Ex Post Impacts of Chashma Right Bank Irrigation Project on Cropping Pattern in D.I. Khan district, Pakistan

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Abstract: This paper carries out the ex post environmental impacts of Chashma Right Bank Irrigation Project (CRBIP) on the cropping pattern of district D.I. Khan, Pakistan. Work on the Chashma Right Bank Canal (CRBC) was started in 1984 and subsequently completed in three stages during 2003-2004. The total cultivable command area of CRBC is 250,000 ha. It commands only left bank area as the slope is from west to east. It spreads over the two provinces i.e. Khyber Pakhtunkhwa and Punjab. The ultimate goal of the CRBIP was to enhance agricultural productivity, employment opportunities and alleviate poverty.

The analysis revealed that there had been large scale changes in the agricultural system, with the construction of CRBC in the arid tract of district D.I. Khan. These changes were both positive and negative. After the advent of CRBC, acreage of both Kharif (summer) and Rabi (winter) crops has improved. The analysis revealed that positive changes have occurred in rice, sugarcane, pulses, wheat, barley, orchards and vegetables. Contrary to this, negative changes were registered in sorghum, millet, oilseed, barley and maize. While comparing the ex post changes in the cropping system, new water loving crops has been introduced as a result of CRBC. It has directly affected the water-table. It was found from the analysis that water-table is inclining at a rapid pace and is serious threat to the crop area.

Keywords: Chashma Right Bank Canal, impacts, cropping pattern, *ex post*.

1. INTRODUCTION

This article analyses the *ex post* impacts of Chashma Right Bank Irrigation Project (CRBIP) on the cropping pattern in D.I. Khan district. It is the southernmost district of Khyber Pakhtunkhwa (KPK) province and stretches between 31° 15' to 32° 32' North latitude and 70° 11' to 71° 20' East longitude (Figure **1**). The climate of D.I. Khan is characterized by long hot summer and short cool winter. District D.I. Khan has a total reported area of 730,575 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.

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 irrigation) and *rainfed* farming dominates the system, 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 Chashma Right Bank Canal (CRBC).

Work on the Chashma Right Bank Irrigation Project (CRBIP) has been started in 1984 and completed in three stages during 2003-2004. 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 Khyber Pakhtunkhwa (KPK) and 102 Km in Punjab. The CRBC commands 250,000 ha, out of this 61% lies in district D.I. Khan of KPK and remaining 39% in district D.G. Khan of Punjab province. The CRBC commands only left bank area as the slope is from west to east.

The analysis revealed that with the advent of CRBC, there had been large scale changes in the agricultural system in the arid tract of D.I. Khan district. These changes are both positive and negative. With the construction of CRBC, almost 152,000 ha have been brought under canal irrigation, which greatly changed the cropping pattern particularly in the CRBC command area. Prior to the inception of CRBC, major Kharif (summer) crops included millet, fodder, sorghum, while wheat, barley and gram were Rabi (winter) crops. After the advent of CRBC, cropped area in both Kharif and Rabi season was largely increased.

