The minimum prices for tobacco of different grades are also fixed by the Government.

(9) The Punjab

The Punjab has a reported area of 17.3 million hectares of which 11.7 million hectares are cultivated and 1.9 million hectares is cultivable waste. The total cropped area is 13.7 million hectares, of which 11.8 million hectares are irrigated, including 2.0 million hectares by tubewells. Area under forests is estimated at 407,000 hectares and area not available for cultivation at 3.2 million hectares.

According to the 1980 Agricultural Census, the number of farms in the Punjab totalled 2.5 million, or over 60 per cent of the number of farms in Pakistan. Of these 70 per cent were smaller than 12.5 acres (5.0 ha), as compared to a national average of 75 per cent, and accounted for 35 per cent of cultivated area, as compared to a national average of 39 per cent. About 55 per cent of farms were owner farms, as in the case of Pakistan as a whole, and 50 per cent of farm area was tenanted.

LAND UTILIZATION STATISTICS, THE PUNJAB (thousand hectares)

	1983/84	1984/85	1985/86	1986/87	1987/88
Reported area	17,008	17,034	17,001	16,980	17,310
Cultivated area	11,606	11,719	11,836	11,850	11,761
• Net sown	10,489	10,663	10,746	10,840	10,112
• Current fallow	1,117	1,056	1,090	1,010	1,649
Uncultivated area	5,402	5,315	5,165	5,130	5,549
• Culturable waste	1,978	1,889	1,815	1,850	1,934
• Forest	452	452	435	450	407
• Area not available for cultivation	2,972	2,974	2,915	2,830	3,208

Source: 1990 Statistical Pocket Book of the Punjab.

NUMBER AND AREA OF FARMS BY SIZE OF FARM, THE PUNJAB: 1980 CENSUS

(area in acres)

	Farms		Farm area		Cultivated area	
	Number	%	Total	%	Total	%
Private farms, total	2,544,413	100.00	29,897,882	100.00	26,308,786	100.00
Under 1.0	109,338	4.30	53,810	0.18	49,039	0.19
1.0 to under 2.5	290,118	11.40	464,522	1.55	436,498	1.66
2.5 to under 5.0	404,428	15.89	1,419,132	4.75	1,347,076	5.12
5.0 to under 7.5	430,192	16.91	2,551,367	8.53	2,426,143	9.22
7.5 to under 12.5	566,249	22.25	5,462,486	18.27	5,136,854	19.53
12.5 to under 25.0	493,594	19.40	7,981,134	26.69	7,204,505	27.38
25.0 to under 50.0	183,960	7.23	5,791,675	19.37	4,953,676	18.83
50.0 to under 150.0	59,250	2.33	4,230,682	14.15	3,384,671	12.87
150.0 and above	7,284	0.29	1,943,074	6.50	1,370,324	5.21

Source: Pakistan Census of Agriculture, 1980, Volume III.

The province offers a variety of soil types and climatic conditions so that a wide range of agricultural crops is grown in the province and makes up a considerable proportion of national production. In 1990, for example, the Punjab accounted for over 73 per cent of Pakistan's production of wheat, 46 per cent of rice (of which 95 per cent of basmati), 38 per cent of maize and 70 per cent of gram. With respect to cash crops, the Punjab accounted for 87 per cent of the national production of cotton and 52 per cent of the output of sugarcane. The Punjab's progress has been remarkable in cotton, rice and wheat, which together make up over 60 per cent of cropped area. Area under fodder crops, at 15 per cent of total cropped area, supports a substantial livestock population. The Punjab's share of Pakistan's cattle and buffalo populations averages 60 per cent and 80 per cent, respectively, while sheep and goats make up about 55 per cent and 50 per cent, respectively.

Agriculture in the Punjab is, however, still at a relatively low level of productivity and shortage of irrigation water has been identified as a major constraint on crop yields. These differ widely between irrigated and unirrigated areas and are still, in the best of cases, well below potential. In the case of wheat, maximum yields of 2,000 kgs and 1,100 kgs per hectare have been recorded in irrigated and unirrigated areas of the Punjab, respectively, over the last five years. These figures contrast sharply with estimated wheat yield potentials for the Punjab of 2,900 kgs and 1,400 kgs for progressive farmers and traditional farmers, respectively. In the case of rice, maximum yields of 1,300 kgs per hectare were achieved in 1986. The yield potential for basmati in the Punjab is estimated at 1,500 kgs and 1,200 kgs for progressive farmers and traditional farmers, respectively. Only in the case of cotton does production in the Punjab stand out as an example of what can be achieved: yields of almost 640 kgs per hectare (lint) have been recorded. (see Table 2.3).

2.2.3 Agricultural Development Strategy

There is a checkered history of agricultural performance in Pakistan. The post-independence leadership was concerned with creating an industrial base for the new country but this damaged the agricultural sector. The annual output of foodgrains declined from 6 million tons in 1951 to 5 million tons in 1955 and, from being in a position of surplus, the country became a net importer of foodgrains at an average of 64,000 tons per year during the second half of the 1950s. To manage scarce food supplies the Government introduced rationing and compulsory procurement at less than market prices, fuelling a vicious circle of further deterioration.

By the end of the 1950s food shortages, foreign exchange scarcity and raw material constraints on industrial development forced the Government to adopt an agricultural strategy aimed at achieving self-sufficiency in food, increasing production for both domestic use and export, reducing unemployment and underemployment and restructuring land relationships. Large-scale public investments in agriculture were undertaken. Simultaneously, land reforms were also introduced, which placed a ceiling on land ownership and attempted to make tenure conditions uniform. Compulsory procurement was abandoned. As a result of these measures, accompanied by adequate supplies of fertilizers, better water supply schemes, the creation of specialized agricultural finance institutions and the setting up of support prices for sugarcane, rice and wheat, the annual output of foodgrains rose to 7 million tons by 1965. Value added in agriculture rose by 4 per cent per annum.

The Third Five-Year Plan (1965-1970) brought with it the Green Revolution, i.e. the use of high-yield varieties of wheat and rice combined with adequate supplies of seeds, fertilizers and water. Liberal subsidies for inputs and higher price incentives provided the motivation needed for the adoption of the new technology by farmers. Agricultural performance made impressive gains and value added in agriculture surged at an annual rate of 6.3 per cent, while the annual output of foodgrains increased at 6.5 per cent per annum to reach 11 million tons at the end of the plan period. In 1970 Pakistan reached the threshold of again achieving self-sufficiency.

Agricultural growth slowed down to 1.9 per cent in the 1970s. The Green Revolution had ridden on the wave of high agricultural subsidies which propelled the initial stages of the breakthrough. However, the development of support services, especially agricultural extension, research, education and training, had been neglected. Despite further land reforms in the early 1970s and the greater availability of key inputs such as fertilizers, high-yield varieties of seeds and water, agricultural activities therefore began to show diminishing returns. Moreover, adverse weather admittedly played a role for diminished growth.

The new government that took over in 1977 focussed considerable attention on the agricultural sector. A new National Agricultural Policy was announced in 1980 to guide Government programs and investments for much of the 1980s. Major elements of the policy included shifting of investment and maintenance expenditures away from new irrigation projects and toward optimizing use of the existing system, progressive adjustment of agricultural prices to reflect the real costs of inputs and provide incentives to farmers, and gradual contraction of public activities such as distribution of agricultural inputs and installation of tubewells in favor of these and other operations by the private sector. An Agricultural Prices Commission was established in 1981 to provide officials with recommendations on prices for inputs and produce that would consider the effects on farm incomes and productivity, consumer prices, consumption and the competitiveness of Pakistan's agricultural products in world markets.

By 1983 the Government had taken a number of actions implementing the new policy. Subsidies on pesticides were eliminated in the Punjab and Sind and soon would be in other provinces. Fertilizer prices were raised substantially and the subsidy was expected to be eliminated by 1985. Private companies became partial suppliers of pesticides and fertilizer. Water charges were increased, agricultural credit was expanded and extension services were upgraded. Prices paid to farmers for wheat approximated the international price and those for cotton and rice were close to it.

By the time the Sixth Five-Year Plan (1983-1988) was formulated and the objectives of the Government had shifted to redistributing the benefits of high growth. In agriculture, the theme of the sixth plan was to move from self-sufficiency to export and the strategy was to increase yields; use water efficiently by improvement in on-farm water management; encourage intensive farming on medium and small-size farms; modernize extension services; diversify agriculture; expand the export markets for wheat and rice; expand domestic oilseeds; and develop barani (rainfed) areas. The

Government also began to make concerted efforts for rural development and poverty alleviation.

Despite the steady growth of agriculture over the past few years, Pakistan's agriculture faces several problems. Production relies heavily on irrigation but irrigation schemes have led to waterlogging and salinity. Another issue is land reform: there have been only limited steps to reduce the size of the largest holdings and transfer land rights to the actual cultivators. Finally there has been concern that development policies have not addressed the particular problems facing barani agriculture, whose economic importance is evident: it contributes Rs 15 billion to GNP (10 per cent of agriculture's share), supports 18 million inhabitants (16 % of total population), 70 per cent of the total livestock population, and produces 90 per cent of all grain legumes. Recognizing that further investment in irrigated agriculture will not increase as in the past as suitable land is being depleted, the Government regards the improvement of barani agriculture as a key objective for the 1990s and beyond. For this reason, flood management in districts such as D. G. Khan and Rajanpur figures prominently in the current plan.

2.2.4 The New National Agricultural Policy

A synopsis of the New Agricultural Policy was unveiled in May 1991. The major weakness in the agricultural sector was identified to be the communication gap between researchers and growers and it was announced that the cooperative system would be re-organized to help growers adopt new technology and use quality inputs. The synopsis consists of five policy goals, six policy parameters, nine basic objectives and seven strategy points.

