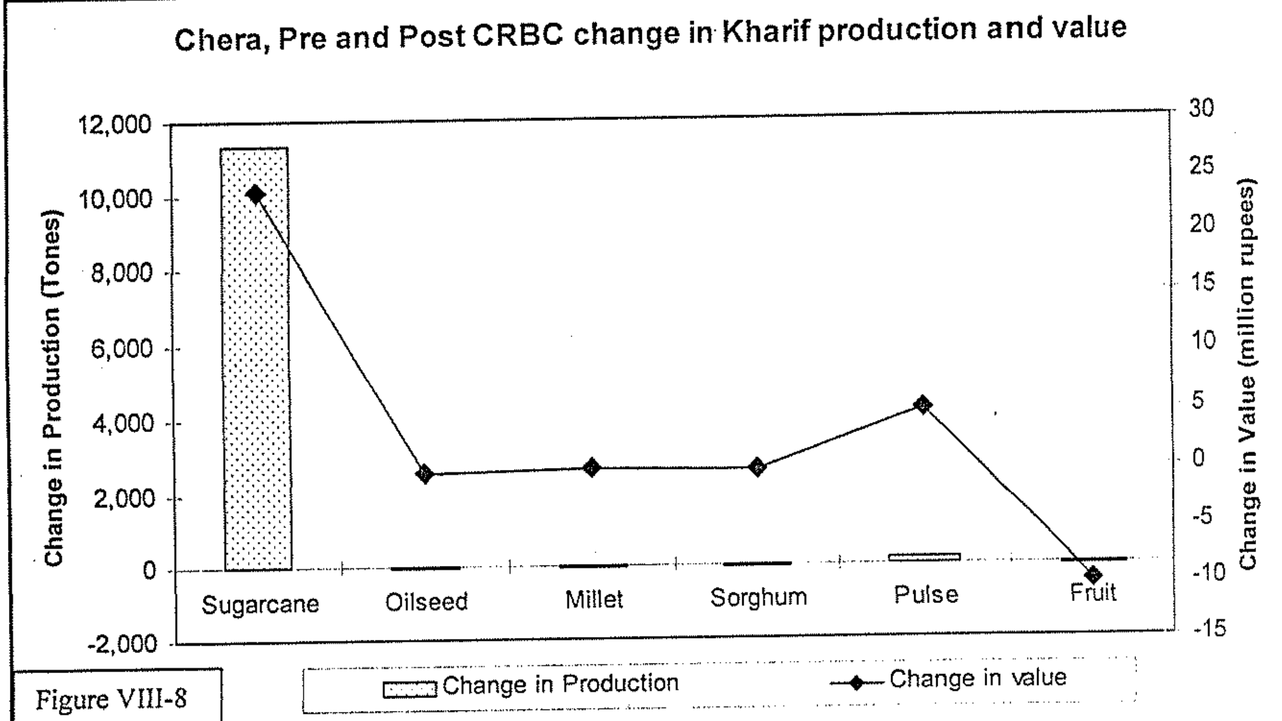


Figure VIII-8

B. Rabi Production

i. JARRA

The analysis reveals that after CRBC Rabi production has increased. The figure VIII-9 indicates that yield per ha has enhanced for almost all Rabi crops. The table VIII-9 elaborates that after comparing pre and post CRBC condition a positive change in production has been recorded for wheat and fruit, whereas negative changes have occurred in barley, pulse and oilseed. The analysis further indicates that after CRBC the gross production of Rabi crops have been increased several fold. The figure VIII-9 also reveals that positive change in production value has recorded for wheat and fruit, whereas negative changes occurred in barley, pulse and oilseed. The negative changes are attributed to the farmer's preferences to more profitable and high return crops under canal irrigation.

Table VIII-9
Jarra, Pre and Post CRBC Rabi Production and value

Period	**Indicators**	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Fruit*
Pre CRBC (1987-88)	Yield in Kg/ha	416	322	90	370	-
	Production in tones	108.576	0.644	1.4	0.370	-
	Value in million rupees	1.08	0.002	0.04	0.01	-
Post CRBC (2003-2004)	Yield in Kg/ha	1,531	-	-		6,000
	Production in tones	418	-	-		78
	Value in million rupees	4.2	-	-		2.34
Change	Change in production (in tones)	309.5	-0.644	-1.4	-0.370	78
	Change in value (in million rupees)	3.12	-0.002	-0.04	-0.01	2.34

Source: Field survey 2005 and revenue record of mouza Jarra *Value is estimated at market price, 2006*

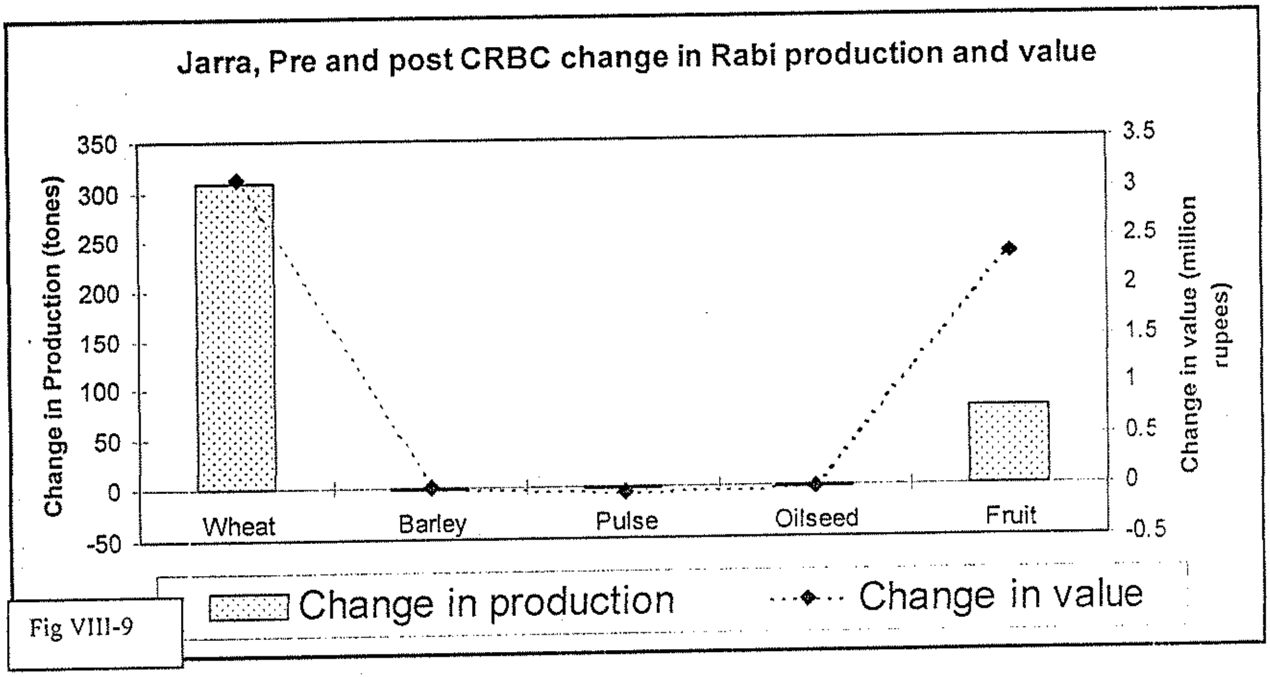


Fig VIII-9

ii. GOMAL

The analysis reveals that the production and value of all the Kharif crops have increased after CRBC. The table VIII-10 indicates that after CRBC, yield in kg per ha has increased several folds. This has positively affected the production value and as a result high production value has been recorded for wheat, pulse, oilseed, fruit and barley, respectively. The figure VIII-10 reveals that after CRBC the gross production of Rabi crops has been multiplied.

Table VIII-10

Gomal, Pre and Post CRBC Rabi Production and value

Period	**Indicators**	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Fruit*
Pre CRBC (1987-88)	Yield in Kg/ha	2,880	322	768	1,920	-
	Production in tones	1,918	0.966	1.5	3.8	-
	Value in million rupees	19.2	0.003	0.046	0.11	-
Post CRBC (2003-04)	Yield in Kg/ha	4,800	692	1,152	2,880	10,000
	Production in tones	5,170	4.8	138.2	63.3	20
	Value in million rupees	52	0.014	4.1	1.9	0.4
Change	Change in production (in tones)	3,252	3.834	136.7	59.5	20
	Change in value (in million rupees)	32.8	0.011	4.054	1.79	0.4

Source: Field survey 2005 and revenue record of mouza Gomal *Value is estimated at market price, 2006*

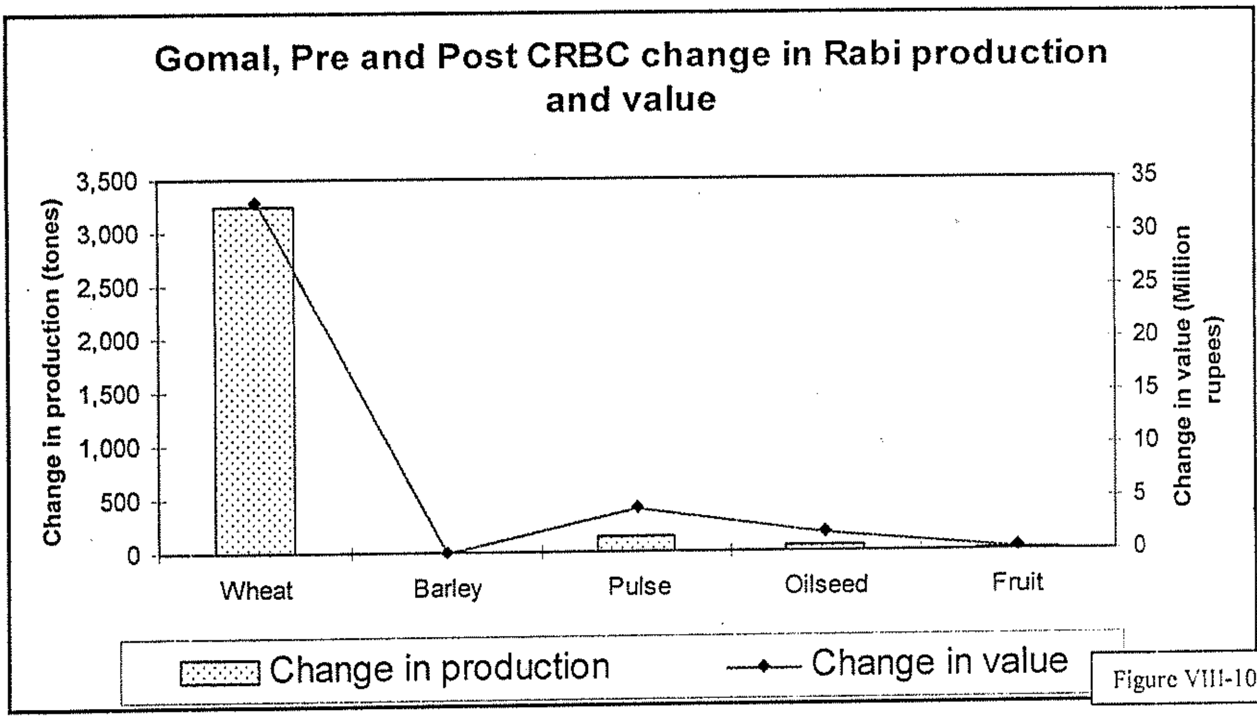


Figure VIII-10

ii. GOMAL

The analysis reveals that the production and value of all the Kharif crops have increased after CRBC. The table VIII-10 indicates that after CRBC, yield in kg per ha has increased several folds. This has positively affected the production value and as a result high production value has been recorded for wheat, pulse, oilseed, fruit and barley, respectively. The figure VIII-10 reveals that after CRBC the gross production of Rabi crops has been multiplied.

Table VIII-10
Gomal, Pre and Post CRBC Rabi Production and value

Period	**Indicators**	*Wheat*	*Barley*	*Pulse*	*Oilseed*	*Fruit*
Pre CRBC (1987-88)	Yield in Kg/ha	2,880	322	768	1,920	-
	Production in tones	1,918	0.966	1.5	3.8	-
	Value in million rupees	19.2	0.003	0.046	0.11	-
Post CRBC (2003-04)	Yield in Kg/ha	4,800	692	1,152	2,880	10,000
	Production in tones	5,170	4.8	138.2	63.3	20
	Value in million rupees	52	0.014	4.1	1.9	0.4
Change	Change in production (in tones)	3,252	3.834	136.7	59.5	20
	Change in value (in million rupees)	32.8	0.011	4.054	1.79	0.4

Source: Field survey 2005 and revenue record of mouza Gomal   *Value is estimated at market price, 2006*

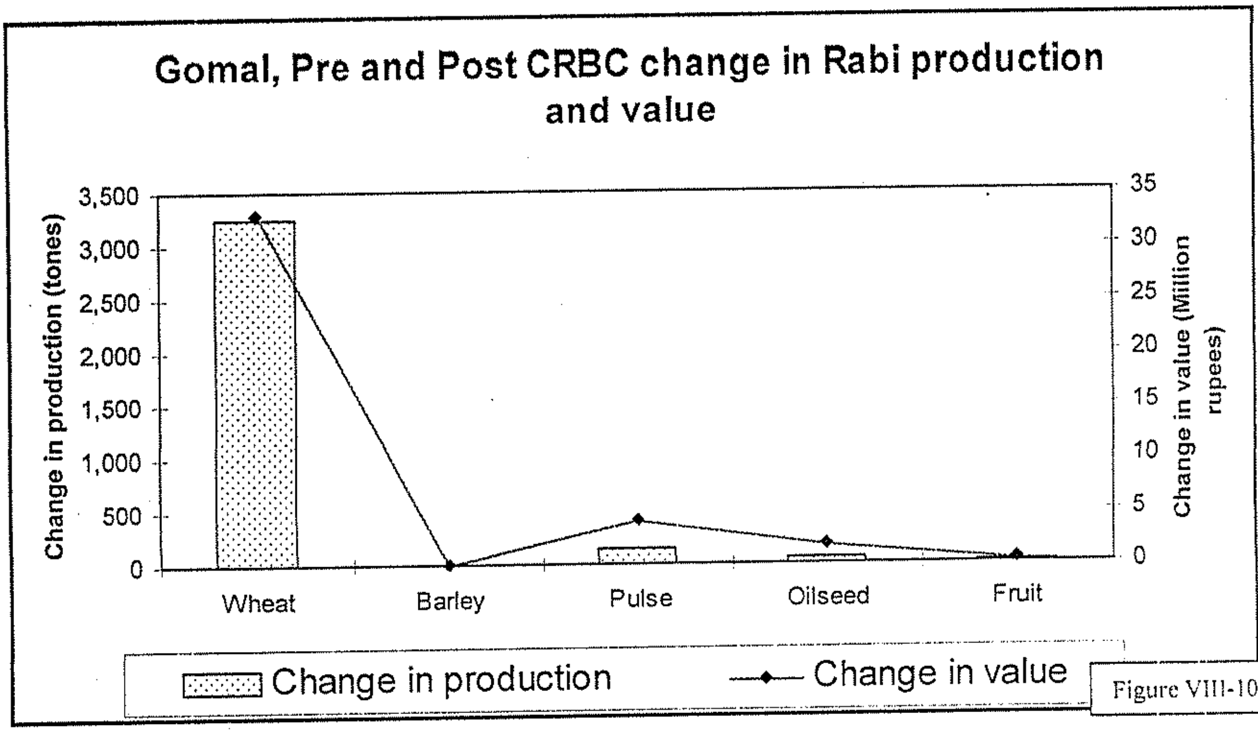


Figure VIII-10

iv. CHERA

The analysis reveals that after CRBC positive changes in production and value have been recorded. The table VIII-12 indicates that positive production changes have occurred in wheat and pulses, whereas negative changes have been registered for oilseed. The analysis also indicates that yield in kg per ha of all the Rabi crops have been increased, as a result the production of wheat and pulses have multiplied during the study period. The analysis reveals that negative change in the oilseed is mainly due to the preferences to wheat and pulses as against oilseed. The figure VIII-12 further reveals that after CRBC the production value of wheat and pulses has enhanced, whereas that of oilseed has decreased.