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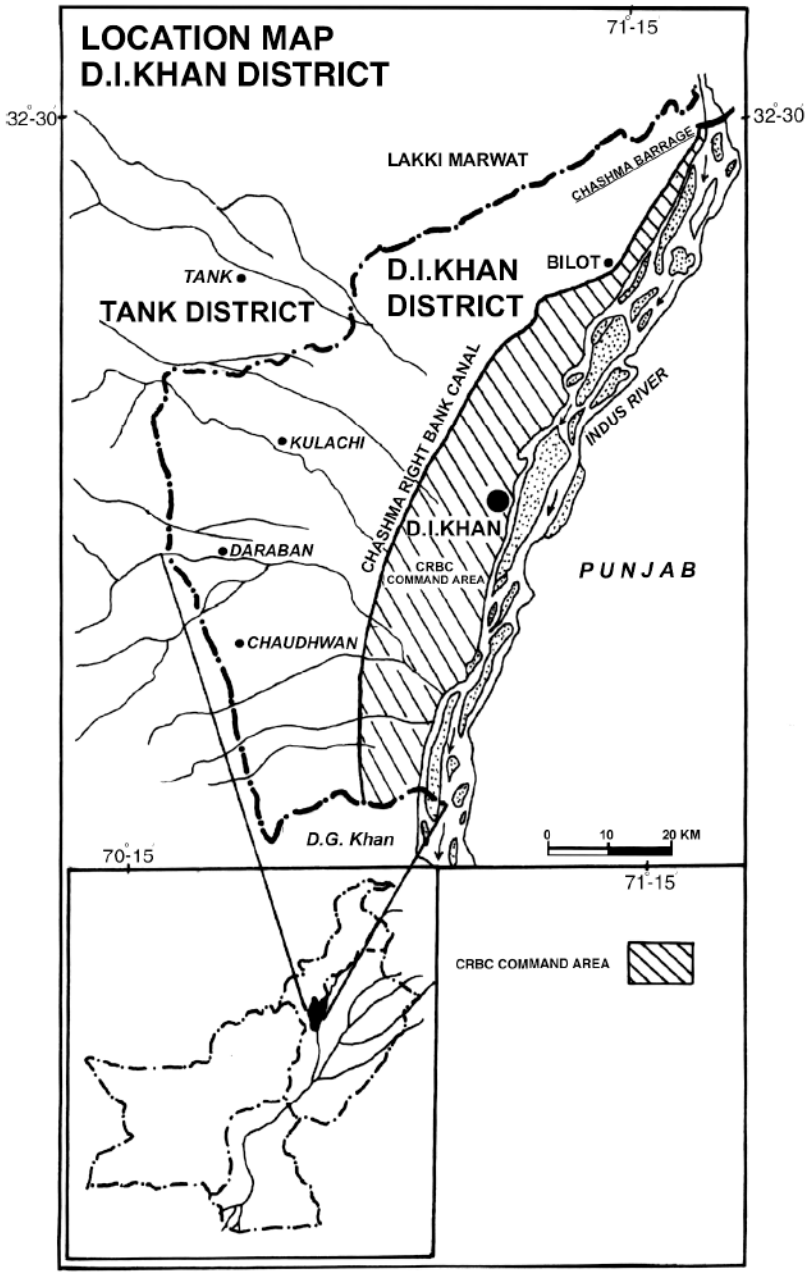

Figure 1: Location map of the study area.

The 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 analysis further revealed that area under sugarcane, rice, wheat and orchard has considerably increased, whereas area under sorghum, millet, barley, oilseed and maize has been reduced. 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 area. The analysis revealed that outside the CRBC command area, several times even a single plot was not cultivated. Therefore, in the present study an attempt has been made to find out the ex post impacts of CRBC on the cropping pattern of district D.I. Khan.

2. METHODS AND MATERIALS

2.1. Conceptual Framework

Water is the greatest resource of humanity [1-3]. It not only helps in survival but also in making life comfortable [4]. 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 [1, 2]. When sufficient and timely water is unavailable to the crops, it fades away and resulting in low yields. Irrigation can thus save us from such disasters [4-6]. Cropping pattern means the proportion of area under various crops in a cropping season [7-10], whereas changes in the cropping pattern refers to variation in the proportion of area under two different cropping seasons [8]. 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 and socio-political situation [11, 12]. The cropping pattern is a changing phenomenon and hence influenced by water availability.

2.2. Data Collection and Analysis

The following methodology was adopted for this study to achieve the stated goal. For the collection of data and information both primary and secondary sources were consulted. Data about the pre and post CRBC impacts on the cropping pattern were obtained from the relevant organizations. Initially, a series of reconnaissance visits were made to grasp an idea of positive and adverse impacts of CRBC on the cropping intensity.

In D.I. Khan district, there are a total of 384 villages [13]. Data about cropping pattern pre and post CRBC of entire district were collected. Ideally, the entire villages should have been surveyed for in-depth analysis. However, due to time and resource constraint, sampling technique was applied. The sample sites were selected from all the three stages of CRBC. Hence, for micro level analysis four villages were randomly selected from the CRBC command area namely: Jarra, Gomal, Buchari and Chera. Likewise, one village i.e. Khudaka was also selected by random means from outside the CRBC command area.

For collection of primary data, four different types of questionnaires were designed i.e. questionnaire for individual household, questionnaire for Focused Group Discussions (FGD's), questionnaire for the line agencies and questionnaire for the *Patwari* (in-charge revenue record). Questionnaire for the individual households were administered to the general public (Figure **2**). Similarly, for every sample village two to three questionnaires for the whole village were computed during FGD's with the community leaders and elderly people. Questionnaire for the line agencies were filled-up by interviewing officials of the concerned line agencies. Data regarding each and every plot of sample villages ex and post CRBC were obtained from the concerned *Patwari* to grasp the ex post impacts of CRBC on the cropping pattern of D.I. Khan district.