The five policy goals are: (i) self-reliance; (ii) social equity; (iii) export orientation; (iv) sustainable agriculture; and (v) enhanced productivity.

The six unchanging policy parameters are: (i) rapid population growth; (ii) potential for higher agricultural productivity; (iii) dependence on vertical (productivity) improvement rather than horizontal (areal) expansion; (iv) raising incomes, which propel demand for non-cereal agricultural products; (v) concentrating on optimizing production in areas of comparative advantage (larger irrigated farms); and (vi) dependence of a rapidly growing number of non-farm households on agri-business development.

The nine basic objectives are: (i) achieving self-sufficiency in cereal and other essential farm products; (ii) developing high-value products for exports; (iii) ensuring equitable and stable prices for farmers; (iv) ensuring adequate and easy availability of farm inputs, including credit; (v) improving marketing infrastructure; (vi) conserving the agricultural resource base of land, forests and water; (vii) concentrating on research gaps and ensuring rapid transmissions of new technologies through an effective extension program; (viii) emphasizing agri-business and agro-industry; and (ix) enhancing the role of the private sector in agriculture.

The seven strategic pillars are: (i) a growth rate faster than the population growth rate; (ii) higher productivity in all sub-sectors; (iii) emphasis on high-value crops in exports; (iv) conservation and development of natural resources; (v) promotion of the private sector in production, processing and distribution; (vi) greater attention to small farmers and barani area development; and (vii) greater employment in rural areas through agri-business and agro-related industries. A package of incentives for the agricultural sector was outlined, comprising: (i) a productivity enhancement program; (ii) fiscal incentives; and (iii) non-fiscal incentives.

Details are not yet revealed however, the synopsis gives no indication as to priorities and inter-relations and there is no assessment of resources, particularly of the regenerative type to be raised from the agricultural sector itself.

2.2.5 Foreign Economic Assistance

Pakistan depends on substantial inflows of foreign capital, most of which come in the form of official aid. By the end of 1988, Pakistan's outstanding disbursed debt was estimated at US$17,000 million. Total disbursements of aid in 1990 were US$2,779 million. Grant assistance as a proportion of total aid was as low as 12 per cent in the late 1970s, but rose thereafter as a consequence of aid intended for the relief of Afghan refugees. However, the burden of debt repayment is steadily growing and makes up a large part of budgetary spending. Repayment of long-term debt as a percentage of exports of goods and services rose from 10.1 per cent in 1982 to 17.5 per cent in 1988 and as a percentage of GNP increased from 1.9 per cent to 3.5 per cent over the same period. Because of the rising level of debt servicing, the volume of net aid each year is much less than the gross figure.

Most foreign aid comes from the Aid to Pakistan Consortium, which is composed of a number of Western countries (notably the USA and Germany), Japan, and multilateral agencies. In 1989/90, 87 per cent of aid came from the consortium countries. In April 1990 the consortium pledged a sum of US$3,000 million for 1990/91.

CHAPTER 3 THE STUDY AREA

3.1 Area Coverage

The Study Area is located in the south-west of the Punjab and is bordered by the provinces of Sind in the south, Baluchistan in the west, and the N.W.F.P in the north. It lies between the Indus and the Suleiman Range and is classified into hilly regions, piedmont plain and the alluvial plains of the Indus. In addition to this geographical classification, the area can be classified into hilly regions, the pachad area, the canal irrigated area and riverain area.

The hilly region is a part of Suleiman Range with a maximum elevation of about 2,500 m. It forms the watershed of hill torrents and lies in two provinces of Baluchistan and Punjab. The pachad is a part of piedmont plain and sandwiched between canal irrigated area and the hilly regions. The torrent-watered cultivation has been practiced in the pachad. The canal irrigated area includes the area irrigated by the D. G. Khan canal and Dajal Branch canal systems and also the area to be irrigated in future by Chashma Right Bank Irrigation Project (CRBIP) and the Extension of Dajal Branch canal. The riverain area is located along the west of Indus to the canal irrigated (or to be irrigated) area. For the purpose of convenience, the canal irrigated, to be irrigated and the riverain areas are tentatively called "the canal area" in this Report.

The Study Area generally includes the hilly regions, the pachad and the canal area, but excludes the area to be irrigated by the scheduled projects of CRBIP and Extension of Dajal Branch. The canal area irrigated by the existing systems is included in the Study Area for assessment of hill torrent flood damages. The project formulation, however, focuses the development of the pachad and the watershed within Punjab province.

The hill torrent watercourses originated from the hill ranges are about 200 in number of which 13 are major hill torrents. They are, namely, from north to south, Kaura, Vehowa, Sanghar, Sori Lund, Vidore, Saki Sarwar, Mithawan, Kaha, Chachar, Pitok, Sori Shumali, Zangi and Sori Janubi. In accordance with S/W, Kaha, the largest hill torrent, is excluded from the Study. Mithawan hill torrent is also excluded from the prioritization during the course of project formulation.

Using topographical maps with scale of 1/250,000, the area coverage is measured for the hilly regions, the pachad and canal area for each hill torrent (see Table 3..1.1). Total pachad area is about 498,200 ha of which 159,000 ha belong to the 12 major hill torrents (excluding Kaha). Cultivable area having water right is measured at 106,420 ha (see Table 3.1.2). Cultivable area of about 22,400 ha is also measured within the watershed of these hill torrents.

AREA COVERAGE OF MAJOR HILL TORRENT

Name of Hill Torrent	Catchment Area (km^2)	Pachad (ha)	Canal Area (ha)
Kaura	450	11,390	55,850
Vehowa	2,720	13,100	
Sanghar	4,880	8,240	
Sori Lund	520	13,860	
Vidore	770	19,350	390,500
Sakhi Sarwar	160	15,690	
Mithawan	680	23,470	
Chachar	800	23,220	
Pitok	240	13,630	66,840
Sori Shumali	330	6,000	
Zangi	400	4,300	
Sori Janubi	1,680	6,540	
Total	13,630	158,790	

CULTIVABLE AREA OF MAJOR HILL TORRENT

Name of Hill Torrent	Within Catchment Area (ha)	Within the Pachad with Water Right (ha)
Kaura	50	11,170
Vehowa	5,980	12,300
Sanghar	9,720	6,680
Sori Lund	800	11,980
Vidore	1,170	13,350
Sakhi Sarwar	20	3,510
Mithawan	840	11,010
Chachar	2,430	17,100
Pitok	10	12,730
Sori Shumali	-	5,970
Zangi	-	160
Sori Janubi	1,400	540
Total	22,420	106,500

3.2 Physical Geography

3.2.1 Topography

The Study Area encompasses the south-west of Punjab and the east of Baluchistan and includes the riverain area of EL.120 m at west side of the Indus and the mountain areas of Suleiman range of more than EL. 2,000 m. It extends about 300 km from north to south and about 80 km from east to west. The topographic features of the Study Area are shown in Fig. 3.1. The watershed or catchment area of hill torrents has following topographic features.

1. Steep mountain range is located at northern part of the Study Area along the main axis of Suleiman range including the peak of more than EL. 2,000 m.

2. Plateaus of EL. 1,000 m - EL. 1,500 m are located at northern part of the Study Area along the west side of Suleiman range including gentle slopes and wide valleys.

3. Peneplains of EL. 500 m - EL. 100 m are located at southern part of the Study Area along the east side of Suleiman range.

4. Steep hills are located at EL. 250 m - EL. 500 m and cut through by numerous number of hill torrent courses.

After the torrent flows fan out from the above hilly regions, the pachad area is formed with alluvial fan and piedmont alluvial plain. There are more than 200 number of hill torrent courses of which 13 are major. The watershed and the pachad area of these major hill torrents is classified with elevation. About 1 % of the area lies at an elevation of more than EL. 2,000 m, 12 % between EL. 1,500 m - EL. 2,000 m, 33 % at EL. 1,000 m - EL. 1,500 m, 34 % at EL. 500 m - EL. 1,000 and 20 % less than EL. 500 m. (see Table 3.1)

3.2.2 Meteorology

The Study Area is characterized by a semi-arid to arid climate. The winter season extends from December to March and the summer season lasts from June to September. The remainder serves as what may be called transition seasons.

The distribution of average annual rainfall in the Study Area differs considerably. It amounts to approximately 400 mm in the northwestern hilly region and 200 mm at the foot of the hills. More than 50 % of annual rainfall is concentrated in two months of July and August, and 15 % in March and April.

Annual mean temperature is 21.8 °C in the hilly region (Barkhan EL. 1,097 m) and 24.9 °C in the plains (Muzaffargarh EL. 116 m about 50 km east of D. G. khan) with the difference as 3.1 °C. Monthly mean temperature in the hilly regions varies from 31.2 °C in June to 11.0 °C in January. Extreme maximum temperature, however, was recorded in April at 48.3 °C at Muzaffargarh. In the hilly area, monthly mean temperature is 37.9 °C at maximum in June and 4.0 °C at minimum in January.

Evaporation is observed at Muzaffargarh. Mean annual evaporation is 2,429 mm with maximum 349 mm in June and minimum 80 mm in January. Climatological data of the Study Area in hilly regions and the plain are summarized in Table 3.2.

3.2.3 Hydrology

There are 25 rain gauge stations under operation within the Study Area, of which 24 were installed by the Punjab Provincial Government and began observations from 1975. One station (Barkhan) was installed by the Federal Meteorological Department in 1967. It is located within the Study Area and its observations cover all the major fields of meteorology. Outside of the Study Area, there are three stations of Meteorological Department are under operation. The data available from these stations are considered accurate and reliable.

Annual mean rainfall of catchment area for each hill torrent is summarized as follows.