Table VIII-12
Chera, Pre and Post CRBC Rabi Production and value

Period	**Indicators**	*Wheat*	*Pulse*	*Oilseed*
Pre CRBC (1989-90)	Yield in Kg/ha	1,920	768	1,920
	Production in tones	57.6	6.912	48
	Value in million rupees	0.576	0.2	1.4
Post CRBC (2003-04)	Yield in Kg/ha	6,720	1,152	2,880
	Production in tones	2,345	74.88	11.5
	Value in million rupees	23.4	2.2	0.345
Change	Change in production (in tones)	2,288	67.968	-36.5
	Change in value (in million rupees)	22.82	2	-1.055

Source: Field survey 2005 and revenue record of mouza Chera *Value is estimated at market price, 2006*

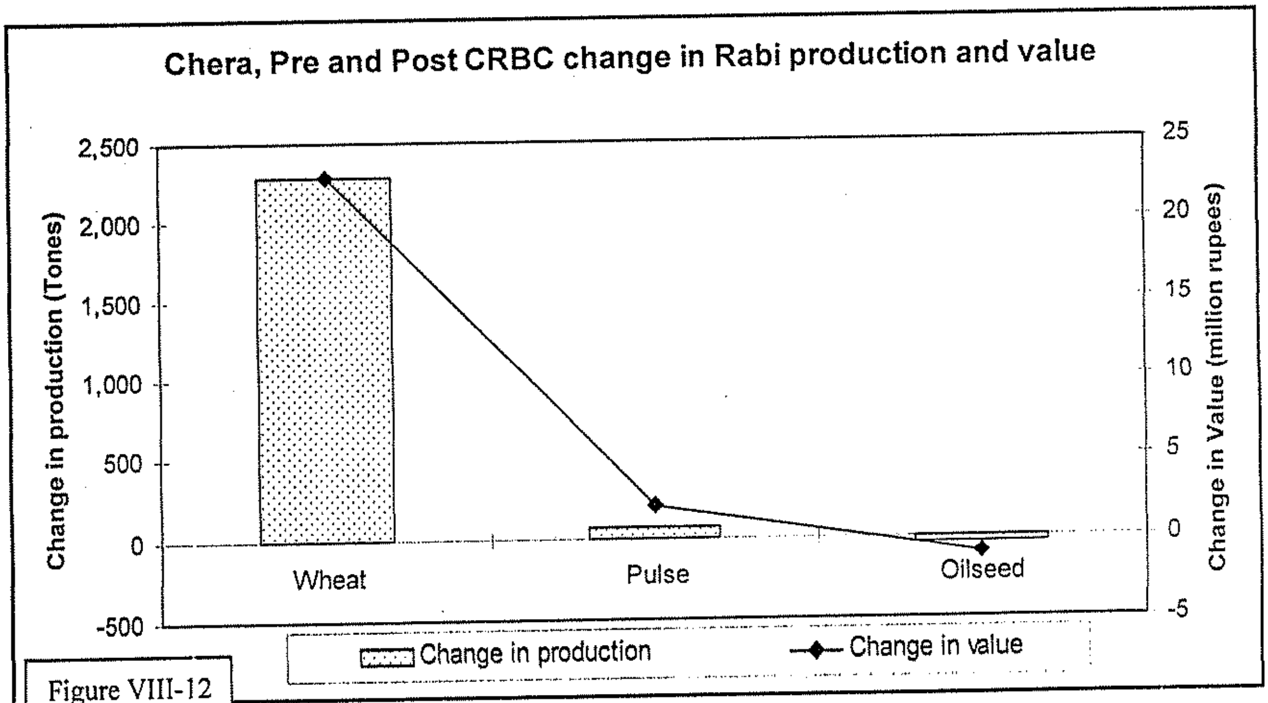


Figure VIII-12

iv. CHERA

The analysis reveals that after CRBC positive changes in production and value have been recorded. The table VIII-12 indicates that positive production changes have occurred in wheat and pulses, whereas negative changes have been registered for oilseed. The analysis also indicates that yield in kg per ha of all the Rabi crops have been increased, as a result the production of wheat and pulses have multiplied during the study period. The analysis reveals that negative change in the oilseed is mainly due to the preferences to wheat and pulses as against oilseed. The figure VIII-12 further reveals that after CRBC the production value of wheat and pulses has enhanced, whereas that of oilseed has decreased.

Table VIII-12
Chera, Pre and Post CRBC Rabi Production and value

Period	**Indicators**	*Wheat*	*Pulse*	*Oilseed*
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	Production in tones	57.6	6.912	48
	Value in million rupees	0.576	0.2	1.4
Post CRBC (2003-04)	Yield in Kg/ha	6,720	1,152	2,880
	Production in tones	2,345	74.88	11.5
	Value in million rupees	23.4	2.2	0.345
Change	Change in production (in tones)	2,288	67.968	-36.5
	Change in value (in million rupees)	22.82	2	-1.055

Source: Field survey 2005 and revenue record of mouza Chera *Value is estimated at market price, 2006*

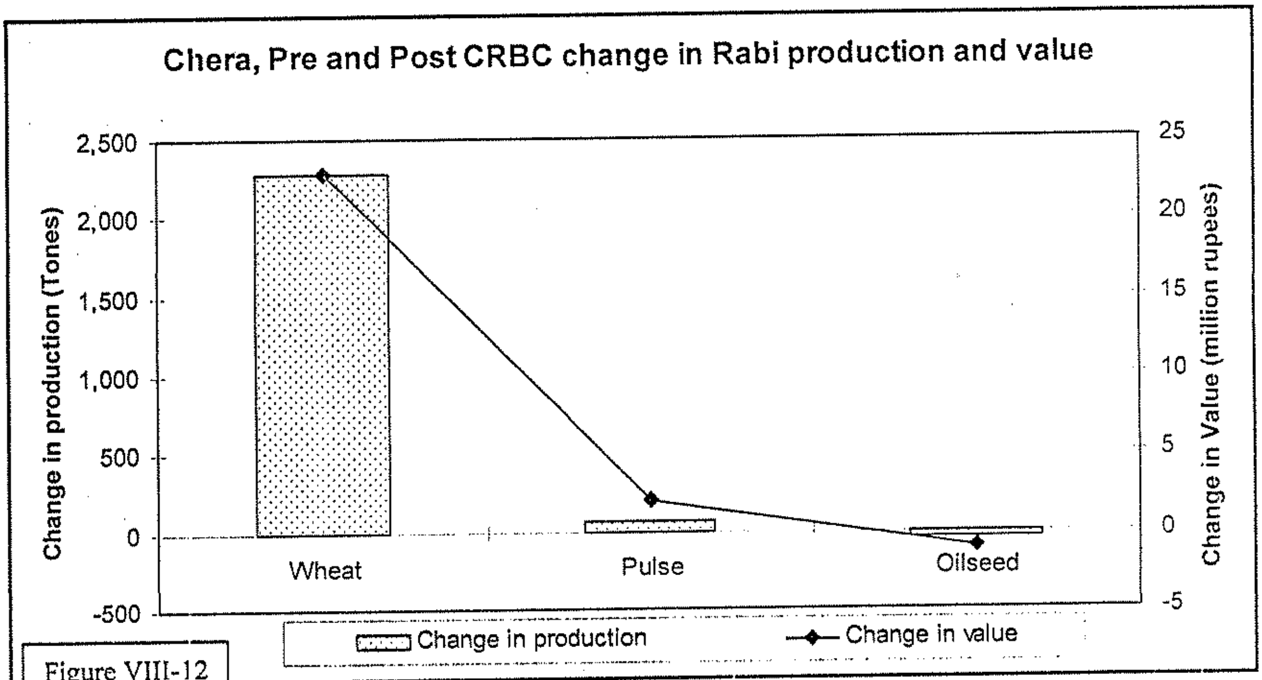

Figure VIII-12

v. KHUDAKA

The analysis reveals that after CRBC negative changes have occurred in all the Rabi crops. This is a unique situation when compared with the other four sample villages. Prior to CRBC wheat, barley, pulse and oilseed was cultivated but after CRBC (2003-04) even a single plot was not cultivated. It is mainly due to the non-availability of water and drought spell over the Pakistani territory (table VIII-13). The figure VIII-13 reveals that negative change has been registered for wheat, barley, pulse and oilseed.

Table VIII-13
Khudaka, Pre and Post CRBC Rabi Production and value

Period	**Indicators**	*Wheat*	*Barley*	*Pulse*	*Oilseed*
Pre CRBC (1984-85)	Yield in Kg/ha	2,000	322	768	1,500
	Production in tones	226	2.5	24.5	48
	*Value in million rupees	2.2	0.007	0.73	1.44
Post CRBC (2003-04)	Yield in Kg/ha	-	-	-	-
	Production in tones	-	-	-	-
	Value in million rupees	-	-	-	-
Change	Change in production (in tones)	-226	-2.5	-24.5	-48
	Change in value (in million rupees)	-2.2	-0.007	-0.73	-1.44

Source: Field survey 2005 and revenue record of mouza Khudaka **Value is estimated at market price, 2006*

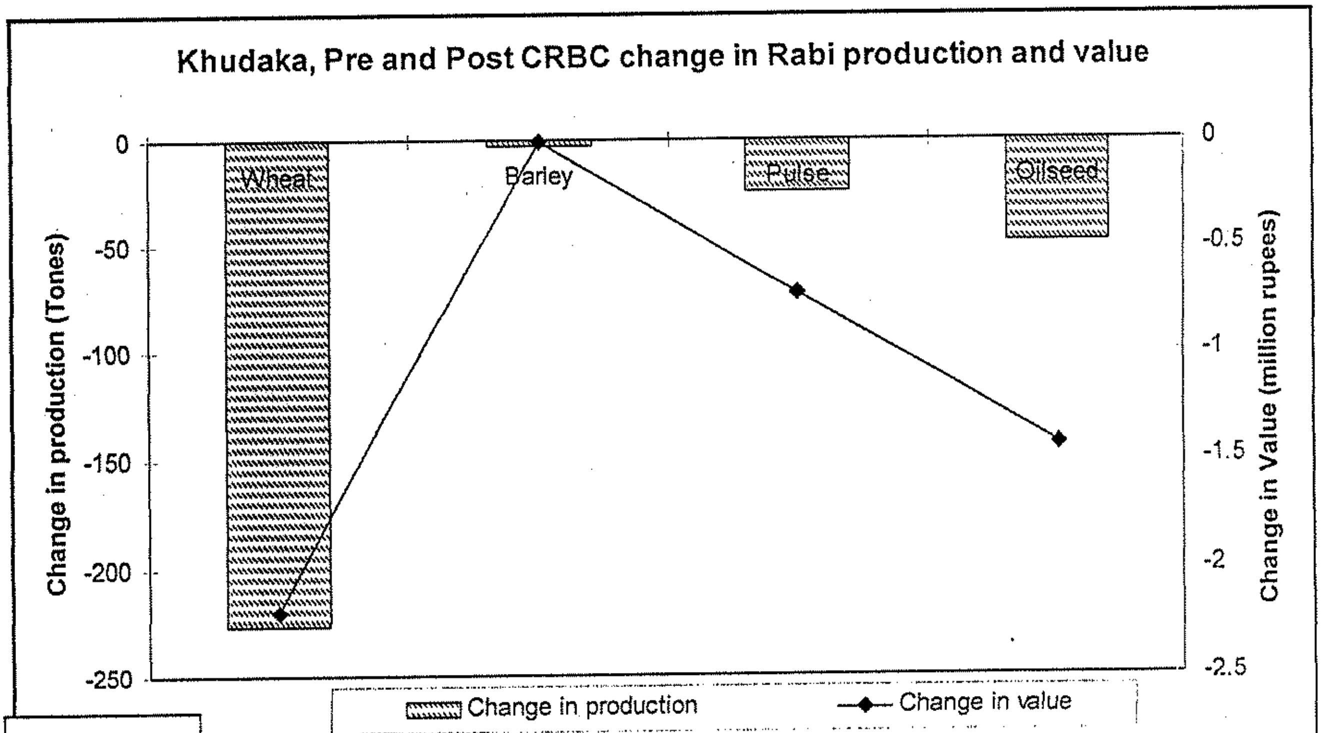

Figure VIII-13

8.2 ENVIRONMENTAL IMPACTS OF CRBC ON THE MECHANIZATION AND FERTILIZER

In D.I.Khan district, CRBC played a pivotal role in the mechanization of agriculture. Mechanization in agriculture reduces farmers' workload, saving time and increases productivity. Before the construction of CRBC, farm to market roads and communication were very limited, because of scarce agricultural production. Prior to CRBC, in the study area, cultivation was predominantly dependent upon Rod Kohi and sporadic rainfall.

Pre construction of CRBC, trend to use the modern agricultural implements were very limited. Its use was mainly reported from those areas, where perennial irrigation was available (Table VIII-14). In Jarra prior to CRBC, there were irrigated agriculture through old Paharpur canal. Therefore, the use of tractor for ploughing and threshing was common practice in the mouza. Likewise, in Gomal one fourth of the respondents said that they have been using modern agricultural tools. It was possible because there were 13 tube wells for irrigation purposes. However, prior to CRBC in Buchari, Chera and Khudaka, none of the household have used modern agricultural implements. No tractor was available in these three sample villages before CRBC and almost all the farmer used traditional method of cultivation including ploughing and threshing manually or animal power (pair of bullocks).