Secondary data was obtained from the offices of related line agencies, NGO's, reports, journals, maps and electronic database searches etc. The collected data was then analysed, using GIS and statistical techniques. Finally, the data was presented in the form of maps, tables, statistical diagram and description.

3. ANALYSIS, RESULTS AND DISCUSSION

This section assesses the ex post impacts of CRBC on the cropping pattern of D.I. Khan district. This section is further classified into three sub-sections and focuses on the land use, macro and micro level analysis of cropping pattern. The land use changes has been analysed in the first section, whereas ex post impacts of CRBIP on the cropping pattern has been discussed in the second and third section of the article.

3.1. Ex Post 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 overall picture of environmental impacts of CRBC on the land use can be discerned from Figures **3** and **4**. It can be seen that there are three land use classes including cultivated land, cultivable waste land and uncultivated land.

In D.I. Khan district, cultivated area is the second largest land use category after cultivable waste. The total reported area is 730,575 ha, out of which 232,036 ha was cultivated before CRBC in 1969-70 [14]. However, in 2003-04 the cultivated area was 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.

The Figures **3** & **4** shows that there is an uninterrupted belt of cultivated land in active floodplain of river Indus and eastern half of the piedmont plain. Before CRBC, the central and western part of the piedmont plain was cultivated through sporadic flood