Annual Average Rainfall (1969 - 1988)

(unit: mm)

Kaura	305	Vidore	310	Pitok	211
Vehowa	353	Sakhi Sarwar	215	Sori Shumali	211
Sanghar	333	Mithawan	268	Zangi	183
Sori Lund	227	Chachar	239	Sori Janubi	211
				Average	296

Total catchment area is 13,630 km^2 excluding Kaha hill torrent. The peak flood discharges with 25-year probability are calculated in each catchment area. The maximum peak flood discharge per one square kilometer with 25-year probability is 4.62 $m^3/sec/km^2$, and the minimum of it is 0.77 $m^3/sec/km^2$.

Peak Flood Discharge with 25-year probability (1958-1989)

Hill Torrent	Catchment Area (km^2)	m^3/s	$m^3/s/km^2$	Hill Torrent	Catchment Area (km^2)	m^3/s	$m^3/s/km^2$
Kaura	450	1,338	2.97	Mithawan	680	2,460	3.62
Vehowa	2,720	3,075	1.13	Chachar	800	2,032	2.54
Sanghar	4,880	3,742	0.77	Pitok	240	524	2.18
Sori Lund	520	1,500	2.88	Sori Shumali	330	774	2.35
Vidore	770	1,795	2.33	Zangi	400	938	2.35
Sakhi Sarwar	160	739	4.62	Sori Janubi	1,680	2,325	1.38

Mean annual runoff and that of 25-year probability is worked out as follows.
The maximum mean annual runoff is 784 MCM of Sanghar and the minimum of it is 17 MCM of Sakhi Sarwar.

Mean Annual Runoff and Annual Runoff of 25-year probability (1969 - 1988)

(unit: MCM)

Hill Torrent	Average	25-year	Hill Torrent	Average	25-year
Kaura	66	118	Mithawan	88	157
Vehowa	463	829	Chachar	92	165
Sanghar	784	1,403	Pitok	24	44
Sori Lund	57	102	Sori Shumali	34	60
Vidore	93	167	Zangi	35	63
Sakhi Sarwar	17	30	Sori Janubi	171	306

3.2.4 Geology

Formation of sedimentary rocks of Cretaceous to Tertiary are dominant in the Study Area. Older geological formation is found in north-western part of the Study Area. Sedimentary rocks of mainly sand stone and limestone in Cretaceous to Jurassic are formed at west side of Sulaiman range axis within the catchment area of those hill torrents located at middle to northern part of the Study Area ie; Kaura, Vehowa, Sanghar, Vidor and Mithawan. Sedimentary rocks of Tertiary sand stone, shale, conglomerate and limestone are found at east side of Suleiman range axis and at the area of higher than EL. 200 m to EL. 300 m within the catchment area of Sori Lund and Saki Sarwar. In the catchment area of the above hill torrents, relatively older geology is formed at higher elevation. In the middle to southern part of the Study Area, Tertiary Sedimentary rocks are formed in the catchment areas of Kaha, Chachar, Pitok, Sori Shumal, Zangi and Sori Janubi. In those areas, Paleogene sedimentary rocks are dominant in the area higher than EL. 750 m and Neogene sedimentary rocks below EL. 750 m.

AREA DEVIDED BY GEOLOGY

(Unit: km^2)

Hill Torrent	Mesozoic		Tertiary		Quaternary	
KAURA	72	(16%)	378	(84%)	0	(0%)
VEHOWA	1,550	(57%)	816	(30%)	354	(13%)
SANGHAR	927	(19%)	3,611	(74%)	342	(7%)
SORI LUND	0	(0%)	514	(99%)	5	(1%)
VIDOR	92	(12%)	570	(74%)	108	(14%)
SAKI SARWAR	0	(0%)	87	(54%)	73	(46%)
MITHAWAN	102	(15%)	313	(46%)	265	(39%)
KAHA	43	(1%)	4,527	(84%)	840	(16%)
CHACHAR	0	(0%)	776	(97%)	24	(3%)
PITOK	0	(0%)	209	(94%)	13	(6%)
SORI SHUMALI	0	(0%)	226	(94%)	14	(6%)
ZANGI	0	(0%)	388	(97%)	12	(3%)
SORI JANUBI	0	(0%)	1,478	(88%)	202	(12%)

The sedimentary rocks in the Study Area are of neuritic sediment but thickness of the sedimentary layer is large. In the upper reach of catchment areas of Vidor and Mithawan, the Ghazij formation composed of early Eocene sedimentary rocks has 1,000 m to 1,600 m thick layers and the Kirthar formation of late Eocene has 700 m to 1,000 m thickness. The Quaternary strata are formed in the alluvial fan and piedmont alluvial plain between the Indus and the Suleiman range. It is also formed in the flatter area located between the several anticlinal axis running north to south in the Suleiman range. The flatter area sometimes forms of several kilometers wide and several ten kilometers long.

The stratigraphic classification of the Study Area is summarized as follows.

Quaternary		Holocene	Unconsolidated deposit (silt, sand, gravel) Streambed deposit Flood plain deposit Piedmont plain deposit (coarse detritus materials) Terrace deposit (fine detritus materials)
		Pleistocene	Clay, silt rock, sand stone, Conglomerate
Tertiary	Neogene	Pliocene	Sedimentary rocks (sand stone, conglomerate, shale)
-----Unconformity-----			
		Miocene	Sedimentary rocks (sand stone, conglomerate, shale)
	Paleogene	Oligocene	Sedimentary rocks (sand stone, mud stone)
-----Unconformity-----			
		Eocene	Sedimentary rocks (sand stone, shale, mud stone, marl)
		Paleocene	Sedimentary rocks (sand stone, shale, limestone, conglomerate)
-----Unconformity-----			
Cretaceous			Sedimentary rocks (sand stone, conglomerate, limestone)
Jurrasic			Sedimentary rocks (limestone)

Geological structure in the middle to northern part of the Study Area is the alternation of syncline and anticline structures which has north to south axis of a fold affected by the Himalayan orogeny distortions during late Pliocene to early Pleistocene. In the southern part of the Study Area, the geological structure is same but has north-east to south-west axis of fold. Under these structures, each geological strata has parallel arrangement with the fold axis. Large fold movement and severe weather conditions had made each stratum weathered deeply and rocks are exposed on the most of slopes in the catchment area of the Study Area. The geological map of the Study Area is shown in Fig. 3.2.

3.2.5 Soil and Land Use

(1) Soil

Approximately 55% of the Study Area consists of the Suleiman Range, which has little to no soil cover. In addition, another 5% of the area consists of gravel or stony lands, dune lands, gullied lands and torrent beds, which are classified as miscellaneous areas. In the piedmont plains, two types of parent materials are found;

i) local piedmont alluvium of the Suleiman Range derived mainly from sedimentary rocks; and
ii) mixed river alluvium of the Himalayas deposited by the Indus.

The soils of the piedmont plains range in texture from sand to clay but clay and loam are the dominant soil textures. Each piedmont alluvial fan has soils of similar texture throughout its extent. The soil texture differs, however, from fan to fan. Generally, all the soils are uniformly calcareous. Organic matter contents are low and the soils are desertic, especially in the southern part of the Study Area.

The soils are rich in montmorillonitic clays. Fine gypsum crystals are found in the clay soils, which probably originate from within the parent materials. The soils of the piedmont plains are generally nonsaline and nonalkaline, with the exception of small patches of saline soils near Choti Zarin and Rojan. The pH of the soils ranges from 8.0 to 8.4. The soils in unirrigated areas generally remain dry for most of the year.

The soils of the alluvial plains range from sand to clay, though silty clay is the dominant soil texture and occupies the nearly flat cultivated areas. The organic matter content is generally low. Clayey soils are generally confined to depressions and are cultivated, if water-logging is not too serious a problem. On higher, level, physiographic sites, the soils are well-drained but drainage conditions are poorer in low sites and cause water-logging. Salinity is associated with high water tables in some locations in the riverine areas.

(2) Present Land Use

Much of the native vegetation of the Study Area has been eliminated by cultivation, overgrazing, shrub or tree harvesting, or has been replaced by introduced species. However, some natural vegetation remains on foothills, terraces, piedmont basins, and in the unreclaimed areas occupied by saline-alkali soils. The mountainous areas are generally bare lands, except for some vegetation that survives along waterways. The piedmont area has sparse and light vegetation, while the river plain has several species of grass and shrubs due to better soil moisture conditions.

The soils of the Study Area are put to multifarious uses according to the water supply, although socio-economic factors, land forms, and the nature of the soil materials also affect land use. In the Study Area, land use is largely restricted to food and fodder crops for domestic consumption.

Torrent-watered cultivation is the dominant cropping system in the piedmont plains. It is practiced near the mountains and along the larger torrents, where a relatively assured supply of torrent water is available during most years. The south areas of Rajanpur District remain unused during most years because of the low rainfall and relatively smaller catchment areas of the torrents. Areas away from the mountains and from the main torrents are also inundated only rarely.

Perennial torrents locally known as Zams are potentially better source of irrigated cultivation. These torrents provide year-round supply of water, although on a limited scale and to small areas near the mountains. Because of the limited available supplies, the land under each Zam is divided into blocks and each block receives irrigation in rotation.

The areas which are not maintained in any other way but support natural vegetation are used for livestock grazing and the collection of firewood. Small areas within this category of land use fall under the reserved forests maintained by the Forestry Department. The main tree species in the area are babool (Acacia arabica), jand (Prosopis spicigera) and frash (Tamarix articulata). Poor grazing land is scattered throughout the Pachad area. The major problem of these areas is their higher relief and low availability of water. Another limitation is saline and alkalinity in soil and water. Particularly in Pitok and Sori Shumali, torrent water is moderately to highly saline, which is not good for irrigation.

Hill torrent wise land use data is shown in Table 3.3.