However, after CRBC, drastic changes have occurred in the use of agricultural implements. After CRBC due to increase in the acreage and yield, the farmers were in a better position for higher use of energy in the form of tractor. It is obvious that mechanized farming is much cheaper on per kWh basis. Therefore, the highest use of mechanized farming techniques in land preparation and other operations gave further boost to the yield and ultimately to the net return. This development has been attributed to the socio-economic uplift of the area as a result of CRBC. Presently, in all the sample villages, farmers are using modern techniques and trend towards the mechanization is positive (Table VIII-14). The positive consequences of mechanization are not only over the CRBC command villages but also off the command villages. This mechanization has an impact on the land tenancy as well because the number of owner cultivators has greatly increased as compare to pre CRBC.

It could be concluded that during post CRBC all farmers were mostly using tractors as their main power-source that has reduced the use of human labour as compared to pre CRBC. The analysis also indicates that the progress towards mechanization has increased the crop production tremendously by increasing the yield, the cropped area and the cropping intensity.

Table VIII- 14
Pre and Post CRBC, Use of tractor as perceived by the respondents

Sample villages	*Pre CRBC (%)*				*Post CRBC (%)*			
	Pre CRBC use of tractor for Ploughing		*Pre CRBC use of tractor for Threshing*		*Post CRBC use of tractor for Ploughing*		*Post CRBC use of tractor for Threshing*	
	Yes	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
Jarra	30	70	25	75	100	0	100	0
Gomal	25	85	30	70	100	0	100	0
Buchari	0	100	0	100	100	0	100	0
Chera	0	100	0	100	100	0	100	0
Khudaka	0	100	0	100	100	0	100	0

Source: Field survey, 2005

In D.I.Khan district, use of agricultural implement, trace back to the CRBC commissioning. After CRBC, extensive area was brought under cultivation and tractors are necessary where large farm tracts are sown more than once. Despite its use for several agricultural operations, in D.I.Khan district it has become a major vehicle for the cane transportation from farm to factory. For agricultural machinery, they sell either their land or take loan from the banks. In Gomal, Buchari and Chera, 25-35% farmers have their own modern agricultural implements, whereas in Jarra very few farmers have new agricultural implements (Table VIII-15). This can be finally justified that those households, who have higher size of holding, will have greater chance of implement ownerships. Because, rent of tractor per hour, vary from Rs.200 to 250 (Field survey, 2005). Therefore, majority of landlords have their own agricultural implements. As far as small size landholders are concerned, they hire the tractors and related machinery of others. One of the remarkable features of the analysis is that modern agricultural implements were not found in Khudaka, but during sowing and threshing, they hire the tractors from outside the village.

Banks also provide loans to the farmers on easy instalments including Agricultural Development Bank, Habib Bank of Pakistan, National Bank of Pakistan, United Bank of Pakistan, Askari Commercial Bank of Pakistan and Muslim Commercial Bank of Pakistan (GoP, 2004b). Out of five sample villages, only in Jarra, Gomal and Buchari, very few people availed the loan facility (Table VIII-16). People complaint that banks provides loans on high interest rate. Majority of the loan were extended for agricultural machinery as well as for bringing cultivable waste under cultivation. Banks are mostly located in D.I.Khan city and Paharpur. The data revealed that as the distance from city increases the proportion of loan availing is decreasing and vice versa. The table VIII-16 shows that farmers of Gomal, Jarra and Buchari availed the loan. Whereas Khudaka and Chera located far from urban centre, therefore none of the respondents availed loan facility.

Table VIII-15
Use of modern agricultural implements

Sample village	*Use Pre-CRBC*		*Use Post CRBC*	
	Yes	*No*	*Yes*	*No*
Jarra	60	40	100	0
Gomal	25	75	100	0
Buchari	0	100	100	0
Chera	0	100	100	0
Khudaka	0	100	100	0

Source: Field survey, 2005

Table VIII-16
Loan and ownership of agricultural implements

Sample village	*Loan availed*		*Ownership of agricultural implements*	
	Yes	*No*	*Yes*	*No*
Jarra	*20*	*80*	5	95
Gomal	*25*	*75*	30	70
Buchari	*20*	*80*	25	75
Chera	*0*	*100*	35	65
Khudaka	*0*	*100*	0	100

Source: Field survey, 2005

Fertilizer is another key input in modernization of agricultural. It plays predominant role in increasing the fertility of soil. After water, it constitutes the next most vital input for modern agriculture. The status of soil fertility in the CRBC command area is very poor and the yield potential of most crops can't be realized without using fertilizer. Field survey reveals that in the study area, three types of fertilizers are used e.g. phosphate (P), nitrogenous (N) and potash (K). The data reveals that use of fertilizer is generally higher in stage I and II as compared to stage III.

The analysis reveals that prior to the construction of CRBC, use of chemical fertilizer were not very common. Out of five sample villages only in Jarra and Gomal chemical fertilizer was used, while in rest of the villages, the farmer had no idea of the use of chemical fertilizer. They generally used farmyard manure. Every household had some livestock, which produce some farmyard manure. The use of chemical fertilizers has close relation with irrigation. The farmers can afford the application of fertilizer if sufficient water made available for irrigation.

According to field survey, after inception of CRBC, farmers are using both farmyard manure as well as chemical fertilizer. As a result, farmer has realized increasing yield. According to field survey, most of the farmer (95%) in the study area has used chemical fertilizer during last cropping season and few could not bear the cost of chemical fertilizer. Therefore, they are not using chemical fertilizer. Generally, farmers provide more fertilizer to newly introduced crops varieties as compared to local varieties. Super-phosphate (only in Chera, because of soil salinity), phosphate, nitrate, potash, nitro-phosphate and DAP (Di-Ammonium Phosphate, a chemical fertilizer) are the most commonly used chemical fertilizers. It was found that use of DAP and urea is comparatively higher than rest of the fertilizers.

Field observation revealed that crops, which are frequently treated with the chemical fertilizer, include wheat, rice and sugarcane. After application of chemical fertilizer, farm production has been greatly improved. However, in Khudaka, the situation regarding the use of chemical fertilizer is quite different from the CRBC command villages. Here, farmers are not using any kind of fertilizer because their cultivation are dependent on the Rod Kohi irrigation, which after application carpet fertile silt and hence do not require any fertilizer.

8.3 ENVIRONMENTAL IMPACTS OF CRBC ON THE LAND VALUES

The analysis reveals that after CRBC, the land values of all the land use categories including residential, agricultural and cultivable waste have been increased several fold. According to revenue record, before CRBC, the land prices were not as high as today, however after CRBC the land values have considerably increased. There are several factors behind this rapid rise of land prices. Primarily, due to the inception of canal irrigation income level of the people has improved particularly of those who had large holdings and secondly due to high return from the land. Secondly, despite of large land holdings in the area, they want to maintain their hold mainly due to socio-political reasons. Thirdly, the population of D.I.Khan is increasing at an alarming rate, which puts tremendous pressure on the land resources and in effect, the land prices have gone very high.

It was found from the analysis that in almost all the sample villages, the residential land prices were found higher then rest of the land types. Per unit cultivable waste was found the lowest as compared to that of land for residential or agricultural use, which is considered as more valuable. The increase in the residential land value is mainly because of the compact settlement pattern, security, accessibility and location of residential area at higher altitude. The following discussion gives the micro level analysis of land values.

Prior to CRBC, village Jarra was under the command of the old Paharpur canal for almost 88 years. Waterlogging and salinity adversely affected this village in the initial stage of CRBC, but with the introduction of Paharpur SCARP, most of the area was reclaimed. Amongst the sample villages, Jarra has agriculturally more productive lands, where mixed type of farming (crops and orchards) is practised. The Table VIII-17 shows that the residential land prices increased from Rs[1] 336,000 per ha pre CRBC to present residential land price of Rs 2,372,300 per

[1] Rs = Pakistan Rupee, 60 Rs = 1 US$ (price level 2006)

ha, whereas the cultivated land value has increased from Rs 79,000 pre project to Rs 790,700 per ha and cultivable waste land from Rs 19,800 to Rs 296,500 per ha in last sixteen years (Figure VIII-14, 15 and 16).

Gomal has quite different land prices, pre and post CRBC. Being part of CRBC stage II irrigation through CRBC started from 1990-1991. Prior to CRBC, the village was partially under the command of Government and private tube wells. Currently, CRBC passes through the north-western part of the village. On average, the price of cultivated land has increased from pre CRBC price of Rs 158,152 per ha to post CRBC Rs 691,915 per ha and that of cultivable waste land from worth Rs 39,500 to Rs 296,500 per ha, whereas residential land prices increased from Rs 494,225 per ha pre-project to Rs 2,174,600 per ha post project (Table VIII-17). This indicates the direct impact of CRBC on the land prices. Some part of Gomal lies outside the CRBC command area, where the land prices are comparatively low.

In Buchari, irrigation was started in 1993, after commissioning of stage II of CRBC. According to revenue record, the land prices have significantly increased. On average the price of cultivable waste land was only Rs 59,300 per ha pre-project, which increased to Rs 395,400 per ha (Figure VIII-16). Likewise, the price of cultivated land has increased from Rs 98,845 pre-project to Rs 1,581,620 per ha (Figure VIII-15). As far as average residential land price is concerned, it was Rs 197,690 per ha prior to CRBC and presently, it is about Rs 1,976,900 per ha (Table VIII-17). Luni Nala divided the settlement into two halves. Old Buchari is located on the right bank of Luni, whereas new Buchari is on the left. The land prices are higher in new Buchari then the old one, mainly because of the accessibility and nearness to the main link road.

Chera is located in stage III of CRBC and commissioned in 1998-1999. This is one of the CRBC command villages, where extensive cultivable waste land (hillocks of Aeolian material was levelled) has been brought under the command of CRBC. Now this land is very productive and fertile, therefore the land prices have remarkably increased. The average agriculture land price has increased from Rs 39,538 to Rs 296,535 per ha, whereas average price of cultivable waste land increased from Rs 29,600 to Rs 237,000 per ha and residential area from Rs 197,690 to Rs 1,186,140 per ha in only seven years (Table VIII-17). Out of five sample sites, the land prices in Chera have increased at a very rapid pace.

Khudaka is one of the sample villages that lying outside the command of CRBC. Here, cultivation is entirely dependent on the traditional Rod Kohi irrigation system. Underground water is saline and not fit for drinking and irrigation purposes. Therefore, a slight increase has occurred in land prices. The average agricultural land value has increased from Rs 19,769 to Rs 59,300 per ha, cultivable waste land from Rs 15,800 to Rs 59,300 per ha and land for residential purpose from pre CRBC Rs 29,653 to Rs 395,380 per ha to post CRBC in last twenty years (Table VIII-17).