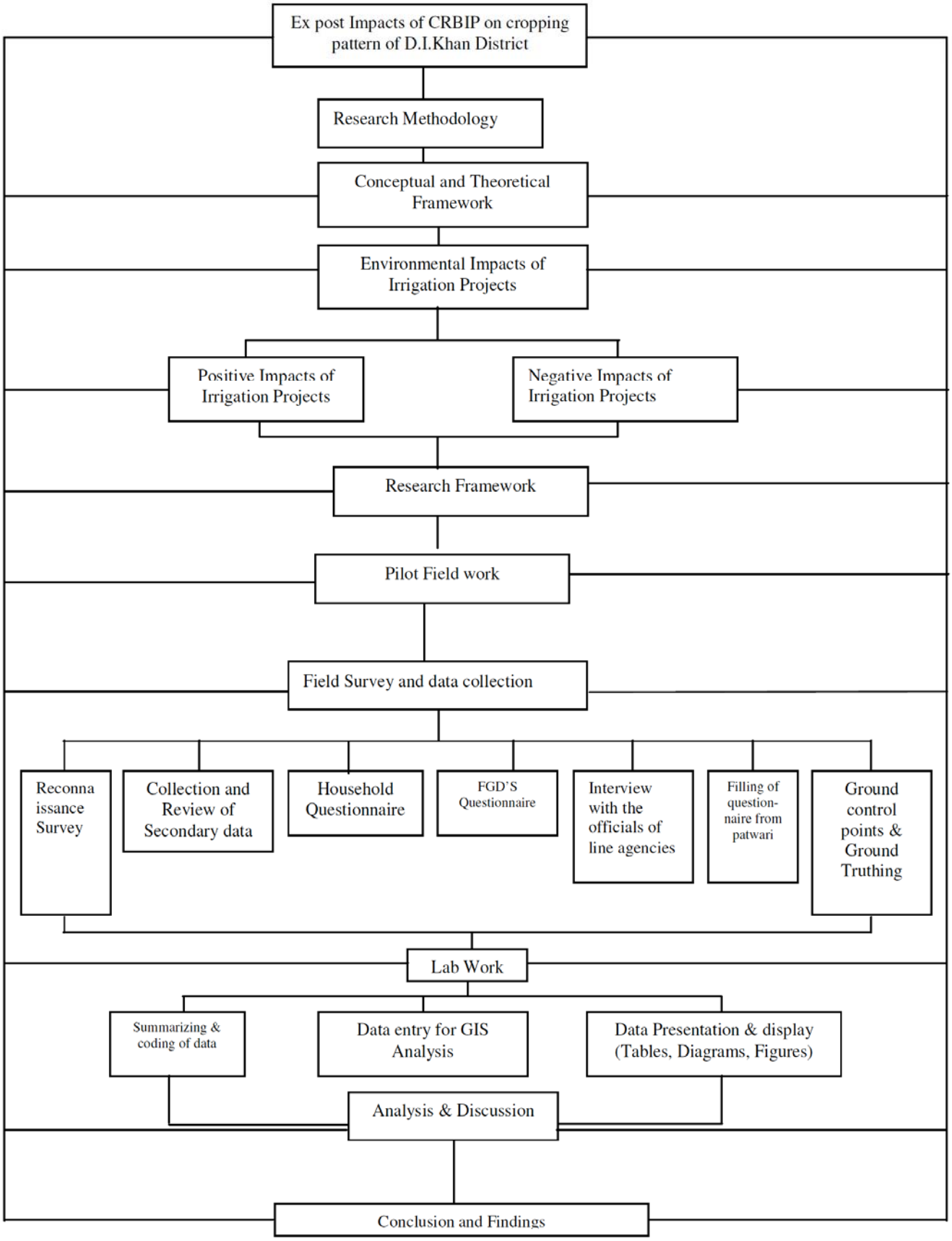

Figure 2: Research Model.

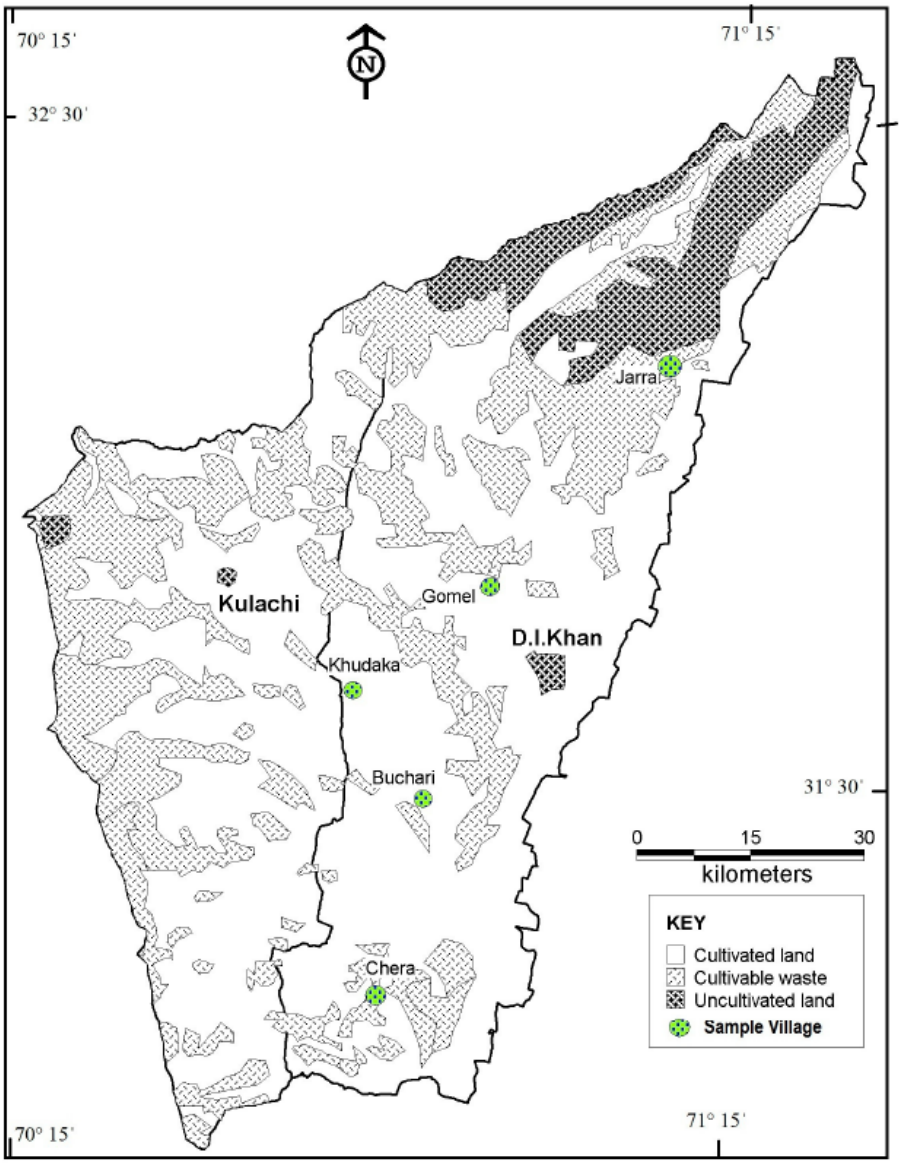

Figure 3: Pre CRBC land use pattern in D.I. Khan District, 1979-80.