(3) Land Capability Classification

Land capability classification is a method of appraisal an grouping of soils to show their relative suitability for crop production, grazing or forestry. The system used is similar to that used by U.S. Soil Conservation service. Some modifications, however, have been made to adapt it to local conditions prevailing in the surveyed area. In particular, availability of irrigation water has been taken into account to classify the area.

Five (5) classes as follows are found in the Study Area.

1 Good agricultural land
2 Moderate agricultural land
3 Marginal agricultural land
4 Poor grazing and wood lands
5 Agriculturally unproductive land

Class 1 has the least limitation for agricultural use, and relatively little effort is required to produce high yields of a wide range of crops. The suitability decreases gradually in accordance with increase in class number. Class 5 is recognized as agriculturally unproductive.

Outline of the classification

(1) Good agricultural land

Potential: Soil units of the area having the highest agricultural potential under irrigated cultivation are grouped under this capability association. Very high returns could be obtained from the main soils of this unit with improved corp varieties and balanced use of fertilizers.

Present land use: General irrigated cropping with canal and additional tube well irrigation. Main crops are cotton, wheat, mustard, clover, oilseeds and mango. Some area is also irrigated by flood.

(2) Moderate agricultural land

Potential: The major part of this unit has moderate potential for irrigated cropping. Total agricultural production can be increased considerably with increase of water supplies, use of balanced fertilizer and growing of improved crop varieties.

Present land use: Restricted cropping with torrent water and poor grazing. Major crops are millet, sorghum, wheat, mustard and oilseeds.

(3) Marginal agricultural land

Potential: The unit has marginal potential for irrigated cultivation. Considerable areas are water shortage due to high relief of land and sandy soil texture. Crop production could be increased by provision of additional irrigation water and introduction of drought resistant crops.

Present land use: Restricted cropping with torrent water and poor grazing. Major crops are millet, sorghum and wheat.

(4) Poor grazing and wood lands

Potential: The land under this unit is not economically capable of large scale development because of severe limitations such as higher elevation, irregular relief, sandy soil texture and arid climate. However, some improvements are possible through controlled grazing, seeding local grasses as fodder and afforestation in the seasonal flooded area.

Present land use: Poor grazing and woodland with some restricted torrent-watered cropping.

(5) Agriculturally unproductive land

Potential: This association is mainly consists of Suleiman Range which is occupied by stony, rocky and eroded lands, and has little potential for agriculture.

Present land use: Most of the area is not used for agriculture.

Land capability of the major hill torrents

The land of the major hill torrents are classified according to the land capability classification (Table 3.4). Table 3.4 shows Vehowa, Sanghar and Vidore have relatively good agricultural land in the Study Area. The land class 1 (Good agricultural land) occupies 6,360, 6,680 and 5,250ha in the Pachad area of those hill torrents, respectively.

Kaura and Sori Lund follow those three hill torrents in terms of land capability. Most of the Pachad land falls under the land class 2 (Moderate agricultural land) in these two hill torrents, which is relatively good torrent-watered land.

Major part of the land of Sakhi Sarwar and Chachar are occupied by the land class 3 and 4, but these four have other limitations for agricultural production. The limitations are high salinity in surface water in Pitok and Sori Shumali, and sandy soils in Zangi and Sori Janubi.

3.3 Socio-Economy

3.3.1 Administrative Divisions

Over the last twelve years there have been shifts within two existing districts of the Punjab, while five additional districts have been created. The boundaries of sixteen tehsils have been revised. These shifts make the preparation of time-series data on structural shifts and trend analysis especially difficult. In the Study Area, the former district of D. G. Khan lost in 1982 both Rajanpur and Jampur tehsils, which were joined to form Rajanpur District. Rojhan Tehsil was created out of Rajanpur Tehsil. This explains why the figures for Rojhan Tehsil are included in those for Rajanpur Tehsil in the relevant data appended at the back of the present.

D. G. Khan Division is made up of the districts of D. G. Khan, Layyah, Muzaffargarh and Rajanpur, each of which is divided into tehsils (see Fig. 3.3). In the case of D. G. Khan District there are two tehsils, namely D. G. Khan and Taunsa. In the case of Rajanpur District there are three tehsils, namely Jampur, Rajanpur and Rojhan. Both districts include tracts of tribal land, which lie parallel to the five tehsils and extend from the piedmont of the Suleiman range across to Baluchistan.

3.3.2 Population

(1) D. G. Khan and Rajanpur Districts

The Study Area covers the two districts of D. G. Khan and Rajanpur. These are the only districts of the Punjab which lie entirely west of the Indus. The two districts spread for more than 300 kilometers from north to south and about 50 kilometers from east to west.

The population of D. G. Khan District, according to the 1981 Population Census, was 861,412; that of Rajanpur District was 617,429 (these figures exclude the population of the tribal areas, which totalled 103,743). The total area of D. G. Khan District was 6,583 square kilometers, which gave a population density of 130 persons per square kilometer. This was higher than the corresponding figure for Rajanpur District which, with a total area of 8,142 square kilometers, had a population density of 76 (these figures exclude the tribal areas). The average size of a family was seven persons. Because of the cropping sequences used in the area, seasonal unemployment is high and emigration to urban areas and abroad is common.

In 1981 the urban population of D. G. Khan District was 121,941, i.e. 14.2 per cent, and grew at an average annual rate of 4.5 per cent between 1972 and 1981, higher than the district average annual growth rate of 3.9 per cent. The urban population of Rajanpur District was 61,902, i.e. 10 per cent, and grew at a higher annual rate of 4.7 per cent over the same period, above the district average annual growth rate of 3.8 per cent. There was only one municipal committee in D. G. Khan District, namely D. G. Khan Municipal Committee, with a total population of 102,007, and one town committee, namely Taunsa, with a population of 19,934 persons.

SELECTED POPULATION STATISTICS OF THE STUDY AREA; 1981

	D. G. Khan Tehsil	% share of total population	Taunsa Tehsil	% share of total population	Rajanpur Tehsil	% share of total population	Jampur Tehsil	% share of total population
Total population	635,612	100.00	225,800	100.00	341,171	100.00	276,258	100.00
Total urban population	102,007	16.05	19,934	8.83	33,953	9.95	27,949	10.12
Total rural population	533,605	83.95	205,866	91.17	307,218	90.05	248,309	89.88
Population engaged in torrent-watered cultivation	142,956	22.49	167,752	74.29	13,983	4.10	63,353	22.93

Source: Adapted from 1981 District Census Report of D. G. Khan.

Note: Figures for Rojhan Tehsil included in those for Rajanpur Tehsil.

In Rajanpur District, there were four town committees, namely Jampur (population 27,949), Rajanpur (18,789), Kot Mithan (8,531) and Rojhan (6,633). The two districts combined had a total of 1,220 villages (mauzas), of which 43 had populations of 5,000 or more inhabitants, 370 had populations of less than 5,000, 465 had populations of between 200 and 1,000 inhabitants, and 342 had populations of less than 200.

The sex ratio, i.e. the number of males per 100 females, was 111 for D. G. Khan District and 115 for Rajanpur District. The population of the two districts combined was relatively young and infants (below 1 year of age) made up 3 per cent of the total population, while children below 5 and 15 made up 16.8 and 47.1 per cent, respectively. The adult population (18 years of age and above) made up 48.8 per cent.

The literacy ratio for the two districts combined was 16.3 per cent, much lower than the national average of 26.2 per cent, and much higher in the urban areas (42.3 per cent) as compared to the rural areas (12.8 per cent). The population is overwhelmingly Muslim (99 per cent), with small communities of Christians. In December 1990 the population of D. G. Khan District was estimated at 1,382,000 persons and that of Rajanpur District at 925,000 (including the population of the tribal areas, which probably totalled over 170,000 in the two districts combined).

(2) The Pachad

It is, for a number of reasons, particularly difficult to ascertain with any degree of accuracy the number of communities, hence the size of the population, now engaged in torrent-watered cultivation in the districts of D. G. Khan and Rajanpur. First, the Study Area attracts a significant number of in-migrants and is also affected, although to a lesser extent, by out-migration. Second, hill torrents frequently change their courses over time, while a number of villages are irrigated by water from minor hill torrents, of which there are several. Third, communities surrounded by large cultivable areas and irrigated by hill torrents sometimes do not actually engage in agriculture but prefer trading. Fourth, the results of the next population census are overdue and it is necessary to rely on figures from the 1981 Population Census: some villages listed in it are no longer inhabited, or have been washed away by hill torrent flash flows.

In the study, estimation of population engaged in torrent-watered cultivation in major hill torrent areas has been exerted. These are Kaura, Vehowa and Sanghar, in Taunsa Tehsil (other minor hill torrents not studied in that tehsil are Litra, Bathi, Kawan and Mohi); Sori Lund, Vidor and Sakhi Sarwar, in D. G. Khan Tehsil (other minor hill torrents are Sori Polab and Sori Khosa; Mithawan, a major hill torrent, was not studied); Chachar, in Jampur Tehsil (other minor hill torrents are Khosarah, Khumbi, Gazi and Khara; Kaha, a major hill torrent, was not studied; Chachar both irrigates and affects portions of Rajanpur Tehsil); Zangi and Sori Janubi, in Rojhan Tehsil (Pitok and Sori Shumali, two major hill torrents, were not studied). In Rajanpur Tehsil are found such minor hill torrents as Bighari and Chezgi.

Information concerning the population engaged in torrent-watered cultivation is summarized in table below. In Taunsa Tehsil, it totalled 167,752 persons in 1981. In D. G. Khan Tehsil, it totalled 142,956. In Jampur Tehsil, it totalled 63,353. In Rajanpur Tehsil, it totalled 4,894. In Rojhan Tehsil, it totalled 9,089. According to the 1981 Population Census, the 1972-81 inter-censal average annual growth rates were 3.99 per cent, 3.77 per cent, 3.84 per cent and 3.73 per cent for Taunsa, D. G. Khan, Jampur and Rajanpur tehsils respectively. Using compounding factors it is therefore possible to estimate the size of these populations in 1991. These are, conservatively, of: 247,000 for Taunsa Tehsil; 206,000 for D. G. Khan Tehsil; 92,000 for Jampur Tehsil; 7,000 for Rajanpur Tehsil; and 13,000 for Rojhan Tehsil.