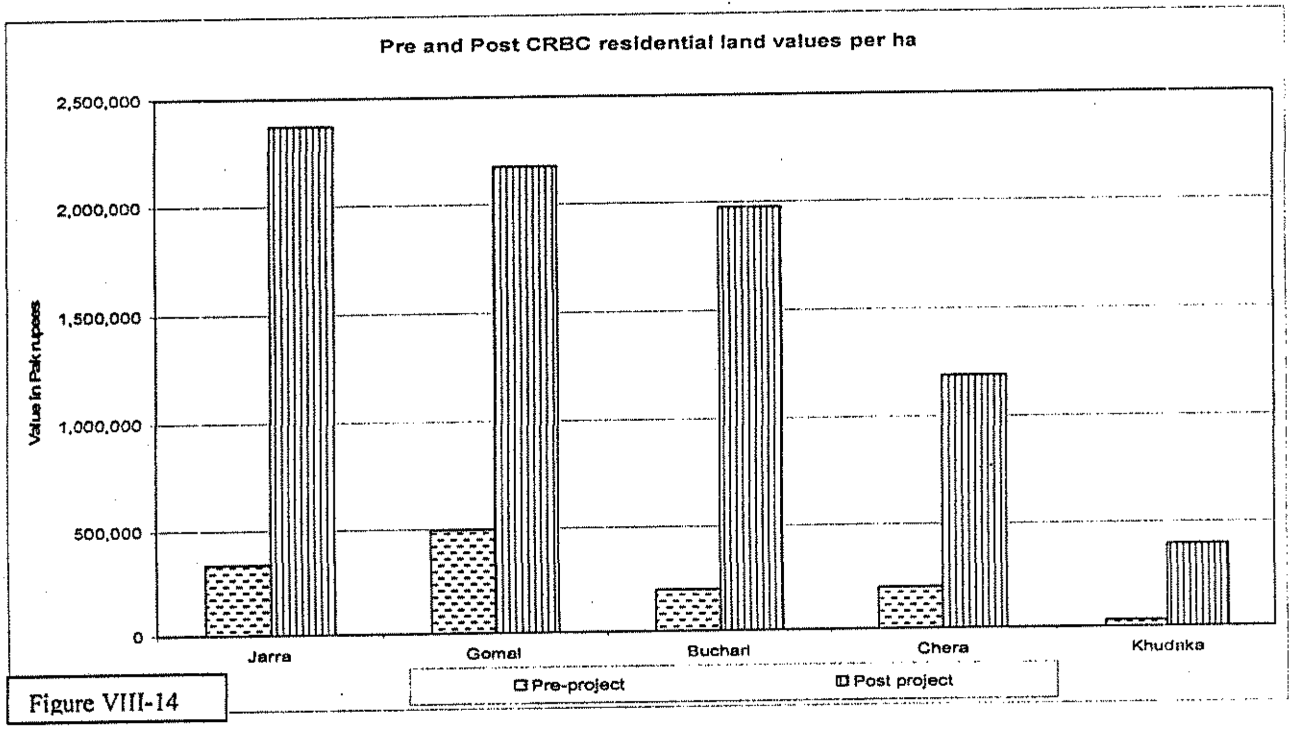

Figure VIII-14

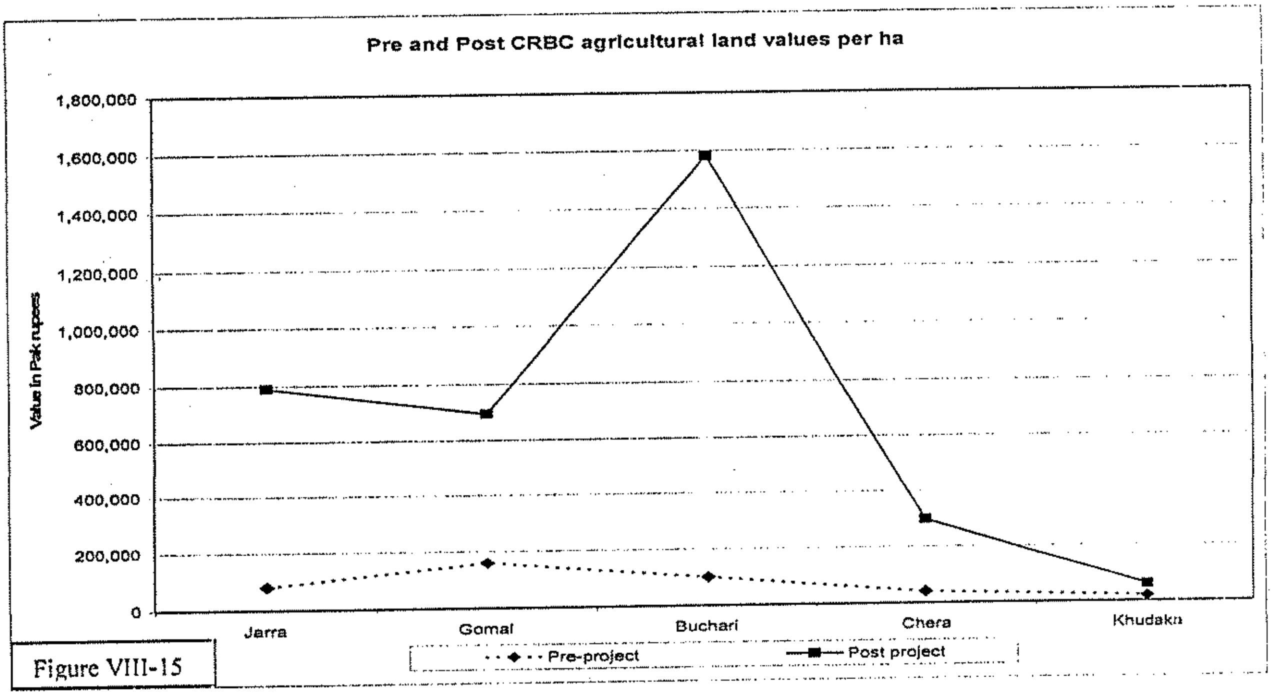

Figure VIII-15

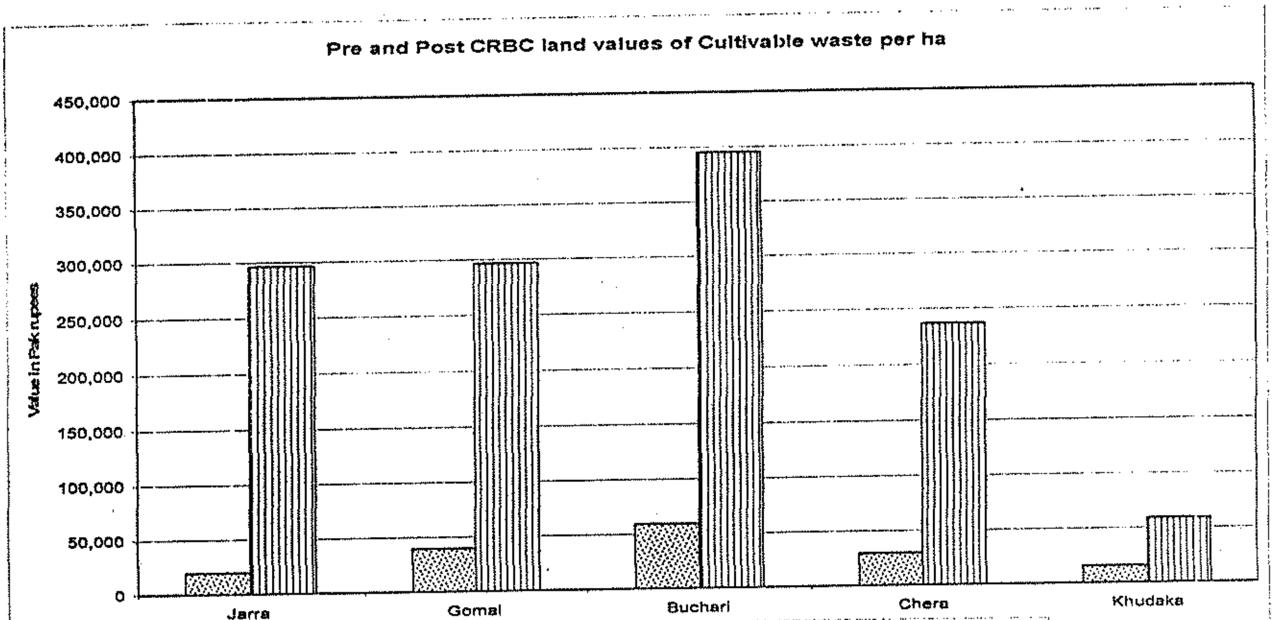

Figure VIII-16

Table-VIII-17

Changes in the land prices pre and post CRBC (price is in Pak Rupees)

Sample villages	*Residential land price per ha*		*Agricultural land price per ha*		*Cultivable waste price per ha*	
	Pre-project	*Post project*	*Pre-project*	*Post project*	*Pre-project*	*Post project*
Jarra	336,000	2,372,300	79,000	790,700	19,800	296,500
Gomal	494,225	2,174,600	158,152	691,915	39,500	296,500
Buchari	197,690	1,976,900	98,845	1,581,620	59,300	395,400
Chera	197,690	1,186,140	39,538	296,535	29,600	237,000
Khudaka	29,653	395,380	19,769	59,300	15,800	59,300

Source: Revenue Record, 1985 to 2005 and own survey April 2005

8.4 ENVIRONMENTAL IMPACTS OF CRBC ON THE GROUND WATER-TABLE

The CRBC was designed with a water allowance fixed at 0.60 L/s/ha to meet peak crop water requirements for a projected annual cropping intensity of 143% (WAPDA, 2002a). To increase the flexibility of water delivery, the CRBC was also designed to use crop-based irrigation, in which water is to be supplied more in response to crop water requirements. This discussion attempts to analyse various factors leading to the problems of rising water-table for drawing the conclusion.

The average height of the sample village Jarra is 191 meters above mean sea level. As one proceeds down stream up to Chera, the altitude decreases continuously. The average height of Chera is 179 meters above mean sea level (Table VIII-18). As far as Khudaka is concerned, its elevation is 190 meters as it is located outside the CRBC command area. In certain part of CRBC command area, groundwater is saline and even unfit for domestic supply as well as for irrigation.

The ground water-table in most parts of the floodplain is generally less than 20 metres, whereas in the piedmont plain it ranges from 20 metres to over 100 metres (GoP, 1985). Large quantity of fresh groundwater is also available in the area, but it is commonly overlain by saline water. In the saline water belt, the presence of fresh groundwater could not be determined, to a depth of 283 metres in the piedmont plain. However, the water quality improves between 217 to 296 metres depth and the aquifers appear to contain fresh groundwater.

In D.I.Khan district, groundwater is progressively deeper as one move from the Indus river bank towards the piedmont (East to west). According to the respondents, both inside and outside the CRBC command area, water-table is steadily inclining. Farmers in a given vicinity experienced localized changes in the water-table, but outside the command area, majority of the respondents replied that no changes in water-table occurred. According to field survey, seepage and percolation is a significant problem all along the unlined watercourses. The analysis found that the problem of waterlogging is severe in certain parts of stage I, where water-table is close to the surface. On the average, the water-table in stage I and II is 3.3 and 10 meters, respectively (Table VIII-18).

The unwise utilization of water, intensive irrigation and trend towards the water loving crops has significantly inclined the water-table in the CRBC command area. After the inception of CRBC, in Jarra large area was severely affected by waterlogging and salinity. The twin problem continued to affect the land for almost eight years. The problem was mitigated when watercourses lined and anti-waterlogging drain was dugout, under the name of Paharpur SCARP (Plate VIII-1). This project was launched by water wing, WAPDA during 1989-90. The table VIII-18 reveals that in Jarra prior to CRBC, the ground water-table was -14 meters below the surface (1986), which inclined to -5 meters after CRBC in 2005. The analysis reveals that there is a significant difference in land levelling between stage I, II and III. The fields are more levelled at the tail end in stage I and II. However, stage III has extensive unlevelled land at the head and tail reaches due to which a lot of water is wasted and consequently added to the groundwater.

According to field survey together with the secondary data reveals that in Gomal, the water-table was on average -20 meters below the surface during 1988 (Pre CRBC), which inclined and reached to -10.5 meters in 2005 (post CRBC) (Figure VIII-17). If this increasing trend of water-table continues, it will soon adversely affect the cultivated land and in effect, the land will become unfit for cultivation. According to field observation together with the focused group discussion found that intensive irrigation, unlevelled land and trend towards crops that require plenty of water are the dominant contributing factors for inclining water-table in Gomal.

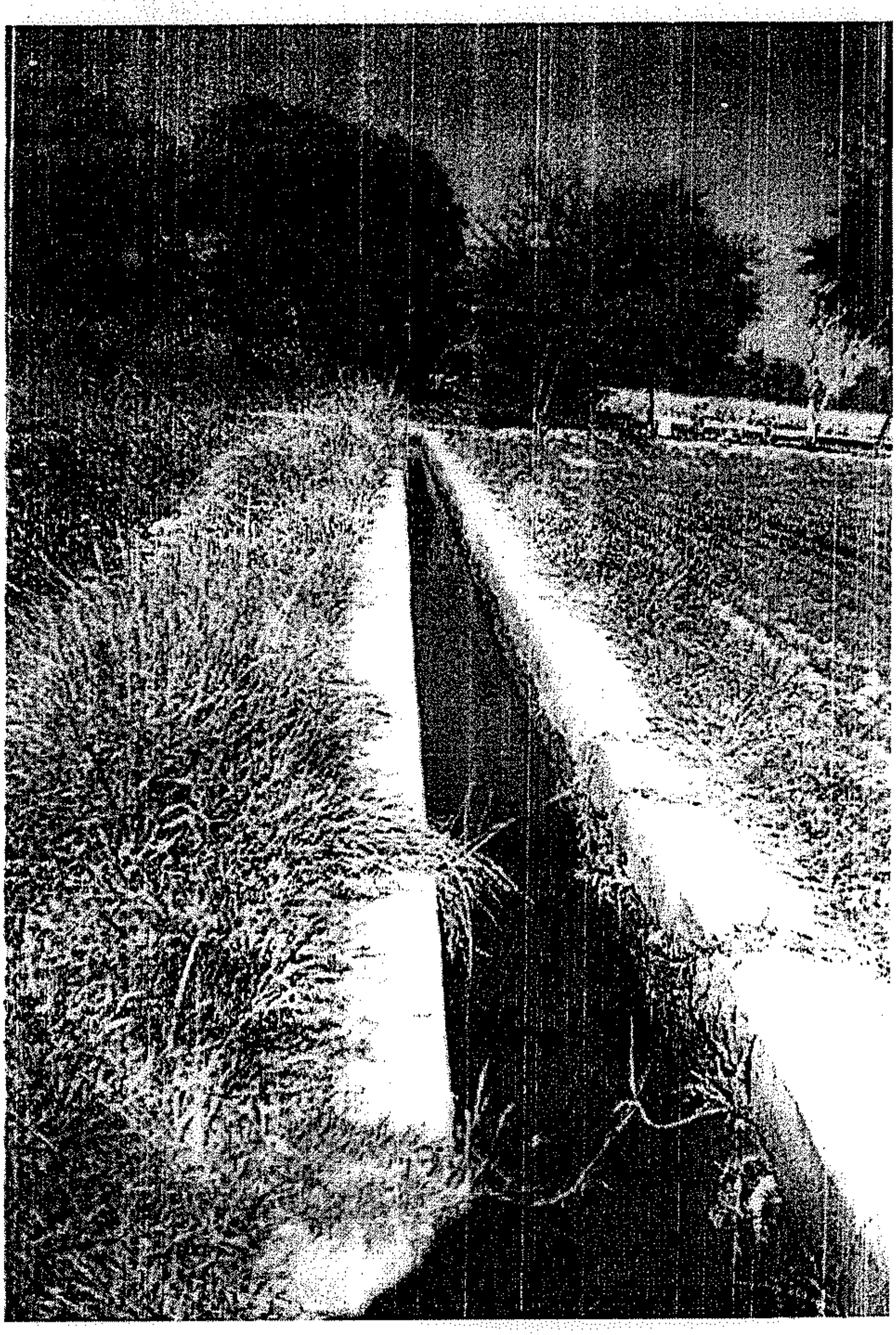

Plate VIII-1. Lined watercourse in the CRBC command area

Similarly, in Buchari, the water-table was -61 meters prior to CRBC during 1991, which inclined to -44 meters below the surface during 2005 (Table VIII-18). It means that the inclining rate at the average is 1 meter per year. This is very rapid pace. If, this trend is compared with that of Chera, it is relatively slow increase. This increase is mainly due to the introduction of water loving crops and unwise irrigation practice as a result of CRBC.

In Chera, the water-table pre CBRC was -21 meters below the surface, but after 5 years of CRBC commissioning, the water-table rose to -9 meters (Figure VIII-17). It means that the rate per year is roughly 2 meters. This indicates the rapid rise of water-table in the CRBC command area. During field survey, it was observed that in Chera several unpaved ponds along the watercourses were constructed. These ponds were used to store canal water and then supply it to their houses for domestic purpose using electric pumps. Hence, there was permanent seepage from the stagnant water of these unpaved ponds. Similarly, most of the irrigation channels are unlined (Plate VIII-2). Besides this, intensive irrigation and introduction of more water loving crops have severely disturbed the equilibrium of water-table in the area. Khudaka, which lying outside the command area showed no changes in the water-table both in pre and post CRBC situation.