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. Subsequently, the previous uncertainty of crops failure was modified by the assured water supply.

The cultivated area is further classified into net sown and current fallow. In the study area, net sown and current fallow varies from year to year. 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 availability of water. 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. 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.

Similarly, in the study area, large tract is uncultivated and hence agriculturally unproductive and devoted to settlement, gullies, torrent beds, canals, roads, water body and others. Before CRBC (1969-70), the uncultivated land was 132,408 ha, which after the advent of CRBC has been gradually increased to 132,487 ha in 2003-04 [15]. This gradual but consistent enhancement in the uncultivated area is attributed to the alarming increase in the population, rapid increase in the area under housing, roads, canals and other infrastructures after the advent of CRBC.

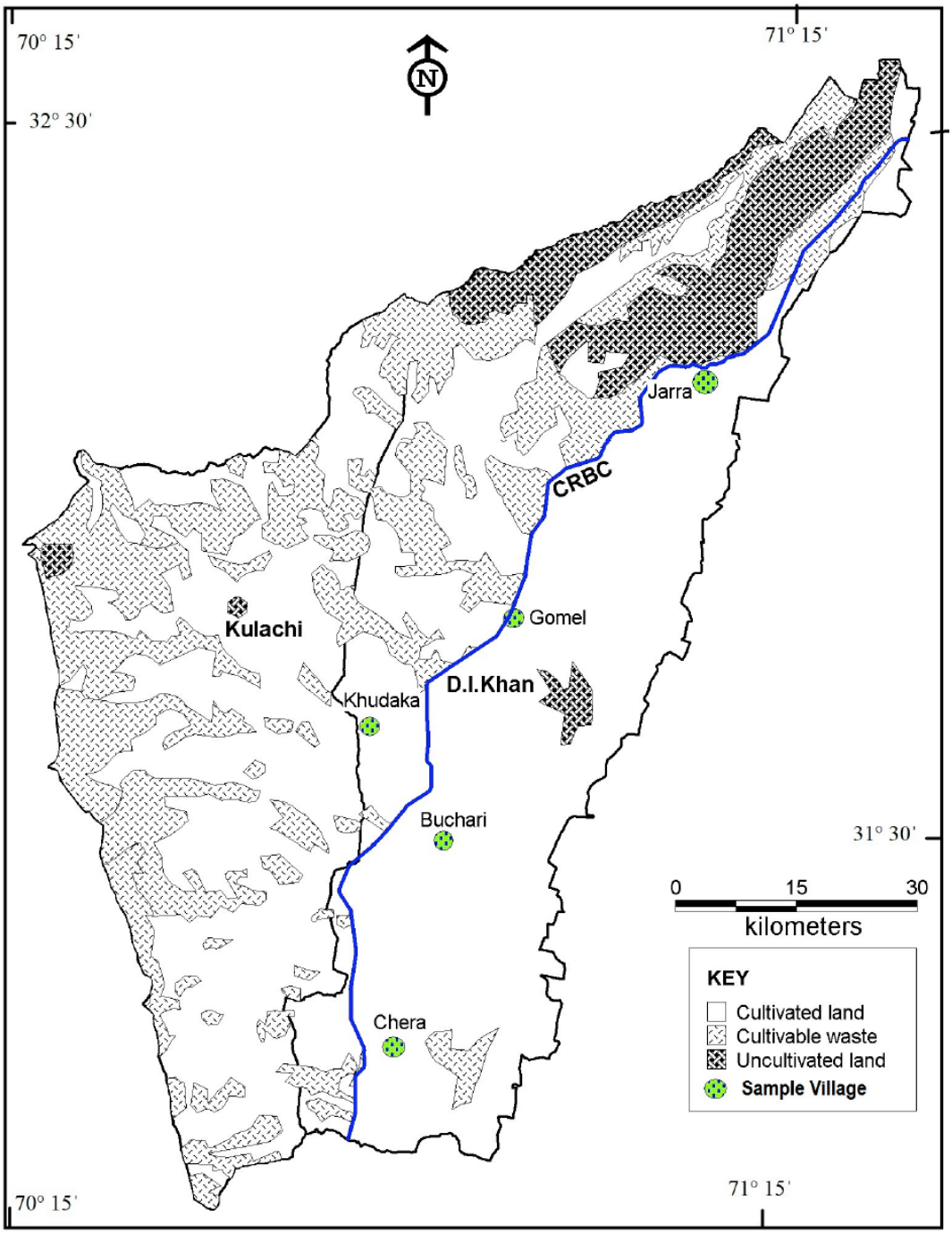

Figure 4: Post CRBC, land use pattern in D.I.Khan District, 2003-2004.