ESTIMATED POPULATION IN 1991 OF COMMUNITIES IN THE STUDY AREA ENGAGED IN TORRENT-WATERED CULTIVATION BY MAJOR HILL TORRENT SURVEYED

	1981 population	Compound factor	1991 population
Kaura Hill Torrent	18,466	1.478	27,293
Vehowa Hill Torrent	52,445	1.478	77,514
Sanghar Hill Torrent	43,097	1.478	63,697
Sori Lund Hill Torrent	23,863	1.447	34,530
Vidore Hill Torrent	38,293	1.447	55,410
Sakhi Sarwar Hill Torrent	17,963	1.447	25,992
Chachar Hill Torrent	12,526	1.457	18,250
Zangi Hill Torrent	3,719	1.442	5,363
Sori Janubi Hill Torrent	5,370	1.442	7,744
Total	215,742	N.A.	315,793
Reference:			
Mithawan Hill Torrent	33,085	1.447	47,874
Kaha Hill Torrent	44,784	1.457	65,250

Note: Population figures for Mithawan and Kaha are given for referencepurposes only.

For Kaura, it totalled 18,466 persons in 1981. For Vehowa, it totalled 52,445. For Sanghar, it totalled 43,097. For Sori Lund, it totalled 23,863. For Vidor, it totalled 38,293. For Sakhi Sarwar, it totalled 17,963. For Chachar, it totalled 12,526. For Zangi, it totalled 3,719. For Sori Janubi, it totalled 5,370. The population engaged in torrent-watered cultivation on the basis of the nine hill torrents surveyed amounted to 215,742 persons in 1981, or 14.6 per cent of the total population of the districts of D. G. Khan and Rajanpur (excluding the tribal areas).

Again it is possible using the relevant compounding factors to estimate the size of the subject populations in 1991. These are, conservatively, of: 27,000 for Kaura; 77,000 for Vehowa; 63,000 for Sanghar; 34,000 for Sori Lund; 55,000 for Vidor; 25,000 for Sakhi Sarwar; 18,000 for Chachar; 5,000 for Zangi; and 7,000 for Sori Janubi. The total population engaged in torrent-watered cultivation on the basis of the nine hill torrents surveyed is therefore estimated, conservatively, at 310,000 persons in 1991.

3.3.3 Socio-Economy

Agriculture, including livestock rearing, dominates the economy of the districts of D. G. Khan and Rajanpur and canal waters or local precipitation consequently play important roles in the life of the people. While canal waters support a permanent cropping pattern and higher incomes in canal-irrigated areas, the low and variable rainfall severely constrains agricultural production outside the canal-irrigated areas, where cropped land uses water from torrent-spreading and, if available, tubewells, and where household incomes need always be supplemented by income from livestock rearing and services. Agricultural development and, by extension, economic development are therefore tied to expanding irrigation and using hill torrents for cropping, via better water control and improved distribution of water.

The socio-economic infrastructure of the Study Area likewise reflects the duality of agricultural activities and is most developed in the permanently irrigated areas of the two districts, particularly in D. G. Khan Tehsil. Available data indicate a strong concentration of social and economic infrastructure such as roads, post offices, schools, hospitals or telephones, into the canal-irrigated areas, though approximately 90 per cent of the population live in rural areas.

IRRIGATED AND RAINFED FARM LAND OF THE STUDY AREA; 1980 (in acres)

	Cultivated area	Irrigated (any source) Area	%	Barani Area	%	Sailaba Area	%
D. G. Khan Tehsil	321,360	307,340	95.64	3,123	0.97	319	0.10
Taunsa Tehsil	270,777	215,972	79.76	14,241	5.26	30,449	11.25
Rajanpur Tehsil	423,479	314,506	74.27	21,284	5.03	40,222	9.50
Jampur Tehsil	284,484	227,636	80.02	16,305	5.73	460	0.16
Total	1,300,100	1,065,454	81.95	54,953	4.23	71,450	5.50

Source: Adapted from Pakistan Census of Agriculture, 1980, Volume III.

Note: Figures for Rojhan Tehsil included in those for Rajanpur Tehsil.

SOURCE OF IRRIGATION OF THE STUDY AREA; 1980 (in acres)

	Irrigated area	Canals + canals & other sources Area	%	Wells & tubewells Area	%	Unspecified Area	%
D. G. Khan Tehsil	307,340	231,121	75.20	25,740	8.38	50,477	16.42
Taunsa Tehsil	215,972	6,324	2.93	53,798	24.91	155,846	72.16
Rajanpur Tehsil	314,506	234,527	74.57	71,768	22.82	8,212	2.61
Jampur Tehsil	227,636	196,815	86.46	9,338	4.10	21,485	9.44
Total	1,065,454	668,787	62.77	160,644	15.08	236,020	22.15

Source: Adapted from Pakistan Census of Agriculture, 1980, Volume III.

Note: Figures for Rojhan Tehsil included in those for Rajanpur Tehsil.

Although the major constraint to agricultural development in the Study Area is climatic, the lack of such amenities strengthens the dependence of rural population on urban areas, reduces employment opportunities and exacerbates migration from rural areas. According to the 1981 Population Census, a cumulative total equivalent to over 95 per cent of the 9,937 rural residents of the two districts went abroad in the last ten years preceding to the Census. The corresponding figure for the whole Punjab was 78 per cent.

Paradoxically, migration to the two districts is high. The total numbers of in-migrants over the ten years preceding the Census was 59,593, over 80 per cent of whom were illiterate. The majority, or 43 per cent, of in-migrants came from other countries, presumably Afghanistan, while another 19 per cent came from neighboring regions of the Punjab. Over 70 per cent of the total settled in rural areas, thereby putting further pressure on the land.

In December 1990 the combined population of the two districts was estimated at 2.3 million, or about 4 per cent of the population of the Punjab, and grows at 3.8 per cent per annum, according to a computed average of official estimates. Population density averaged 95 persons per square kilometer, as compared to a provincial average of 300. However, the proportion of land not available for cultivation from reported area totalled 27 per cent for the two districts as compared with 19 per cent for the Punjab as a whole (1987/88). Moreover, the area that could not be cultivated for lack of irrigation and other facilities, i.e. cultivable waste (land left uncultivated for four consecutive harvests), amounted to 29 per cent of reported area the same year, or almost three times the corresponding figure for the Punjab.

The Study Area is both relatively and absolutely underdeveloped. In the absence of other resources (whatever industry exists in the two districts is concentrated in D. G. Khan Tehsil and is overwhelmingly agro-based), its development is synonymous with development of agriculture through irrigation, so as to meet the basic and urgent needs of the rural population in the pachad.

3.4 Agriculture

3.4.1 Hill Torrent Agriculture

In the plain in the Study Area, mean annual rainfall is less than 300 millimeters mostly concentrated during the Kharif season. Consequently, the acreage under cultivation varies every year, and in much of the cropped land water from torrent is used for irrigation. Jowar, bajra and pulses are the main Kharif crops. Wheat, gram, fodder and oilseeds are the main Rabi crops, Grazing is an important activity in the pachad. Shortage of water and its storage facilities for crops and fodder production are major constraints for development of irrigation system and effective use of water from hill torrents in the Pachad area. The soils comprise rich alluvial soils of a high fertility and good moisture sustainability.

Torrent-watered agriculture has long time been practiced in the Study Area in ways as described in 3.5.2. Supply of labor for construction and maintenance of embankments was formerly regulated by rules well known to the farmers and intended to apportion labor in accordance with the benefits received from the water. Recently, however, migration of farmers to the Middle East and canal-irrigated areas has affected the ability of farmers to regulate flood dispersion works. Agricultural activity is declining and the repair of damages to the diversion embankments has become increasingly difficult. Furthermore, the highly erosive streams have changed channels and left many formerly cultivated areas dry, while flows in specific channels have greatly intensified to the detriment of agriculture in the canal-irrigated areas.

Crop selection in the pachad depends on water availability. Jowar and bajra will be sown if hill torrents flow between June and August. Jowar is grown in the more irrigated fields of the pachad, while bajra requires less water and ripens quicker. Bajra is considered to be better in the north, but the reverse is the case in the south. The jowar stalks are succulent and fattening fodder for cattle and horses. A large proportion of the jowar crop is sown as fodder only or becomes so owing to failure of the grain to ripen. In the pachad the heads are formed by October but ripen slowly, and reaping goes on there from November to January. The heads are first pulled and collected on the threshing floor and then the stalks are cut. The stubble is left fairly high and sprouts again after the cold weather rains, and then cattle are let loose to graze on the green blades. The threshing of the grain lasts throughout February and sometimes into March. The chaff of jowar is also valuable as cattle food while that of bajra is worthless.

Should torrents descend in October or November, large areas not cultivated earlier in the season will be sown with wheat. Wheat is also grown in those areas which enjoy perennial flows from hill torrents or where the soil can retain moisture long enough. In all classes of soil wheat is sown in drills. The corn is reaped from early April to middle May and output depends on weather conditions in March. Gram and oilseeds, mainly rape and mustard, are also grown using residual moisture in the Rabi season. The stems and straw of jowar, bajra and wheat are important for livestock feeding and the whole crop will on occasion be fed to livestock if moisture during crop growth is insufficient to yield grains. The stubble of these cereals is also used for animal grazing. In the Study Area, ordinary sawing and harvesting periods for major crops are presented in Table 3.5. Farm inputs are low because of the particularly unstable and unpredictable farming conditions. Fertilizers and pesticides are not usually applied and this, combined with insufficient water, results in very low yields.