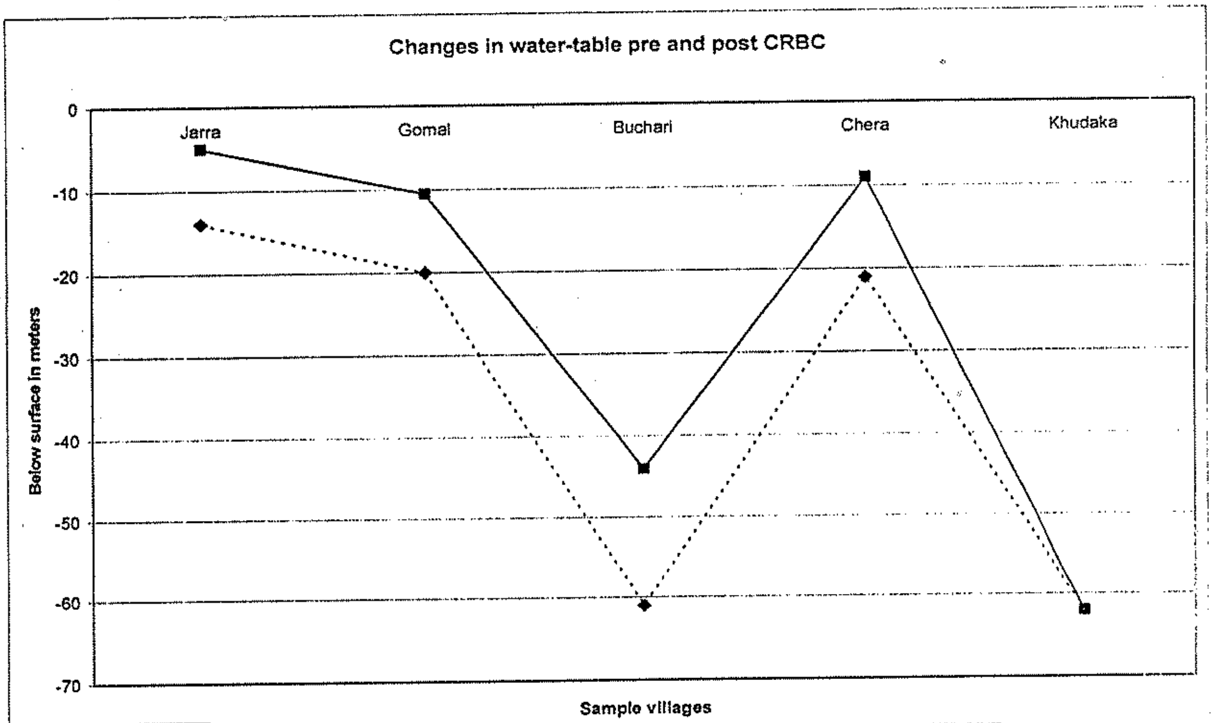

Figure VIII-17

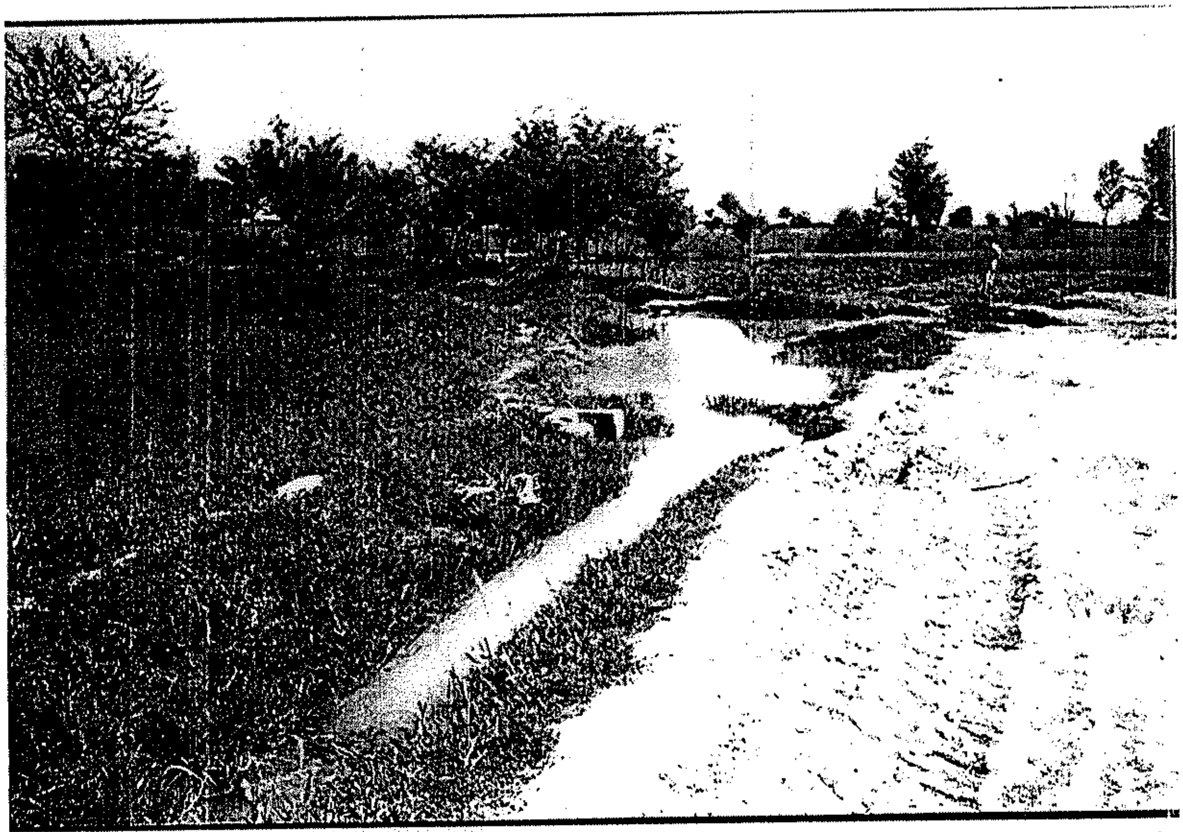

Plate VIII-2. Unlined watercourses in the CRBC command area is a serious threat to land resources

Table VIII-18

Height and ex post CRBC water-table of the sample villages

Sample village	* *Height of village above sea level (in meters)*	*Water-table pre-CRBC below surface (in meter)*	*Water-table post-CRBC below surface (in meter)*
Jarra	191	-14	-5
Gomal	186	-20	-10.5
Buchari	184	-61	-44
Chera	179	-21	-9
Khudaka	190	-62	-62

Source: Field survey April, 2005 and GoP, 1985   * *The Height was calculated using GPS*

8.5 CONCLUSION

The macro and micro level analysis revealed that after inception of CRBC, the agricultural production of almost all the Kharif as well as Rabi crops have improved. The increase in agricultural production has been predominantly recorded in water loving crops such as rice and sugarcane. The analysis also revealed that after CRBC the yield in kg per ha of all the Kharif and Rabi crops have improved.

It was found from the analysis that prior to the advent of CRBC, trend towards the use of modern agricultural implement was very limited and use of modern agricultural implements was mainly reported from those areas, where perennial irrigation was available. The micro level analysis revealed that prior to CRBC, there was limited mechanized agriculture and the farmer mainly relied on the traditional methods of using animate energy for ploughing and threshing. However, after CRBC, drastic changes occurred in the use of agricultural implements. Presently, in almost all the sample villages, farmers are using modern techniques and trend towards the mechanization is positive.

The analysis found that prior to CRBC the use of chemical fertilizer was very limited, but after CRBC the use of fertilizer has increased. The micro level analysis revealed that the application of chemical fertilizer in the CRBC command village was introduced as an agricultural input after canal irrigation. It was found from the analysis that the use of fertilizer is generally higher in stage I and II as compared to stage III. The field survey revealed that 95% farmer has used chemical fertilizer during the last cropping season and few could not bear the cost of chemical fertilizer.

The analysis found that after inception of CRBC the land values of all the land categories have increased several fold. It was also found that in almost all the sample villages, the residential land prices were higher then rest of the land use types.

One of the major problems developed after the large-scale surface water irrigation is the continuous rise of water-table leading to waterlogging and development of salt infestation problems, which was observed in several parts of the CRBC command area. Water-table has started rising in this desert ecosystem due to large scale percolation from the fields, seepage from unlined channels and return flow from irrigated lands. The study found that the water-table has been rising at an alarming rate. The analysis further revealed that both inside and outside the CRBC command area, water-table is steadily inclining.

APPLICATION OF CHECKLISTING AND SWOT TECHNIQUES FOR THE ASSESSMENT OF IMPACTS OF THE CRBC ON THE LAND USE AND AGRICULTURAL RESOURCES

Introduction

The chapter six, seven and eight analysed the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district, whereas this chapter deals with the application of checklisting as well as Strength, Weaknesses, Opportunities and Threats (SWOT) analysis techniques for the assessment of impacts of CRBC on the land use and agricultural resources of D.I.Khan district. The chapter is divided into four sections. Section one deals with the checklist analysis for the evaluation of environmental impacts of CRBC on the land use and agricultural resources. Section two discusses the application of SWOT analysis for the assessment of CRBC impacts on the land use and agricultural resources of D.I.Khan district. Section three focuses on testing of research hypothesis. The chapter is concluded in the final section.

9.1 APPLICATION OF A CHECKLISTING TECHNIQUE FOR THE ASSESSMENT OF IMPACTS OF CRBC ON THE LAND USE AND AGRICULTURAL RESOURCES

Environmental impact evaluation methodologies are widely used and have been categorized into various groups. However, most widely used methodology is the checklist. Therefore simple checklisting technique is used in this study. All small and large-scale irrigation projects, with passage of time after commissioning show impacts on their respective ecosystems. After canal irrigation in the arid tract of D.I.Khan district there has been many environmental changes. Most of the biophysical changes in the study area are due to the advent of CRBC. These changes are both positive as well as negative, when studied on various parameters. The major environmental impacts on important components like land use, cropping pattern, cropping intensity, agricultural production, mechanization, fertilizer, land values, water-table and other components of environment are analyzed in this section.

Table IX- 1

Checklist for the assessment of CRBC impacts

Parameters	No Impact	Nature of impacts															
		Adverse Impacts									Beneficial Impacts						
		ST	LT	R	IR	L	W	SI	M	N	ST	LT	L	W	SI	M	N
Land use			X	X	X	X		X	X		X	X	X		X	X	
i. Cultivated area				X		X			X			X	X		X		
ii. Cultivable waste												X	X		X		
iii. Uncultivated area			X		X	X		X			X		X			X	
Cropping pattern												X	X		X		
Cropping intensity											X		X		X		
Irrigation			X	X		X		X				X	X		X		
Land values												X	X		X		
Agri. production												X	X		X		
Fertilizer											X		X		X		
Mechanization												X	X		X		
Water-table			X	X		X		X									
Water cess/*Abiana*												X		X	X		
Drinking water												X	X		X		
Employment												X		X	X		
Self sufficiency												X	X		X		

Legend

ST	Short Term	IR	Irreversible	SI	Significant
LT	Long Term	L	Local	M	Moderate
R	Reversible	W	Wide	N	Normal or Negligible

9.1.1 Impacts of CRBC on the land use

In D.I.Khan district, after the introduction of canal irrigation, the agricultural landscape of majority of the sample villages have changed significantly. It was the result of CRBC that in the CRBC command area almost all the cultivable waste land was brought under cultivation. Field survey together with the revenue records revealed that there has been considerable enhancement in the cultivated area as a result of CRBC. Likewise, the net sown area has increased considerably. Increase in the cultivated area was noted both in Kharif as well as in Rabi season. According to revenue record and field survey it was found that after CRBC, the acreage of Kharif crops have improved from 10 to 80% and that of Rabi from 15 to 91%. The CRBC has also caused changes in the area under the current fallow. Before the inception of canal irrigation, current fallow was higher as against post CRBC.

In D.I.Khan district, after the introduction of canal irrigation, the land use pattern has greatly changed. As a result many long-term impacts have been identified. Extensive cultivable land has rapidly been brought under non-agricultural uses, mainly such as new settlements, industries, construction of roads and canals etc. Rapid physical development has been started in the area as a result of CRBC. However, in majority cases this development has not been properly planned, which lead to some adverse effects as well. For instance a lot of prime agricultural land has been converted to inappropriate uses such as settlements and other physical developments. This is an irreversible negative impact on local area of this canal-irrigated region. Consequently, it has significant adverse impact on the land use of this canal region. The problem can be minimized if the people switch over to use cultivable waste land for settlement and other physical development. The analysis reveals that in some cases cultivable land in CRBC stage I was also affected by waterlogging and salinity. This is a short-term negative impact of CRBC on the local area, but reversible after applying mitigation measures (Table IX-1).

The analysis further reveals that long-term and significant positive impact on the land use is the increase in cultivated land that has taken place (Table IX-1). The study also indicates that another positive impact has been the development of more settlements and infrastructure in the area. Prior to the construction of CRBC, the area was not that attractive for human habitation because of limited resources. However, after completion of CRBC, the area attracted more people because of prosperity and physical development.

9.1.2 Impacts of CRBC on the cropping pattern

In CRBC command area, rainfed and Rod Kohi farming has been replaced by canal irrigation. Total cropped area in both Kharif and Rabi cropping season in CRBC command area has been increased. It has very positive impacts on the cropping pattern as well. Many rainfed crops have been replaced by water loving crops such as sugarcane, rice and orchards etc. The introduction of these crops has brought prosperity in the region. In the CRBC command area, land under wheat has also enhanced. Most of the increase has taken place at the expense of low rewarding crops such as sorghum, barley and millet etc. The cropped area under millet has been reduced substantially and this area was allocated to high return crops. As a result the choices of crops had increased and physical barriers were modified. This is a long-term positive impact of CRBC that has significantly benefited the study area (Table IX-1).

9.1.3 Impacts of CRBC on the cropping intensity

Prior to CRBC, the uncertain climatic condition was the major limiting factor for low cropping intensity. In D.I.Khan district, the cropping intensity varies from area to area. The analysis reveals that in the CRBC command area the cropping intensity has been increased after introduction of canal irrigation, whereas low cropping intensity prevails in the rainfed and Rod Kohi areas (see section 7.2). In the CRBC command area, the cropping intensity has enhanced, whereas area under current fallow has been reduced to a greater extent. Cropping intensity could further be increased through expansion of canal irrigation to off the CRBC command area. This is significant positive impact on the economic sector of D.I.Khan district (Table IX-1).

9.1.4 Impacts of CRBC on the irrigation

The inception of CRBC has really brought positive changes in the irrigation pattern of D.I.Khan district. In the CRBC command area, mostly the groundwater is saline and unfits both for drinking and irrigation purpose. It has been observed that CRBC has provided assure water both for irrigation and domestic purpose and quenched the thirst of the people of the command area. With the assured water supply the cultivable waste was brought under cultivation, choices of crops were increased, cropping intensity was accelerated, and revenue generation started that boost-up the agricultural production. The study reveals that CRBC has improved the socio-economic condition of the residents particularly in the CRBC command area. Hence, this is one of the long-term, but significant positive impacts on the local residents (Table IX-1).

Despite of wide range of positive impacts, there are some negative consequences of unwise irrigation practices. The unlined irrigation channels, uneven fields, seepage and percolation have inclined the water-table and are serious threat to the precious land resources of D.I.Khan district. This is one of the long-term but reversible significant adverse impacts on the local area (Table IX-1).

9.1.5 Impacts of CRBC on the land values

According to revenue record, during pre-construction phase of CRBC, the land prices were not so high, though the land prices differ from one category to other. Per unit cultivable waste was found lowest as compared to land for residential or agricultural, which is considered as more valuable. The change in the land prices is positive impact. After inception of CRBC, the land value has been constantly enhanced. For landowners, rise in the land prices has a positive impact, as their land becomes more valuable. After availability of canal irrigation they are presently getting higher agricultural production as compared to the pre CRBC situation. The beneficial impacts are long-term and significant in the CRBC command area (Table IX-1).

The higher production from this fertile land has also encouraged well-off people from the surrounding districts to purchase land in the CRBC command area. This has caused cultural interference and became a moderate negative impact of CRBC on the local area.