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 analysis reveals that cultivable waste is the only land use class, which has recorded negative change of 1.13% after CRBC. Before CRBC, area under cultivable waste was 366,132 ha during 1969-70.

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 357,809 ha during 2003-04 [15]. 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 reduction in the cultivable waste 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.

3.2. *Ex Post* Impacts of CRBC on the Cropping Pattern of D.I. Khan District (Macro Level Analysis)

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 enormous changes in the cropping pattern of D.I. Khan district [16-20]. In the study area, wide variety of crops is cultivated ranging from arid to humid. The following sub-sections discuss both Kharif (summer) and Rabi (winter) cropping pattern. 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 of cropping pattern before and after CRBC.

A. Kharif (Summer) Cropping Pattern

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 cropping season. It is evident from Figure **5** 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.

In the KPK, rice was cultivated on 68,411 ha during 2000, out of which 13.6% was reported from D.I. Khan district alone [19]. 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. 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 **5**). It reflects that in the past 30 years, area under rice crop increased almost four fold, representing 483% increase, which indicate farmer's trend towards the water loving crops specially after commissioning of CRBC.

In district D.I. Khan, sugarcane locally called as *Kamad* is an important cash crop [21]. 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 (Figure **5**). 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 **5**). 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 KPK, cotton was grown on 401 ha in the year 2000, out of which 300 ha (75%) was reported from D.I. Khan district alone [19]. In D.I. Khan district, cotton acreage has been reported both in pre as well as post construction of CRBC. The analysis indicates that before CRBC, cotton was grown on 2,152 ha. However, after CRBC it decreased to 2,041 ha (Figure **5**). The analysis 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 recorded (Figure **5**).

In D.I. Khan district, maize is a Kharif crop. The analysis elaborates that before CRBC area under maize crop in 1970 was 1,619 ha, which after CRBC decreased to 1,189 ha. The Figure **5** 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.