Other crops grown in the pachad, although lesser extent, include mung, mash, moth, and Kharif fodders in the Kharif season, and peas, lentil and Rabi fodders in the Rabi season.

The following is a calendar of farm operations in the pachad:

January	: Jowar and bajra reaping finished, threshing continues. (Cotton picking in progress. Wheat gets a top dressing.)*
February	: Jowar threshing finished. Oilseeds reaping commences.
March	: Oilseeds reaping continues. Gram is harvested. Wheat ripens towards the end of month and reaping commences.
April	: Wheat, oilseeds, gram reaping continues and is finished. (Tobacco is planted out. Rice nurseries are sown.)
May	: (Sowing of rice nurseries continues. Tobacco planting continues.)
June	: Water having sunk into the land, the soil is ploughed and jowar and bajra sowing commences.
August	: Jowar and bajra sowing continues. (Rice comes into ear and cotton comes into flower towards the end of month.)
September	: (Rice reaping commences in the latter half of the month.)
October	: Jowar heads in flower. Wheat, oilseeds and gram sowing begins. (Rice reaping continues. Cotton picking continues.)
November	: Wheat sowing continues. (Cotton picking begins.)
December	: Jowar and bajra reaping begins along with threshing. (Cotton picking continues.)

3.4.2 Canal-Irrigated Agriculture

The network of irrigation channels of the D. G. Khan and Dajal Branch canal system commands approximately 354,000 hectares of the riverine tract and adjoining plains of the districts of D. G. Khan and Rajanpur. The irrigated areas lie between the Indus and the D. G. Khan and Dajal Branch canals and lift-irrigation is also practised in some areas to the west of the canals. Most of the canal-commanded area down to the Mithan Kot enjoys sweet water. Canal irrigation is available in summer and on occasion in mid-winter. Rabi crops are sown before the winter closure of canals, or in the absence of canal water, using residual soil moisture supplemented by water from tubewells, wells and rainfall.

The main Kharif crops are cotton, rice, sugarcane (cropping intensity 42 per cent, 20 per cent and 3 per cent, respectively, in 1989) and fodders. The main Rabi crops are

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* (   ) : Operations in canal areas

wheat and oilseeds (cropping intensity 70 per cent and 7 per cent, respectively), and fodders. Farmers are progressive and employ relatively modern cultivation techniques, including farm machinery, fertilizers and pesticides. Cooperative activities and extension services are also concentrated in this area. Accordingly, crop yields are higher than those obtained in the pachad.

The main problems facing canal-irrigated agriculture in the Study Area are damage from torrent flows, waterlogging and associated salinity. First, the D. G. Khan and Dajal Branch canal system comprises a number of crossings for the disposal of flood flows from hill torrents. When these flows exceed the capacity of crossings water accumulation breaches the canals and causes considerable damage to both crops and infrastructure in the canal command area. Second, relatively high water allocation in the Kharif season and seepage from the canals has resulted in the rise of the water-table and waterlogging in parts of the canal command area. Third, the rise of the water-table has induced the capillary ascent of salts. In 1989, out of a total area surveyed of 345,000 hectares, saline area in the districts of D. G. Khan and Rajanpur amounted to 24,600 hectares and 25,300 hectares, respectively, or over 14 per cent of cultivated area.

3.4.3 Structure of Agricultural Holdings

A Farm Economic Survey, covering the major hill torrent areas of the districts of D. G. Khan and Rajanpur except Mithawan, Kaha, Pitok and Sori Shumali, was carried out in Phase I of the Study to ascertain the structure of agricultural holdings in the pachad (see Table 3.6).

Average household size is 12 persons (6 males and 6 females) but varies from less than 5 to more than 20 persons. Household size is relatively large in the hill torrent areas of Sanghar, Vidor and Chachar, and relatively small in those of Vehowa and Sori Janubi. A number of households also engage in occupations other than hill torrent cultivation and such occurrences are frequent where households are located in the vicinity of large rural communities.

Average farm size is 36 hectares per household, of which 14 hectares are cultivated, 4 hectares are under rotation and 18 hectares are cultivable waste land. Farm sizes are larger in the hill torrent areas of Kaura, Vehowa and Sakhi Sarwar, and smaller in those of Vidor and Zangi. The proportion of cultivable waste to farm size is considerable in Kaura and Sakhi Sarwar. The average number of farm plots is 7 per farm and the size of a plot ranges from 4 to 19 hectares, while distance from farm to plot ranges from 1 to 5 kilometers. Because the sample collected includes farms of over 200 hectares the true average size of a farm is likely to be smaller than the calculated average suggests (see Table 3.6).

3.4.4 Crop Output

Average cropping intensity is 37 per cent and ranges from 23 per cent to 52 per cent. Such figures, however, perhaps present an unduly optimistic picture of hill-torrent agriculture since respondents to surveys frequently happen to be relatively progressive farmers. However, data obtained from local revenue offices suggests the ratio of cropped area to cultivable area for each hill torrent surveyed to be smaller than the results of the Farm Economic Survey indicate (see Table 3.5).

Jowar is the main crop and is cultivated throughout the hill torrent areas. In the southern parts of the Study Area, such as in the hill torrent areas of Zangi and Sori Janubi, only jowar is cultivated. Cultivation of bajra, wheat and gram is limited to the northern and central parts of the Study Area and wheat cultivation is practiced mainly in those areas where perennial flows are found or tubewells are available.

The average yield of jowar is approximately 900 kgs per hectare and higher in the hill torrent areas of Vehowa, Sori Lund and Vidor. The average yield of bajra is approximately 800 kgs per hectare. Yields of wheat, gram and oilseeds are approximately 1,200 kgs, 850 kgs, and 800 kgs per hectare, respectively. Wheat yields are significantly higher in the hill torrent areas of Vehowa, Sanghar and Sori Lund.

Crop production fluctuates according to water availability from hill torrents. The hill torrent areas of southern part of the Study Area witnesses wild fluctuations. On the other hand, hill torrent areas enjoying perennial flows, such as Vehowa and Sanghar, exhibit steady crop production levels because the cropping pattern adopted is simple and land is under a single crop. Furthermore, vast areas of cultivable waste owe their existence to the shortage of water. These become progressively more extensive as one moves from north to south.

Fertilizers are not commonly used except, on occasion, for wheat cultivation. The use of pesticides is limited to progressive farmers, of whom there are very few. Seeds of local varieties are usually produced by farmers. Bullocks are used for land preparation and the repair of bunds and only 5 farmers in 87 surveyed reported the use of tractors for farming.

3.4.5 Livestock

Livestock rearing is a traditional activity for most farmers in the pachad because torrent-watered cultivation depends on rainfall and is not necessarily practiced regularly.

Small ruminants form a higher percentage of the total herd in the Study Area than in other barani areas. Nevertheless, they are under-represented on the basis of uncultivated land, indicating the low forage productivity of range land. Sheep outnumber goats by more than two to one. Sheep and goats are equally common in the hills whereas in the adjoining plains of the districts of D. G. Khan and Rajanpur there are about five times more sheep than goats. Fertility of both sheep and goats is lower than in other regions but estimates suggest growing populations for each species. The landless own a moderate fraction of both small ruminant herds. Sheep herd sizes are moderate at small farm sizes but rise rapidly with farm size, indicating that sheep are integrated with cropping to an extent not evident in other barani areas. They are nonetheless still disproportionately held by small farm owners. In contrast the size of goat herds is relatively insensitive to farm size. The normal size of a sheep and goat flock varies from 50 to 150 head, though smaller flocks are often found.

Large ruminants form a smaller proportion of the animal herd. The cattle herd is not always represented with respect to total area and cultivated area and has a strong draft component. Cattle fertility is average and the bullock component is increasing while the cow component is static. Thus, the cattle herd is becoming more of a draught herd. The landless own a smaller portion of the cattle herd but small farmers own a disproportionate share of the cattle (see Table 3.7).

According to the Farm Economic Survey conducted the average numbers of livestock kept per household is 8 head of cattle, 17 sheep and 9 goats. Average figures are generally higher in the south. Camels and donkeys are found in limited numbers throughout the pachad. Buffaloes are in the main kept by farmers living in the north of the Study Area.

3.4.6 Marketing, Processing and Storage

The towns of D. G. Khan, Taunsa, Rajanpur, Jampur and Rojhan, in that order, are the largest marketing centers in the Study Area for both farm outputs and farm inputs. At the divisional level, the major market is Multan. Smaller marketing centers in the Study Area include Vehowa, Shah Sadar Din, Kala, Shadan Lund and Kot Chutta.

Since the output of wheat and other cereals surplus to farm family subsistence requirements in the pachad is small, cereals are usually sold in small markets; some wheat is purchased by the Government at fixed prices. Cash crops like sugarcane and cotton are normally sold in the field, directly to processors. Marketing arrangements are not considered to be a significant constraint to agricultural activities in the Study Area, though distance to markets and the lack of roads affect most pachad farmers.

The processing of wheat, cotton and oilseeds is mostly carried out by private sector enterprises in and around the Study Area. There are 3 private flour mills in the districts of D. G. Khan and Rajanpur with a total processing capacity of 250 metric tons per day, 20 cotton ginneries, and 4 vegetable oil extraction and processing plants.

Storage facilities in and around the Study Area are generally adequate. In addition to farm-level facilities, cereal storage capacity available with the Food Department, though considerably smaller than in other districts of the Punjab, totals 15,000 metric tons in D. G. Khan District and 20,000 metric tons in Rajanpur District. While the quality of such facilities is not excellent, low rainfall and humidity in the region tend to minimize storage problems.