9.1.6 Impacts of CRBC on the agricultural production

In D.I.Khan district, agricultural inputs particularly availability of canal irrigation have played a pivotal role in boosting the agricultural production. The analysis reveals that prior to

CRBC, the yield of almost all the crops were very low, while after CRBC, the yield of both Rabi and Kharif crops have been increased. This is one of the long-term, significant positive impacts on the local economy (Table IX-1).

The crop varieties grown in pre CRBC were different from the crop varieties grown in post CRBC by the farmers. Prior to CRBC, farmer mainly relied on the traditionally old seed variety. They usually reserved part of their production as a seed for next season and in effect, the production remained low. However, in canal irrigated area farmers have used modern seed varieties obtained from the local market. Only in Gomal, about one third of the respondents said that prior to CRBC they used modern seeds obtained from the agriculture farm (Table IX-2). In the sample villages, prior to CRBC, majority of the farmer used local seed, which clearly reflect farmer's trend towards old and traditional means of agriculture in the area.

After CRBC, great changes occurred in almost all sectors. Increasing awareness, accessibility, irrigation etc. encouraged farmers to switch over to new and high rewarding crops (Table IX-2). Field survey reveals that high proportion of the farmers is now using approved seed obtained from the agricultural farms or local market. Therefore, after CRBC, reliance on the traditional seed varieties has substantially reduced. However, in Khudaka, all the farmers were of the view that they are getting seed from the local market, as their farming depends on the availability of Rod Kohi irrigation system, which is very uncertain and hence, it is very wasteful to keep seed for uncertain season that some time extend to even twelve years.

Table IX-2
Impacts on seed varieties

Sample village	*Pre-CRBC source of seed (%)*			*Post CRBC source of seed (%)*			
	Own	*Local market*	*Agriculture depot*	*Own*	*Local market*	*Agriculture depot*	*Other Farmer*
Jarra	85	10	5	10	25	65	0
Gomal	60	10	30	25	10	55	10
Buchari	95	5	0	10	50	45	5
Chera	85	15	0	25	20	35	20
Khudaka	0	100	0	0	100	0	0

Source: Field survey, 2005

9.1.7 Impacts of CRBC on the fertilizer

Prior to the inception of CRBC, the use of chemical fertilizer were not common because of non availability of canal irrigation. The farmer mainly relied on the farmyard manure. However, after CRBC, the application of chemical fertilizer was increased particularly in the irrigated area of D.I.Khan district. With the application of chemical fertilizer yield per hectare was also enhanced. This is one of the short-term local but significant positive impacts on the dwellers of the irrigated region of D.I.Khan district (Table IX-1).

The misuse of agro-chemicals such as fertilizer is added to the soil, which percolate, added and subsequently pollute the groundwater. If the groundwater is consumed by the people, it is likely to cause the water born diseases. Therefore, in the irrigated tract of D.I.Khan district, the intensive use of chemical fertilizer will pose long-term, irreversible and significant negative impacts on the local residents (Table IX-1).

9.1.8 Impacts of CRBC on the agricultural mechanization

In D.I.Khan district, mechanization has brought revolutionary changes in the modern agricultural sector. Managing extensive cultivable land is only possible with the application of modern agricultural tools and techniques. Prior to CRBC, trend to use modern agricultural implements were very limited but after inception of CRBC, the socio-economic uplift has increased the use of mechanization as a result the number of owner cultivators were increased. Farmer's workload was reduced, time was saved and in effect agricultural productivity was enhanced. This is long-term, significant positive impact on the economy of D.I.Khan district (Table IX-1).

9.1.9 Impacts of CRBC on the ground water-table

The analysis reveals that in the CRBC command area the water-table has been gradual inclined. This rise of water-table indicates that if this trend continued, soon the CRBC command area will become unfit for cultivation. This is one of the serious environmental degradation posed by the area. This is a long-term but reversible negative impact on the command area (Table IX-1).

9.1.10 Impact of CRBC on revenue generation

Like land and property taxes, *abiana* is a water cess. The water taxes vary from one mode of irrigation to other. Lift Irrigation has higher charges per unit area than the canal irrigation. Parallel to this, the water tax is comparatively higher amongst the crops require plenty of water like sugarcane and rice as compared to other crops. Initially, *abiana* was the sole responsibility of revenue department but after 2000-2001, *patwari* of the Provincial Irrigation and Drainage Authority (PIDA) is collecting *abiana* from the landowners, in order to carry-out Operation and Maintenance (O & M) of CRBC system (WAPDA, 2002a).

During field survey, the respondent said that water cess is collected more then the government specified rate. They were also of the opinion that *abiana* vary from year to year and there is no fixed rate. Some of the respondents replied that *abiana* is collected only from the poor people. When this was confirmed with the officials of PIDA, they rejected this objection and elaborated that water tax is collected according to Government specified rates. However, the analysis reveals that it will be more viable if prior to *abiana* collection, the PIDA locally advertise the notification regarding *abiana* rates. This will directly benefit as well as facilitate the farmers and will overcome their mistrust. Likewise, the farmer should be made well aware about the positive impacts of *abiana* collection. The table IX-3 revealed that during 1987-88 only Rs.2.4 million were collected from the farmers, which has been gradually increased to 77.3 million during 2003-2004 (Figure IX-1). This has positively influenced the sustainability of the project and assurance of perennial water. The *abiana* has long-term significant impact on the entire D.I.Khan district (Table IX-1).

Table IX-3

Status of water cess (*Abiana*), 1987-88 to 2003-2004

Year	Stage I *		Stage II		Stage III		Total	
	Area (ha)	Abiana (Million rupees)	Area (ha)	Abiana (Million rupees)	Area (ha)	Abiana (Million rupees)	Area (ha)	Abiana (Million rupees)
1987-88	38,300	2.4	-	-	-	-	38,300	2.4
1988-89	44,467	2.9	-	-	-	-	44,467	2.9
1989-90	47,606	3.2	-	-	-	-	47,606	3.2
1990-91	51,524	3.3	-	-	-	-	51,524	3.3
1991-92	50,210	3.4	7,935	0.46	-	-	58,145	3.9
1992-93	52,421	3.7	11,174	0.78	-	-	63,595	4.5
1993-94	54,868	5.4	19,939	1.7	-	-	74,807	7.2
1994-95	55,808	6.5	32,109	3.2	-	-	87,917	9.7
1995-96	56,822	8.1	32,853	4.5	-	-	89,675	12.7
1996-97	59,281	10.6	35,281	6.3	-	-	94,562	16.9
1997-98	60,261	13.6	36,021	8.2	-	-	96,282	21.8
1998-99	60,343	16.5	36,372	10.9	-	-	96,715	27.5
1999-00	61,242	20.8	37,978	14.2	-	-	99,220	35.1
2000-01	62,202	21.1	38,409	14.1	13,064	3.4	113,675	38.7
2001-02	61,413	19.5	38,962	16.4	31,071	10.2	131,446	46.3
2002-03	63,186	30.2	38,957	21.4	34,476	15.7	136,619	67.4
2003-04	59,548	33.7	38,120	23.5	39,808	20	137,476	77.3

Source: Irrigation Dept. GoNWFP, 1987 to 2004 * Abiana in Stage I also includes old Paharpur canal system

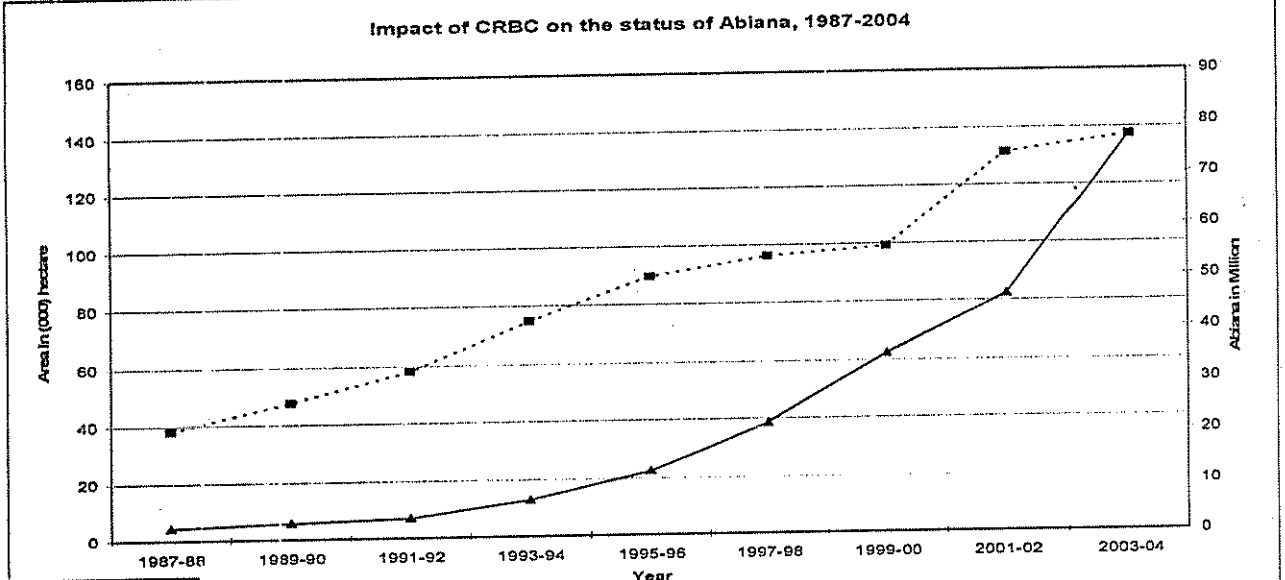

Figure IX-1

9.1.11. Impacts of CRBC on drinking water

In most part of the D.I.Khan district, groundwater is saline and unfits both for drinking and irrigation purpose. Prior to CRBC majority of the household has used torrent or rain water for domestic purpose. However, after CRBC many inhabitants considered CRBC water as a hygienic source for drinking. Presently, majority of the household use canal water for domestic purpose, whereas some use water supplied by the Public Health Engineering Department (PHED). In the CRBC command area, more than half of the population are using canal water for domestic purpose (WAPDA, 2002b). It has also been observed that in CRBC stage II and III, canal is the dominant source of drinking water. Resident considers this one of the major benefit of CRBIP, since much of the area is rain-fed and groundwater is saline.

In Gomal, Buchari and Chera respondents said that after CRBC the groundwater is gradually converting to better taste as compared to pre CRBC. In Chera, there is an age-old pond, from where people still obtain water for drinking purpose. Prior to CRBC, this pond was fed from the rain and hill torrent water, but after CRBC, canal water is main source of drinking water in the village. There are several small ponds on the watercourses. This feature is very common in Buchari and Chera. However, outside the CRBC command area, government water supply schemes are also the prominent feature. Before CRBC, people had to bring fresh water from quite far off areas particularly during dry period. Some time they started migration due to non-availability of drinking water. Hence, after the inception of CRBC, canal water became a major source for drinking. This is long-term and significant beneficial impact of CRBC on the local area (Table IX-1).

9.1.12. Impacts of CRBC on employment generation

CRBC has opened new windows for employment and this is long-term beneficial impacts on both inside and outside the command area (Table IX-1). In the CRBC command area creation of employment opportunity is the most significant positive impact. With increased agricultural development in the area, agglomeration of economy has started. With the passage of time, the spread effect of development will further boost the economic condition in the study area.

Prior to CRBC, farming remains the predominant economic activity particularly in the CRBC command villages. However, outside the CRBC command area, off farm employment dominates the scene. Field study reveals that very few people in the sample villages are engaged in the overseas employment. After the inception of CRBC, the on-farm employment has been increased. In the initial phase of CRBC most of the labourer was involved in bringing cultivable waste under cultivation. Therefore they were mainly employed in ploughing, threshing and land levelling. Focused Group Discussion together with the questionnaire survey reveals that after canal irrigation their employment became more secure and income level has been greatly enhanced and quality of life was improved. New local markets were opened, where daily use items, selling and buying of agricultural products were marketed. Some of the local people were also engaged in marketing the agricultural products to other districts of Pakistan (WAPDA, 2002b). As far as source of annual income is concerned, the highest share is from the farming sector. Generally, male work on farm and mostly 15 to 60 years dominate the farm labour. To some extent female, also participate in the farming economic activity. Off farm employment mainly constitute by the labour force having age group 15 to 60 years and this age group is the main bread earner, working either inside the village or outside the village. Nevertheless, CRBC greatly increased the per capita income and living standard in the CRBC command area.

9.1.13. Impacts of CRBC on livestock

The table IX-4 shows that the number of livestock has been increased from pre CRBC, 1.11 Million in 1985 to post CRBC of 1.4 Million during 1996. This indicates improvement in the carrying capacity of Cultivable Command Area of D.I.Khan district since the commissioning of CRBC. The analysis reveals that cattle, goats and sheep are the dominant species (Plate IX-1). However, prior to CRBC, number of livestock was comparatively small, because of inherent low

Plate IX-1. Dominent Livestock species under tree shadow during hot summer economic base of the farmers, lack of fodder and pastures. After CRBC, thorough changes occurred in animal husbandry. Previously, extensive cultivable wastes were used for grazing, which was currently converted into cultivated land. It means that the farming system transformed from nomadic to sedentary. Another important feature is the over whelming increase in number of buffalos in the CRBC command area. In the sample villages, some of the household had developed a dairy farm and subsequently milk was supplied to the city and earning a lot from dairy farming. The trend towards dairy farming is maximum in Jarra and Gomal (milk is non-durable product), because of nearness to the urban centre as against other villages.

TableIX-4
Livestock population in D.I.Khan district

Livestock	*Livestock Population*			
	1985	*1990*	*1996*	*% age of 1996*
Cow	232,150	234,760	371,039	24.81
Buffaloes	50,040	52,540	85,987	5.75
Sheep	131,700	138,300	144,080	9.64
Goats	180,880	189,920	340,994	22.80
Camels	16,800	16,960	18,603	1.24
Horses	2,030	2,130	2,191	0.15
Donkey (Asses)	20,160	21,170	30,545	2.04
Poultry (Chicken)	478,000	501,900	501,900	33.56
Total	1,111,760	1,157,680	1,495,339	100

Source: GoNWFP, 1991; 1996b; 2000c

9.2 APPLICATION OF SWOT ANALYSIS TECHNIQUE FOR THE ASSESSMENT OF CRBC IMPACTS ON THE LAND USE AND AGRICULTURAL RESOURCES

Strengths, Weaknesses, Opportunities and Threats (SWOT) is one of the technique applied for the evaluation of CRBC impacts on the land use and agricultural resources of D.I.Khan district. Using standard questionnaires, data were collected from the general public, farmers, community leaders, official of the line agencies etc. For detailed environmental impacts evaluation, nine indicators were taken for interpretation including land use, cropping pattern, cropping intensity, agricultural production, irrigation, mechanization, fertilizer, land values and water-table. Following is the result of SWOT analysis.