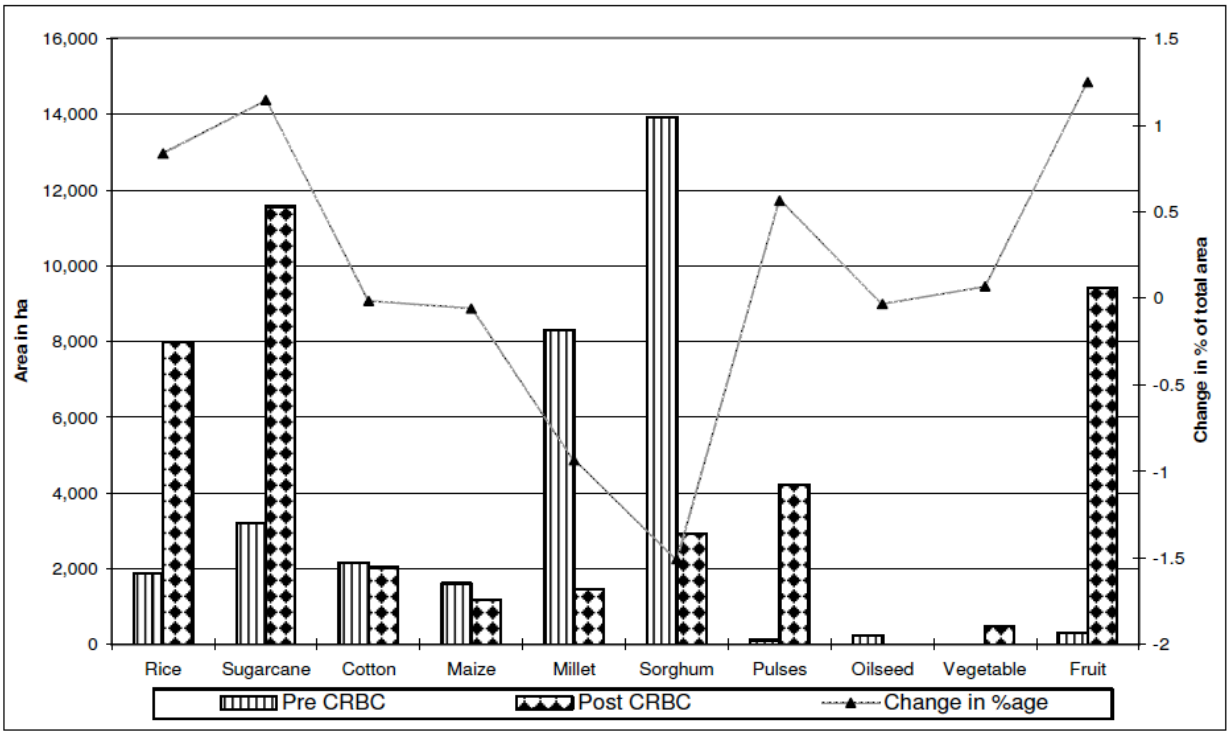

Figure 5: District D.I. Khan, Change in pre and post CRBC Kharif cropping pattern.

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 analysis 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 **5** 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 Figure **5** 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 **5**). 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 Figure **5** 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 Khrif pulses were compared (Figure **5**). 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. The Figure **5** 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 **5** 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 analysis reveals 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 **5**). 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 (Winter) Cropping Pattern

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 (Figure **6**). 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 **6**). 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 [16, 20]. Whereas before CRBC in 1969-70, over un-irrigated area wheat was cultivated on 21,457 ha, this after CRBC dropped to 7,395 ha (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 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 (Figure **6**). The analysis 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, this has shown a gradual decrease and marked the figure of 805 ha after CRBC (Figure **6**). 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. While comparing pre and post CRBC condition of barley, a negative change of 0.145% has been noted. 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. The analysis 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. The statistical data further reveals that the acreage of pulses increased more than two fold in last 30 years. It is clear from Figure **6** 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.

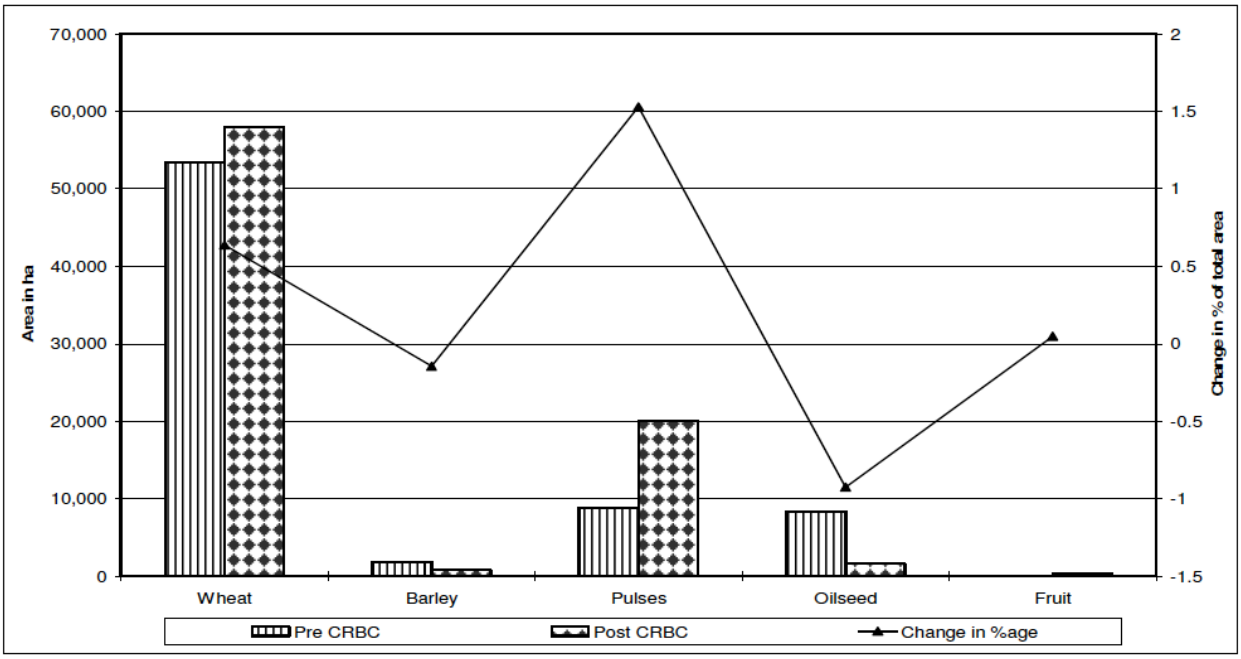

Figure 6: District D.I. Khan, Change in pre and post CRBC Rabi cropping pattern.