Livestock markets open once a week. In D. G. Khan Division, which had in 1986 the largest number of cattle in the Punjab and by far the largest number of sheep (about 1.4 million and 1.9 million respectively, with 1.5 million goats), the largest market is D. G. Khan itself, followed by Taunsa, Rajanpur, Jampur and Rojhan.

3.4.7 Agricultural Support Services

(1) Farm Mechanization

The Agricultural Engineering Organization was established to provide custom-hire services of agricultural machinery for land development and the drilling of tubewells, implement subsidy schemes for diesel tubewell installation, train farmers in agricultural machinery operation, repair and overhaul, and provide technical guidance for the purchase, maintenance and upkeep of such machinery. Its divisional office for D. G. Khan Division is located in D. G. Khan and the Organization has posted a field office in each tehsil headquarters.

Drilling services for tubewells are performed for farmers at subsidized rates and diesel engines are provided on a non-refundable basis at a subsidy of Rs 20,000 per unit for barani areas and Rs 16,000 for canal-irrigated areas. Mobile pumping sets are sold at 50 per cent of cost for lift-irrigation schemes. The service charges for bulldozers are of Rs 132 per meter-hour for barani areas and Rs 169 for canal-irrigated areas, substantially below the true cost of these services, which is Rs 384 per meter-hour. Many inhabitants of the pachad request use of the Organization's bulldozers for bund-making. Tractors are, in the main, hired from the private sector. They are of 64 HP on average, operator-driven, and provided with a set of farming attachments. The Organization fixes the service charge at Rs 80 per meter-hour but private sector rates range from Rs 75 to Rs 100 per meter-hour.

The main problem facing the Organization in D. G. Khan Division is lack of operating machinery. Its pool of bulldozers totals 125 units, one third of which are not in running condition. In the Study Area, the Organization has posted 23 bulldozers in D. G. Khan District and 14 in Rajanpur District. The Organization estimates its real needs at 250 working bulldozers for D. G. Khan Division.

Approximately 70 per cent of farms in the districts of D. G. Khan and Rajanpur reporting use of tractors are located in D. G Khan Tehsil, which also claims over 40 per cent of farms reporting use of tubewell water in the Study Area.

(2) Agricultural Credit

The amount of institutional credit provided through the Agricultural Development Bank of Pakistan (ADBP) and commercial banks, which operate only on a land collateral and personal surety basis, and although expanding rapidly, still provides only 10 to 15 per cent of the local requirements for short-term production loans and medium and long-term credit. Short-term production loans for seeds, fertilizers and agro-chemicals carry 12.5 per cent annual interest and are repayable in 12 months. Medium-term credit for bullocks, tubewells and land development, including levelling and perennial crop establishment, carries 12.5 per cent annual interest and is repayable in up to 5 years. Long-term credit is extended for fixed capital requirements such as tractors and cultivation implements, carries 12.5 per cent annual interest and is repayable in up to 8 years. The grace periods are, respectively, of 6 months, 12 months and 18 months. Because of the complicated procedural and collateral requirements for such loans many small farmers make little use of institutional credit and instead obtain loans at high interest rates from non-institutional sources such as landlords, relatives, or money lenders.

In the Study Area, the ADBP advances all three types of loans through its branch offices in D. G. Khan and Rajanpur which cover, respectively, Taunsa and D. G. Khan tehsils on the one hand, and Rajanpur, Jampur and Rojhan tehsils on the other. Farmers in the pachad make up between 10 and 15 per cent of loanees as a result of the nature of agricultural activities in the area, which are undertaken without the use of productivity-enhancing inputs such as fertilizers, high-yield varieties or pesticides, and have smaller fixed-capital requirements. According to the ADBP, the average size of loans secured by these farmers is smaller than those obtained by farmers in the irrigated areas. This is borne out by the figures for Taunsa Tehsil, an area which is not irrigated by canals: the average amounts disbursed for long-term and short-term loans in Taunsa Tehsil are the smallest in the Study Area and in the case of long-term loans are four times smaller than the corresponding figure for D. G. Khan Tehsil. Only in the case of medium-term loans for land development is the figure for Taunsa the second smallest.

(3) Agricultural Research and Extension

An Agricultural Research Division has been created in the Ministry of Food, Agriculture and Cooperatives to supervise and coordinate the research activities of various agricultural institutes in the country both at the federal and provincial level. The Pakistan Agricultural Research Council (PARC) is the principal organization which has carried agricultural research in different fields. In the Punjab, the main agricultural research establishments include the Ayub Agricultural Research Institute in Faisalabad, the Soil Testing Institute in Lahore, the Rice Research Institute in Kala Shah Kaku, the Fodder Research Institute in Sargodha, the Maize Institute in Yousifwala and the Livestock Institutes in Khairi Murat and Bahadurnagar. In the Study Area, there is a Fodder Research Station and a Livestock Experimental Station.

Until recently, virtually no research was aimed specifically at increasing productivity of barani lands. The Barani Agricultural Research and Development project, funded by Canada, spanned ten years from October 1982 to June 1991. Its objectives were to improve the quality of life among farmers engaged in barani agriculture, mainly through the introduction of high-quality, high-yield cultivars suitable for use on barani lands and development of appropriate machinery. The experience gained from the project suggests the following future strategies: (i) develop cropping systems for different agro-ecological zones in conjunction with livestock; (ii) breed high-yield, drought and disease-resistant cultivars for wheat, barley, summer grains, pulses, groundnut, sesame, sunflower, rapeseed and mustard; (iii) design and modify machinery; (iv) increase the participation of rural women in agriculture and other income-generating occupations; and (v) develop farmer-managed agricultural supply centers for dispensing improved seeds, chemicals and custom-hiring of machinery.

Agricultural extension activities in the Punjab are controlled by the Director General of Agriculture (Extension) through Directors of Agriculture (DA); one in Multan Division, one in Lahore Division, and one in Rawalpindi Division. The Director General of Agriculture reports to the Provincial Secretary for Agriculture. At the district level, extension activities are the responsibility of Deputy Directors of Agriculture (DDA) assisted at the tehsil level by Extra-Assistant Directors of Agriculture (EADA), one per tehsil. In addition, each Extra-Assistant Director of Agriculture is helped by an Assistant Plant Protection Officer. The Extra-Assistant Directors of Agriculture supervise approximately 200 Agricultural Officers (AO) who in turn supervise several hundred Field Assistants (FA) working at the Union Council level, a local administration unit comprising about 5 villages. The Field Assistants are the basic extension field worker.

AGRICULTURAL EXTENSION STAFF IN THE STUDY AREA

Name of Post	D.G.Khan District			Rajanpur District				Total
	D.G.Khan Tehsil	Taunsa Tehsil	District Subtotal	Rajanpur Tehsil	Jampur Tehsil	Rojhan Tehsil	District Subtotal	
D.D.A			1				1	2
E.A.D.A	1	1	2	1	1	1	3	5
A.O	5	2	7	3	2		5	12
Cotton Inspector	1		1	1			1	2
Agricultural Inspector	6	3	9(3)	2	3	1	6	15(9)
F.A	34	16	50	15	18	7	40	90

( ) : actual working

The Field Assistants contact 64 farmers in a fortnight in the context of the Training and Visit system being implemented in the Punjab. This does not provide an adequate service and the Field Assistants are extremely busy people who spend most of their time controlling cotton pests during the Kharif season and concentrate on orchards and oilseeds in the Rabi season. The Field Assistants are also likely to be assigned to ginneries during the Rabi season to supervise the selection and ginning of seed cotton and therefore have little time left to give advice to small farmers, especially in the pachad.

3.4.8 Farmer Organizations

In 1990 there were 46,197 cooperative societies in the Punjab, of which 1,063 in D. G. Khan District and 608 in Rajanpur District. Membership totalled 31,000 and 22,000 members, respectively, and a cooperative consists on average of about 20 to 30 farmers. The main function of cooperative societies is to provide loans to its members for the purchase of fertilizers, pesticides, seeds and diesel oil.

To secure a loan, applications are submitted through the cooperative to Sub-Inspectors and Inspectors, and are cleared by Assistant Registrars. There is one Assistant Registrar per tehsil, who reports to the District Registrar. Loans, once obtained, are made with a grace period of one season (Kharif or Rabi) and carry an interest rate equal to that charged by the ADBP. The loan amounts disbursed in the districts of D. G. Khan and Rajanpur in recent years are given in the following table.

CREDIT OUTRAYS TO THE STUDY AREA BY THE AGRICULTURAL COOPERATIVES

	D.G.Khan	Rajanpur	Total
Kharif 1988	18.29	12.84	31.13
Rabi 1988-89	15.55	11.98	27.53
Kharif 1989	22.14	13.12	35.26
Rabi 1989-90	29.00	9.78	38.78

In the Study Area, cooperative activity is relatively high in the hill torrent areas of Vehowa and Sanghar, which currently regroup 99 and 116 cooperatives, respectively. In the remainder of the Study Area, activity is lesser and again concentrated in the canal-irrigated areas, where agricultural inputs are much more extensively used. Cooperative activity in D. G. Khan Division as a whole is lesser than in other parts of the Punjab and the districts of D. G. Khan and Rajanpur are characterized by very low cooperative membership and working capital.

3.5 Flood Irrigation

3.5.1 Historical Background

In prehistoric times, the country between the Suleman mountains and the Indus, now comprising D. G. Khan and Rajanpur districts of the Punjab is believed to be a huge wasteland. There were only three towns namely Harrand, Mari and Asni in the whole area, and with the exception of a small area of cultivation attached to these, all the rest of the country was an uninhabited waste.

In 711 AD Mohammad Bin Qasim captured the area after defeating Raja Dahir. When Baluch tribes moved to the area in the fifteenth century, it was part of Multan province ruled by Langah rulers. Area north of Taunsa was given to a Baluch chieftain Sohrab Khan Dodai as a Jagir (State) by the Multan ruler Sultan Hussain Langah in 1469. Soon other Baluch tribes moved to the area including Miranis led by Haji Khan. Haji Khan's son Ghazi Khan gave his name to the town of Dera Ghazi Khan, while Dera Ismail Khan was named after Sohrab Khan's son Ismail Khan.