9.2.1 The potential Strengths in the land use and agriculture sector

In D.I.Khan district, while talking about the strengths the participants living in different environmental settings pointed out that, they had good quality lands capable of producing high valued crops, vegetables and fruits (Table IX-5). The analysis reveals that farmers are getting good crops and orchard yields particularly in areas where canal irrigation exists. After inception of CRBC the agricultural production was largely increased. In the CRBC command area, the cropping intensity is relatively high. Beside this, the presence of canal irrigation, lift and Rod Kohi irrigation system are other major strengths of the area. Likewise, good quality aquifers are available along the Indus river. Similarly, in the study area, land holdings are mostly large. The analysis reveals that in the CRBC command area, cropped area was mostly found under high yielding seed varieties and almost all farmers have used chemical fertilizer in last cropping season. In the CRBC command area both modern and locally manufactured equipments were available. The analysis reveals that very small proportion of the farmers has used weedicides and insecticides for controlling the weeds and insects, respectively.

9.2.2 The existing Weaknesses in the land use and agriculture sector

The analysis reveals that in D.I.Khan district the major Strengths are encouraging for the land use and agricultural sector of the area but the respondents also reported few weaknesses, which were hindering the land use and agricultural resources of the study area.

The respondents said that after inception of CRBC, built-up area is expanding at an alarming pace and engulfing productive agricultural land. Outside the CRBC command area, cropping pattern is highly dependent on uncertain availability of water. Similarly, non-availability of perennial irrigation outside the CRBC command area has resulted low and uncertain cropping intensity (Table IX-5). In some areas, where canal irrigation doesn't exist and groundwater quality is saline low yield is reported. The participants pointed out various other weaknesses, which include, poor operation and maintenance of existing irrigation system, insufficient quantity and management of surface water, seepage and percolation, heavy dependence on surface water and availability of saline groundwater in large tract of D.I.Khan district. Likewise, in canal irrigated area, the unwise irrigation practice has inclined the water-table. Small but fragmented landholdings in the CRBC command area were found some of the weaknesses in land use and agriculture sector of D.I.Khan district. Low literacy rate has resulted in less awareness about the use of modern techniques of farming (like proper and timely use of weedicides, insecticides and sowing methods, etc.). In stage I, certain areas were affected by waterlogging. The analysis reveals that due to good weather conditions, farmers would get more crops production. The respondents also pointed out that poor road facility is also weaknesses of D.I.Khan district.

9.2.3 The available Opportunities in the land use and agriculture sector

The analysis reveals that there are several opportunities that could be utilized for the uplift of D.I.Khan district. The respondents were of the view that large-scale cultivable waste could be brought under cultivation. They also pointed out various other opportunities that included

Table IX-5, Results of the SWOT analysis for land and agriculture sector, D.I.Khan

Variables	*Strengths*	*Weaknesses*	*Opportunities*	*Threats*
Land use	Availability of extensive cultivable land	Built-up area is expanding at an alarming pace and engulfing productive agricultural land	Large scale cultivable waste can be brought under cultivation	- Cultivated land will be reduced
Cropping pattern	Variety of crops are grown both in Kharif and Rabi season	-Outside the CRBC command area, cropping pattern highly dependent on availability of water	Assured supply of canal irrigation could further increase the choices of crop and production	-Introduction of crops like rice and sugarcane could adversely affect the tail user
cropping intensity	-Relatively high cropping intensity in CRBC command area -Relatively less fallow land in the canal irrigated area	- Non-availability of perennial irrigation in off the CRBC area resulted low and uncertain cropping intensity	Cropping intensities could further be increased through expansion of canal irrigation and better water management strategies	- Cropping intensity could be reduced due to preference to water intensive crops which will ultimately leads to waterlogging and salinity - Pest attack and diseases could reduce yield
Agricultural production	Good crop and orchard yields particularly where sufficient canal irrigation was available	Low yields in some areas, where canal irrigation was not available and groundwater quality was poor	Better crop management and provision of quality inputs at the time of need might lead to high crop yield	If canal water were not provided and maximum dependence remained on natural supply of water, yield would decrease
Irrigation	Existence of canal irrigation system, lift irrigation, Rod Kohi etc.	- Poor O & M of existing irrigation system - Insufficient quantity and management of surface water - In large track, groundwater is saline - Seepage and percolation - Heavy dependence on surface water sources	- Extensive area could be brought under canal irrigation - Better O & M of irrigation system could help to increase yield and reduce poverty -Dams could be constructed on the hill torrents	Deteriorating irrigation infrastructure would lead to decrease in production and increase in poverty - Equity in water distribution could reduce the poverty in the tail end area
Ground water-table	Good quality ground-water is available in the areas along river Indus	-Saline groundwater is available in large track of D.I.Khan -In canal irrigated area water-table is rapidly rising	Application of canal irrigation in the saline area and installation of tube wells in the Indus floodplain can enhance agricultural productivity	Water losses could incline saline water-table and in-effect reduce productivity and cropping intensity
Landholdings	Mostly large land holdings	Small and fragmented landholdings in the canal irrigated area	Consolidation of land	Due to law of inheritance, landholdings would become further smaller/ uneconomical
Improved seed	Majority of farms were under improved varieties	- Difficulty in access to improved seeds - The yield potential of improved varieties could not be achieved due to improper use of inputs	- Yield potential of improved seeds could be obtained by the use of good quality improved seed - Proper and timely use of improved seed could increase the yield of seeds	Susceptibility of seeds to insect, pest or diseases
Mechanization	Modern and locally manufactured equipment were available	Could not purchase modern agricultural machinery due to its high cost	Timely completion of agricultural operations if modern machinery could be available on low rent	Maximum dependence on locally manufactured equipment could reduce management of large cultivated land
Use and availability of fertilizer	Majority of the farmers are using fertilizers	Quality constraints, high prices and low affordability	Quality check, low prices and timely provision of fertilizer could increase the crop production	Without soil analysis use of fertilizer may cause soil infertility
Weeds, pests and disease management	Farmers were using weedicides and pesticides	Majority of farmers were unaware of proper timing for the use of weedicides and likewise of pesticides	Extension Department could create awareness about the selection of weedicides and pesticides for particular type of weed and diseases and time of application	Absence of improved weedicides and pesticides management might lead to decrease in yield
Waterlogging & Salinity	No problem of waterlogging and salinity in off CRBC command area	In CRBC stage I problem of both waterlogging and soil salinity is present	- Land reclamation projects could be started to reduce waterlogging and salinity in order to maintain the soil fertility - Awareness programmes should be started for judicial utilization of irrigation water	waterlogging and salinity may decrease in yield which ultimately lead to poverty

guaranteed and assured supply of canal irrigation which could further increase the choice of crops that could accelerate agricultural production. It was found from the analysis that extensive area with Rod Kohi irrigation could be brought under canal irrigation (Table IX-5). The cropping intensities could further be increased through expansion of canals and better water management strategies. Respondents also pointed out that better crop management and provision of quality inputs at appropriate time might also lead to high agricultural production.

In the study area the respondents also stressed upon the need of dam construction over the hill torrents, provision of canal irrigation in the saline groundwater area and installation of tube wells in the Indus floodplain for the purpose of improving agricultural productivity. The analysis indicates that other opportunity is the ownership of agricultural machinery including tractor, thresher and harvester, which could help in improving the agricultural productivity and also extensive area be brought under cultivation. The respondents further explained that low prices of fertilizers could further increase the crop yield. Another most important opportunity pointed by the respondents is the creation of awareness about the selection of crops, land use planning, judicial utilization of irrigation water, weedicides and pesticides selection at proper time. In order to maintain the soil fertility, land reclamation projects could be started to reduce waterlogging and soil salinity in the already affected areas of stage I.

9.2.4 Major Threats to the land use and agriculture sector

The analysis reveals that despite of all the above-mentioned strengths and opportunities, the respondents also pinpointed major threats, which were adversely impeding the productivity of land and agricultural resources in D.I.Khan district. When the sample households were asked for threats to their land and agricultural practices, they replied that cultivated land would be reduced if the present trends of rapid conversion of cultivable land to the built-up environment continued. In the study area when the participants were further inquired, they said that introduction of crops like rice and sugarcane could adversely affect the tail user. The respondents were of the opinion that preference to new water loving crops such as rice, sugarcane and orchard is one of the major threats, which could reduce the cropping intensity and would lead to the hazard of waterlogging and salinity in the future. The analysis further reveals that pest attack and diseases were also considered the potential threats to the crops production particularly in the CRBC command area (Table IX-5).

The respondents were also of the view that outside the CRBC command area extensive area is barren and if canal irrigation is not extended and maximum dependence remained on natural supply, yield would decrease. The respondents further said that excessive water losses could incline saline water-table and in-effect reduces both crops productivity and cropping intensity. During field survey, the respondents replied that due to law of inheritance, landholdings would become further smaller and uneconomical. Management of large cultivable land is only possible using mechanical energy. However, in D.I.Khan district still large number of farmers is using traditional means. The sample respondents pointed out that without soil analysis, application of fertilizer may cause soil infertility. Similarly, lack of awareness about the use and management of weedicides and pesticides in the CRBC command area might lead to decrease in agricultural production. In the CRBC command area, rapid rise of water-table, waterlogging and salinity might loss prime agricultural land, which ultimately lead to poverty.

9.3 TESTING OF RESEARCH HYPOTHESIS

Irrigation project has both positive and adverse impacts, if judged on various parameters. The negative impacts of CRBC could have been avoided if Environmental Impact Assessment Study could have taken place and mitigation measures could have adopted for adverse impacts.

9.3.1 Hypothesis testing - I

It was hypothesised that after commissioning of CRBC there has been considerable enhancement in the cultivable land as a result of CRBC. The analysis revealed that after commissioning of CRBC in the command area, there is sharp incline in the area under cultivation and resultant decline in the cultivable waste. In the CRBC command area, large scale cultivable waste has been brought under cultivation. Contrary to this, in off the CRBC command area, no significant changes have been reported in the land use categories. Hence, it supports the hypothesis that there has been considerable enhancement in the cultivable land as a result of CRBC.

9.3.2 Hypothesis testing -II

It was hypothesised that canal irrigated area has been increasing in the study area after commissioning of CRBC. It was found that after inception of CRBC, area under canal irrigation in all the CRBC command sample villages has gradually increased. The analysis revealed that as area under canal irrigation increases, area under other sources of irrigation decreases and subsequent there is boosting in the cultivated area. Hence, it supports the hypothesis that after inception of CRBC, there has been constant increase in the canal irrigated area.

9.3.3 Hypothesis testing -III

It was hypothesised that new water loving crops have been introduced in the study area with the launching of CRBC. Prior to CRBC, major Kharif crops were maize, sorghum, millet and that of Rabi included wheat, gram, oilseed and barley. However, after CRBC, new water loving crops such as sugarcane, rice, fruits, vegetables, fodder etc. were introduced on wider area. Hence, it confirms and supports the hypothesis that after inception of canal irrigation new water loving crops have been introduced in the study area,.

9.3.4 Hypothesis testing -IV

It was hypothesised that there has been significant increase in the cropping intensity after the advent of canal irrigation. The analysis revealed that one of the CRBIP objectives was to increase cropping intensity from 28% to 143%. Prior to CRBC, the cropping intensity was uncertain and varied from year to year as the cropped area dependent on the natural supply of water. Since the commissioning of CRBC, the cropping intensity in the CRBC command area has gradually increased. However, the pace was found comparatively slow in stage I and II, whereas in stage III, the cropping intensity is mounting, rapidly. The pace of cropping intensity is rapid in stage III than the cropping intensity of stage II (after twelve years of commissioning) and stage I (after seventeen years of commissioning). In Buchari, the cropping intensity is even higher (169% during 2003-04) than the project assumed (143%). Hence, it supports the research hypothesis that there has been significant increase in the cropping intensity after the advent of CRBC.

9.3.5 Hypothesis testing -V

It was hypothesized that there has been substantial increase in the agricultural production after inception of CRBC. Prior to CRBC, the yield varied from year to year depending upon the availability of water supply. Generally, the production and yield per hectare is higher over the irrigated areas than the un-irrigated areas. The analysis found that after CRBC the agricultural production of all crops has been increased several fold. This is mainly due to the inception of canal irrigation in the form of CRBC. Hence, the analysis supports the research hypothesis that after the inception of CRBC the agricultural production has enhanced.

9.3.6 Hypothesis testing –VI

It was hypothesised that land value has been increased considerably after commissioning of CRBC. The analysis found that after inception of CRBC the land values of all the land categories have increased several fold. Hence, it favours the research hypothesis that after inception of CRBC the land value has increased considerably.

9.3.7 Hypothesis testing -VII

The hypothesis states that the water-table in the command area has been raised as a result of CRBC. It has ultimately led to the problem of waterlogging and salinity in the CRBC command area. The hypothesis was found valid. In certain part of CRBC command area, groundwater is saline. The unwise irrigation practices and trend towards water loving crops had significantly inclined the water-table in the CRBC command area. The rapid rise in water-table indicates that if this trend continues, very soon the CRBC command area would pose the problem of waterlogging and salinity and become unfit for cultivation. Hence, it favours the hypothesis that introduction of canal irrigation in the form of CRBC has raised the water-table.

9.4 CONCLUSION

This chapter discussed the application of checklisting and SWOT techniques for the assessments of impacts of CRBC on the land use and agricultural resources of D.I.Khan district. The checklisting technique was applied on the selected variables in different environmental settings. In D.I.Khan district, after the introduction of canal irrigation, the land use pattern has greatly changed. As a result many long-term impacts have been identified. Extensive cultivable land has rapidly been brought under non-agricultural uses mainly such as new settlements, industries, construction of roads and canals etc. The analysis revealed that in the CRBC command area almost all the cultivable waste land was brought under cultivation. As a result there was considerable enhancement in the cultivated area after CRBC. The analysis further revealed that this is long-term significant positive impact on the land use of D.I.Khan district.

In the study area cropped area in both Kharif and Rabi cropping season was increased. Many rainfed crops have been replaced by water loving crops such as sugarcane, rice and orchards etc. The analysis revealed that after CRBC the cropping intensity was also increased. This is significant positive impact on the economic sector of D.I.Khan district. The high cropping intensity registered in the CRBC command area, whereas low in the rainfed and Rod Kohi areas. The analysis revealed that after CRBC area under canal irrigation was considerably increased. This is one of the long-term, but significant positive impacts on the local area. During pre-construction of CRBC, the land prices were not so high, but after CRBC the land value has been constantly enhanced. The analysis revealed that prior to CRBC, the yield of almost all the crops were very low, while after CRBC, the yield of both Rabi and Kharif crops have been increased. This is one of the long-term, significant positive impacts on the local economy. Prior to CRBC, the use of chemical fertilizer were not common. However, after CRBC, the application of chemical fertilizer was increased particularly in the irrigated area. The analysis revealed that prior to CRBC, trend to use modern agricultural implements were very limited but after inception of CRBC, the use of mechanization increased as a result the number of owner cultivators increased. The analysis further revealed that in the CRBC command area the water-table has been gradual inclined. This is one of the serious environmental threats posed by the area. This is a long-term but reversible negative impact on the command area.