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 analysis 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. 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 **6** reveals that a 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. 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. 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.

3.3. *Ex Post* 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 (Summer) 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 **1**). However, during the study period the dominant Kharif crops were sugarcane and rice, which hold maximum land cover. Maize, sorghum and fodder were also grown, but due to competition with more productive crops it was found on limited area. The Table **1** 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 **1**). 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). The analysis reveals that both before and after the construction of CRBC, the current fallow dominated the Kharif scene. The Table **1** 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.

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 Table **1** shows that before CRBC, two water loving crops such as rice and sugarcane dominated the scene, which after inception of CRBC has 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.

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 **1** shows that prior to CRBC area under Kharif crops varied from 66 to 587 ha indicating wide uncertainty in the cropped area. During post CRBC from 1988 to 2004, area under Kharif crops increased from 89 to 811 ha. The analysis reveals that during the study period negative changes have reported only in sorghum. After CRBC positive changes have occurred in almost all the Kharif crops. The analysis reveals that after advent of CRBC large-scale cultivable waste has been brought under cultivation.

iii. BUCHARI

Prior to CRBC, the cultivated area of Buchari was entirely dependent on rainfall or Rod Kohi irrigation. The Table **1** 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. 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 (Table **1**). 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. Besides this, new water loving crops were also introduced. The Table **1** indicates that after CRBC area under new water loving crops, cereal crops and pulses has been largely increased. The analysis reveals 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. 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. 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

Table 1: Temporal Change in Kharif Cropping Pattern Of Sample Villages (Area in ha)

Sample villages	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 records of the sample villages.

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 **1** 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.

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 analysis 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 analysis 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 (Table **1**). The data 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.

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. However, there are certain spells, when none of these crops were grown in the area (Table **1**). The last lengthy period (1997-2003) was due to long spell of drought over the western part of Pakistan [10]. The analysis 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.

B. Rabi (Winter) 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 analysis 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 **2** 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. 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 Table **2** 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.

ii. GOMAL

In mouza Gomal wheat, barley, pulse, oilseed, fodder and fruits are important Rabi crops. The Table **2** 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. Field survey reveals that before CRBC, wheat, fodder and oilseed predominantly grown over the Rod Kohi, well irrigated and rainfed areas. The data 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 analysis reveals 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. This indicates the impact of CRBC intervention in the agricultural eco-system. The Rabi acreage varies from year to year but during the year 2003-2004, the highest area under wheat was recorded. Barley and pulse are also reported but from a limited area. Amongst the pulses, gram is the major contributor. After comparing pre and post CRBC, area under barley, pulses, oilseed and fodder has been gradually increased after inception of CRBC. The Table **2** 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.

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 **2** 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

Table **2** 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 (1967-68 to 2003-2004), wheat remained the dominant crop in this village. The analysis of data reveals 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. The Table **2** 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 2: Temporal 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.

vi. CHERA

In Chera, prior to CRBC, the cultivated area was entirely dependent on the Rod Kohi irrigation system. The data reveals that before CRBC current fallow was the dominant category. The analysis 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 analysis 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. Comparative analysis reveals that current fallow was the dominant land use, but due to absence of irrigation more crops were not cultivated, whereas after CRBC, current fallow has been decreased to a 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. 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 data 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 Table **2** 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.

v. KHUDAKA

The analysis reveals that in Khudaka Rabi acreage is uncertain and varied from year to year. The comparative analysis 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 (Table **2**). 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. 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. Ussan is predominantly a crop of dry land, whereas, *sarshaf* and *Taramira* are the crops of rainfed areas. 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 Table **2** 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.

4. FINDINGS AND CONCLUSION

The ex post impacts of CRBC on the cropping pattern revealed that a radical changes have been recorded. 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 further 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 little water is supplied. 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.

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