Besides this, the chapter also discussed the application of SWOT analysis technique for the assessment of CRBC impacts on the land use and agricultural resources of D.I.Khan district. Using standard questionnaire the respondents were inquired about the potential strengths in the land use and agricultural sectors of D.I.Khan district. Similarly, the information was also gathered pertaining to the existing weaknesses in the land use and agricultural sectors of D.I.Khan district. The respondents also pinpointed some of the available opportunities in the land use and agriculture sector of D.I.Khan district. The study area posed certain threats, which was identified by the respondents. The results of SWOT analysis has been presented in the form of comparative table.

PART THREE

SUMMARY, FINDINGS AND RECOMMENDATIONS

SUMMARY, FINDINGS AND RECOMMENDATIONS

Introduction

In the previous four chapters' analysis of data were made, whereas this chapter focuses on the summary, findings and recommendations. The chapter is divided into three sections. Section one of the chapter deals with the major findings of the study. Section two gives the policy recommendations, whereas, detailed summary and conclusion of the entire study are given in the final section.

10.1 MAJOR FINDINGS OF THE STUDY

Following are the major findings of the study:

1. The analysis revealed that after inception of canal irrigation in the form of CRBC, cultivated area has gradually increased. It was found that there is a positive change of 0.58% in the cultivated area. This cultivated land has increased at the cost of cultivable waste land.
2. The analysis revealed that after inception of CRBC area under canal irrigation has increased more than seven fold and a net positive change of 10.77% has been recorded.
3. It was found that after advent of CRBC the built-up area has consistently increased and a positive change of 0.01% has recorded. Mostly this is at the cost of cultivated area.
4. The analysis revealed that after construction of CRBC area under cultivable waste has gradually decreased. A negative change of 1.13% of the total area has been recorded in the cultivable waste after CRBC.
5. The analysis of Kharif cropping pattern revealed that after the advent of CRBC a positive change has occurred in the more rewarding water loving crops such as rice, sugarcane, pulse, orchard and vegetables. Contrary to this negative change has been registered in sorghum, millet, oilseed, barley and maize. Similarly, it was found from the analysis of Rabi cropping pattern that after inception of CRBC Rabi acreage has increased considerably, which used to be low because of non-availability of water. It

was found that a positive change has occurred in wheat, pulses and orchard, whereas negative change has been registered in barley and oilseed.

6. It was found from the analysis that there has been considerable enhancement in the cropping intensity as a result of CRBC. It was found that after CRBC a net positive change of 13.05% of the total reported area has taken place.

7. The analysis revealed that after comparing pre and post CRBC condition the yield in kg per ha of all the crops has increased.

8. The analysis revealed that after inception of CRBC the agricultural production of almost all the Kharif crops has improved. The increase in agricultural production was recorded in rice, sugarcane, maize and pulses, whereas negative change in production occurred in millet, sorghum and oilseed. Contrary to this, low productivity has been noted outside the CRBC command area, where scarcity of perennial irrigation has restricted the productive agriculture.

9. It was found from the analysis that after CRBC the Rabi production of majority crops has increased. The positive change was recorded in wheat, pulses and fruits, whereas negative change in production has occurred in barley and oilseed.

10. The analysis revealed that prior to CRBC trend to use the modern agricultural implement was very limited. However, after CRBC due to socio-economic uplift and prosperity among farmer community the use of agricultural implements has been increased to a greater extent. In almost all the sample villages, farmers are using modern tools and trend towards the mechanization is very positive.

11. The analysis found that after CRBC the application of chemical fertilizer has been increased in the study area mainly due to the socio-economic development, which has improved the affordability of farmers to use the fertilizer.

12. It was found that the land values in the CRBC command villages have increased at a rapid pace, whereas outside the CRBC command area, change in the land value was insignificant.

13. The study found that after commissioning of CRBC the water-table in the CRBC command area is inclining at a rapid pace, which is a serious threat and can lead to the problems of waterlogging and salinity.

10.2 RECOMMENDATIONS

Based on findings of the study following are the major recommendations:

10.2.1 Land use Planning

In the CRBC command area, large-scale cultivable land has been brought under non-agricultural uses. This has happened because the development cost is much less on the agricultural land than other types of land. In this process, the development in many cases has been haphazard and without any care to land use planning. Moreover, in the study area land is not used according to its suitability and characteristics. The result might be long-term adverse impact on the agricultural production. It is therefore suggested that there should be proper land use planning, in order to reduce the adverse consequences.

10.2.2 Suitable crop selection

The analysis revealed that after inception of CRBC new water loving crops have been introduced. In order to reduce the existing and foreseen adverse consequences of waterlogging and salinity suitable crops selection should be made instead of reclamation. Some crops require large amount of water, whereas others need only small quantity. With irrigation, large amount of water goes as deep percolation. Consequently, due emphasis should be made on suitable crops selection.

10.2.3 Improving cropping intensity

The study found that in the CRBC command area, the cropping intensity has gradually increased, but still a lot of land was found fallow. In order to further accelerate the cropping intensity, it is recommended that additional areas should be brought under cultivation and double and triple crops should be raised through better use of agricultural inputs and scientific farming technology.

10.2.4 Mismanagement of irrigation water

In the CRBC command area, due to lack of awareness, farmers are unwisely using irrigation water. More preferences are given to water loving crops such as rice, sugarcane, orchards. Similarly, intensive irrigation and unlined watercourses also led to wastages. The CRBIP was designed for crop-based irrigation but unfortunately it was used as demand base. Such mismanagement has inclined the water-table in certain part of the command area. Therefore, wise utilization of irrigation water will increase the life span of this mega irrigation project.

10.2.5 Introduction of demand base irrigation

The analysis found that irrigation water is utilized on crop basis, which is a serious threat to the CRBC command area. Therefore, it is recommended that irrigation water should be delivered on demand basis instead of crop based.

10.2.6 Provision of sub-surface drainage

Major problem developed after canal irrigation in the CRBC command area was gradual rising of water-table, which led to the problem of waterlogging and salinity in several parts. Sub-surface drainage is required when land is affected by high water-table. Other measures including vertical and biological drainage are implemented, where topography doesn't permit gravity sub-surface drain. Unfortunately, in the CRBIP command area sub-surface drainage was not provided as a mitigation measure, which has generated the twin problems with in a few years after its inception. It is therefore recommended that to avoid the danger of waterlogging and salinity, sub-surface drainage should be constructed as an immediate mitigation measure.

10.2.7 Mass awareness programme

With increasing irrigation facilities, the problem of land degradation has been increased. Heavy fertilizer doses, use of *cides* along with excess irrigation and inadequate sub-surface drainage have led to the problems of waterlogging and salinity; a problem of paramount importance in the region. In the CRBC command area, such adverse consequences could be reduced if large-scale mass awareness programme is initiated for judicial and efficient use of land and water resource management. This will further strengthen the CRBC beneficial impacts and would reduce the harmful consequences. Furthermore, the farmer should be made aware about the proper use of water and other agricultural inputs in the CRBC command area. This could be made possible through public meetings, constituting agricultural organization, camps, demonstrations, trainings, workshops and distributing booklets amongst the beneficiaries. In addition, the scientific literature should be made available to the farmers for controlling pests and diseases.

10.2.8 Lining of canal, distributaries, minors and watercourses

Seepage and percolation from existing canal, distributaries, minors and watercourses are some of sources of recharge and rise of water-table in the CRBC command area. The lining of canal-distribution system may reduce significant amount of water losses. It is therefore recommended that the existing channels should be cemented.

10.2.9 General recommendations

i. INTEGRATED APPROACH FOR LAND AND WATER RESOURCE MANAGEMENT

Land and water use must be considered together particularly in the arid and semi-arid areas like D.I.Khan district. The conservation of both land and water resources need integrated approach, which should include water management strategies, judicious land use planning and rational cropping pattern. The emphasis on integrated approach for the CRBC command area could reduce the threat of waterlogging and salinity and could play an effective role in sustaining the ecological balance in the CRBC command area.

ii. FARM MANAGEMENT TECHNIQUE

Farm management is one of the techniques applied for maximizing crop production with a minimum expenditure. It includes soil treatment, preparation of fields, regulation of fertilizer doses, controlled irrigation, proper drainage, use of improved seeds, plant protection measures and crop rotation etc. It is necessary that the farmer of the area should be made aware of farm management.

iii. ESTABLISHMENT OF AGRICULTURAL SERVICE CENTRES

In the study area, agricultural extension services are inadequate. The agricultural services, extended by the agriculture department, GoNWFP are not properly catering the area. Likewise, the innovations in the field of agriculture are also not properly disseminated due to lack of efficient communication system. In this regard, it is recommended that such facilities along with other guidance need to be properly disseminated through agricultural service centres. Such centres should be established at nodal locations.

iv. CHASHMA RIGHT BANK 1ST LIFT IRRIGATION PROJECT

The study also found that large proportion of area was under cultivable waste. This could be brought under productive agriculture by adopting suitable measures. It is therefore recommended that work on the proposed Chashma Right Bank 1st lift Irrigation Project should be started immediately, to bring more land under cultivation and boost-up the economic prosperity of the region.

v. INITIATION OF NEW IRRIGATION SCHEMES FOR INCREASING AGRICULTURAL PRODUCTION

After inception of CRBC, the acreage, production and yield of crops have greatly improved. The high agricultural production is largely confined to the CRBC command areas.

Contrary to this, low productivity is noted outside the CRBC command area, where scarcity of canal irrigation restricted the productive agriculture. The proposed Chashma Right Bank 1st lift Irrigation Project command limited area of D.I.Khan district. Therefore, this low productive area outside the CRBC needs special attention of the agricultural scientists, planners and decision makers at district, provincial and federal level to execute future development schemes in agricultural sector.

vi. POST PROJECT IMPLEMENTATION STUDY

Prior to the implementation of all projects, the Government of Pakistan has made the Environmental Impact Assessment (EIA) mandatory (Environmental Protection Act, 1997). This is for the purpose to avoid the adverse consequences of the proposed project. This huge CRBIP was launched without conducting EIA. As a result several adverse consequences emerged due to lack of EIA. To maintain sustainability of CRBIP, it is therefore recommended that periodic ex post impact evaluation should be made mandatory as a part of project planning cycle.

10.3 SUMMARY AND CONCLUSION

The aim of the study was to find out the environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district. To achieve the mandated task nine indicators were selected including: land use pattern, cropping pattern, cropping intensity, agricultural production, irrigation, fertilizer, mechanization, land values and water-table. Data pertaining to these variables i.e. pre and post construction of CRBC were obtained for district D.I.Khan as whole, but for micro-level analysis five sample villages were randomly selected (four from CRBC command villages and one off the command), to get clear picture of CRBC impacts on the land use and agricultural resources of D.I.Khan district. In the following discussion, the environmental impacts of CRBC on the nine selected indicators have been summarised.

After large-scale canal irrigation in the arid tract of D.I.Khan district had brought changes in the land use and agricultural resources. The analysis revealed that after CRBC area under cultivation has been gradually increased. Contrary to this, area under cultivable waste has consistently declined. It is mainly due to the conversion of cultivable waste into cultivated land. It was found that during the study period there was constant increase in the uncultivated land. This was mainly due to the rapid expansion in the built-up area including settlements, industries, roads, canals etc. The uncultivated area is the major land unit, which has engulfed the prime agriculture land in the CRBC command area. Such changes are not according to the land suitability. It was identified as one of the long-term adverse impacts on the agricultural land.

The analysis revealed that prior to CRBC, major Rabi crops were wheat, barley and gram and Kharif crops included millet, fodder, sorghum etc. However, after CRBC, cropped area in both Kharif and Rabi cropping season has increased. After availability of canal irrigation, some new water loving crops such as sugarcane, rice and orchard have been introduced.

The analysis revealed that before the introduction of canal irrigation in the form of CRBC there were very low cropping intensity prevailed. Pre CRBC, the annual cropping intensity was 39.4%. However, after inception of CRBC the annual cropping intensity has increased to 47% in 2004-05. The analysis further revealed that in the CRBC command area the cropping intensity were high as against the area lies off the CRBC.

The analysis revealed that there has been constant increase in the canal irrigated area as a result of CRBC. It was found that after CRBC canal irrigated area has increased more than seven fold and a positive change of 10.05% has been registered.

The study further revealed that after the inception of canal irrigation the acreage, production and yield of crops have been greatly improved. High agricultural productivity is largely confined to the CRBC command areas. It is evident that these areas are inching forward in agricultural productivity mainly due to the introduction of canal irrigation. Contrary to this, low productivity has been noted outside the CRBC command area.

The analysis revealed that after CRBC the land value has considerably increased. It was found that in almost all the sample villages, the residential land prices were higher than rest of the land types. Per unit cultivable waste land were the lowest as compared to that of land for residential or agricultural use, which is considered as more valuable. There were several factors behind this rapid rise of land prices including prosperity of the people, high return from the land as a result of CRBC, which puts tremendous pressure on the land resources and in effect, the land prices have gone-up.

Prior to CRBC trend to use modern agricultural implements were very limited. However, after CRBC positive changes have occurred in the use of agricultural implements. Prior to the introduction of canal irrigation, the farmer used to grow crops with traditional implements, but after CRBC the cultivation of high return crop has enhanced the capital investment capacity of farmers and consequently, they were in a position to purchase the modern agricultural implements. Similarly, prior to CRBC, use of chemical fertilizer were also not very common. Farmers were generally using farmyard manure. The analysis revealed that after CRBC the application of chemical fertilizer has been increased mainly due to socio-economic uplift of the farmers.

One of the major problems developed after the large-scale surface water irrigation in the CRBC command area was the continuous rise of water-table which led to waterlogging and salinity problems. This threat was observed in several parts of the CRBC command area. Water-table has started rising in this desert ecosystem due to large scale percolation as well as seepage from unlevelled fields and unlined channels. Besides this, introduction of water loving crops and crop based irrigation are other contributing factors. Presently, stage I is severely affected, whereas in stage II and III rate of rising water-table is so rapid. This is a serious threat to the land use and agricultural resources of D.I.Khan district.

The present study found that there have been both positive and negative environmental impacts of CRBC on the land use and agricultural resources of D.I.Khan district. Besides beneficial impacts, the threats and problems like engulfing of prime agricultural land by the built-up area, lack of proper crop selection, waterlogging, salinity and rapid rise of water-table etc. are of special consideration and needs special attention.

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