As Baluch tribesmen moved down the mountains of Suleman Range, they drove the locals towards the Indus and themselves settled in the pachad area. Even today pachad is predominantly inhabited by the Baluch people. The Baluch brought with them their culture, traditions and system of irrigation.

3.5.2 Irrigation System

The indigenous system of irrigation practiced in Baluchistan is such that the cultivators, under an organized method of co-operation, construct annually number of earthen dams in the river for raising the water to the surface. A specially expert cultivator, know as "raza", is selected to superintend the work, and cultivators living for many miles along the banks of the river are called in with their bullocks to construct the dam. Some of these dams are as much as 750 feet (230 meters) long, 180 feet (46 meters) wide at the foot, and 50 to 60 feet (15 to 18 meters) in height. Every village has to supply its quota of men and bullocks, or, should it fail to do so, has to pay a proportionate amount in cash. There are many of these dams and in July and August, when the floods come, the upper dams are broken as soon as sufficient water for the irrigation area has been received.

The Baluch tribesmen adopted the same system for irrigating their lands in the pachad. At suitable intervals earthen embankments are erected extending about halfway across the torrent bed to head up the flood water and lead it down the distributary channels which open immediately above the embankments. 'Bund' is the name of an embankment as well as of an embanked field, and a distributary is called 'wah'.

The earthen embankments are made with the aid of oxen. Some of the embankments in the torrent beds are permanent and the distributaries taking off from them get all the water they can take and only the surplus water goes on to the distributaries whose heads are lower down the torrent. Other embankments have to be cut as soon as their distributaries have received a supply sufficient to afford watering to most of the fields along them in order the water may be available to the distributaries lower down.

The site of each embankment and the rule as to its permanency or its liability to be broken are recorded in the registers of water rights. In the wah or main distributary similar embankments, in this case called wakra, and extending right across the channel are inserted at intervals to entirely dam up the water and force it into the channel (wahi) by which the water is conducted to the fields. Each of these is cut as soon as the field irrigated by it has got a watering. Fig.3.4 illustrated the local terminology and irrigation system.

3.5.3 Water Rights

(1) Register of Rights

The enforcement of rules related to cutting of bunds and wakras is a constant source of disputes. The system of irrigation practiced by the locals was institutionalized by the British in the form of registers of irrigation rights. Normally people owning lands on both sides of a torrent, its shakhs, wahs, and wahis have rights of irrigation based on saropa-paina principle. But there are certain areas of lands which have no rights or secondary tracts rights. No historical explanation exists for this difference. The first regular settlement of the area was commenced in April 1869 and finished in July 1874 by Sir Fredrick Fryer.

At the regular settlement of water rights, the bed of hill torrents were recorded as the property of the government. This was done because of two reasons. First it was thought that it would be difficult to ascertain who the original owners were and an attempt to do so would occasion many disputes, and secondly in was felt necessary to maintain the right of Government to control irrigation from the torrents.

Irrigation right or haquq were revised in the settlement of 1917, under the supervision of Mr. W R Wilson, Collector. Consolidation of then D. G. Khan district, and the revised registers of rights were produced in 1919 after approval from cultivators of all the torrents. There is one register for every torrent having irrigation rights. These hand written registers are still in use as legal document in both D. G. Khan and Rajanpur districts to regulate the irrigation and to solve water disputes.

(2) Saropa Paina (Cardinal Rule for Water Rights)

Saropa-paina is the cardinal principle of the irrigation rights, other rules governing the irrigation are more or less common for all the hill torrents. When conducted into the field the water is allowed to flow until it stands as high as the embankment (Lath) surrounding the field can stand. Often a height is of one meter or more. The head of a torrent or distributary is called Mund and the tail Pand. But the equivalence used in Dera Ismail Khan were Saropa and Paina, and by the middle of the nineteenth century, the name Saropa Paina came to be used for the custom by which the head channels or distributaries are entitled to receive their supply of water before the lower ones.

3.6 Infrastructure

3.6.1 Transport Facilities

The district headquarters of D. G. Khan and Rajanpur are connected with metalled roads to all their Tehsil headquarters and the eastern and southeastern belt of the Study Area is comparatively developed in metalled road transportation. The Study Area is connected with Multan to the east by a bridge at Ghazi Ghat and a road over Taunsa Barrage. It is linked with Baluchistan Province to the west through Fort Munro to Barkhan road across the Suleiman range and with NWFP to the north through D. G. Khan - D. I. Khan road, while Jampur - Rajanpur - Kashmor road links it with Sind province to the south.

Road networks are managed under the Provincial Highway Department, having two district offices in the Study Area. The D. G. Khan and Rajanpur offices management about 660 km and 360 km of road networks respectively. (see Table 3.8 and Fig.3.5) The farm road network, however, is insufficiently developed.

The districts are also served by a railway line which runs along the main metalled road from Taunsa Barrage to Sahiwal, in Rajanpur Tehsil, across which it goes to Jacobabad District. Except for Taunsa, the tehsils headquarters of Jampur, Rajanpur and Rojhan are all connected by rail with the city of D. G. Khan.

3.6.2 Others

(1) Industry

Industrial infrastructure in the Study Area is primarily agro-based and located in the canal-irrigated areas, particularly in D. G. Khan Tehsil. In 1991 there were 27 major industrial units of flour mills, cotton ginning and vegetable oils; one tractor assembly plant; one gypsum plant; and one cement plant.

(2) Social Services

Public health services in the Punjab include Government-run hospitals, dispensaries, rural health centers, basic health units and maternity child centers. In 1990 the districts of D. G. Khan and Rajanpur had 5 small hospitals each (437 beds), 37 dispensaries in all (28 beds), 15 rural health centers (260 beds), 72 basic health units (38 beds, none of which in D. G. Khan District), and 8 maternity child centers. These figures are among the lowest in the Punjab.

Educational facilities in the Study Area include colleges and middle and high schools, most of which are operated by the Government and are located in the canal-irrigated areas. The shortage or absence of teachers in the larger communities of the pachad is directly responsible for the low literacy rate in the rural areas.

3.7 Related Projects

3.7.1 Chashma Right Bank Irrigation Project (CRBIP) Phase III

The Chashma Right Bank Irrigation Project covers a total area of about 260,000 ha of land on the right bank of the Indus, stretching between the Chashma Barrage to the north and Sori Lund hill torrent to the south. The Chashma Right Bank Canal (CRBC) is about 260 km long with a command area which spans two provinces; about 60 % of the command area lies within D. I. Khan Tehsil of NWFP to the north and the remainder within Taunsa and D. G. Khan Tehsil of Punjab. Construction of the main canal system and distributaries has been devided into three stages; Stage I of 79 km, Stage II of 37 km and Stage III of 144 km. Stage III of the system has a CCA of about 135,000 ha of which 35 % is in D. I. Khan Tehsil and 65 % within D. G. Khan District.

According to the Feasibility Report prepared under technical assistance by the ADB in March 1990, the project cost for CRBIP Phase III was estimated at about 330 million US$. It was proposed that the project works would be completed with a construction period of 5 years (mid 1992 - mid 1997), with final water availability by Kharif 1998.

3.7.2 D. G. Khan Irrigation Project and Dajal Branch Extension Project

The first major development effort in the Study Area was iniated in early fifties by the introduction of weir controlled irrigation system when the D. G. Khan Canal System off taking from Taunsa barrage was started. The construction work of Taunsa barrage was started during 1953 and completed in 1958. The D. G. Khan canal runs almost parallel to the Indus river up to about 112 kilometers, where it bifurcates into Dajal Branch and Link-III canals. The work on Dajal Branch was completed in 1968.

According to the PC-1 proforma prepared in April 1991, the CCA of D. G. Khan system is about 243,000 ha and Dajar Branch together with Qadra extension has a CCA of about 107,000 ha. Dajal Branch Extension Project is in fact a sub project of the main project of D. G. Khan Canal. The proposal was submitted in 1970 after completion on the Dajal Branch Canal. Since then, it was kept waiting the decision on apportionment of Indus water. Major dimensions of proposed Dajal Branch Extension Project are as follows.

Length of Canal	:	112 km (70 miles)
Length of Distributaries	:	320 km (200 miles)
Discharge capacity	:	77.3 m3/sec
Gross Area	:	194,500 ha
Project Cost	:	Rs. 1,600 million

3.8 Constraints to Development

3.8.1 Flood Damages

The Report* describes clearly the flood problems of each hill torrents. Quoted from this report, and updated at the field, it is summarized as follows. Recent flood damages were added to the past record and summarized in Table 3.9

(1) Kaura Hill Torrent

This torrent after leaving darrah, bifurcates into two branches. Because of lower topography of the right bank area, the right side branch developed deeper and major part of the flow joins into Vehowa hill torrent. Downstream area of Kaura hill torrent receives only small amount of water for irrigation. Main problem is to stop the overspilling of flood flows into Vehowa hill torrent.

(2) Vehowa Hill Torrent

This torrent after leaving darrah, reaches Vehowa pick up weir which was constructed during 1971 - 1972 along with Gang Canal for the utilization of perennial flow of about 1.4 cms. The weir is outflanked and damaged by the torrent flow almost every year. Below the weir, the torrent flow frequently damages the earthern bunds separating the Non-Haqooq area and beaches many wahs and irrigation channels. The main problem is to train the torrent flow.

(3) Sanghar Hill Torrent

Similar to other hill torrents, this hill torrent has problems of training its flood course. After leaving darrah, the torrent splits into three branches of which the right side branch has tendency to draw more or even entire flow and would result in depriving the area on left branch from irrigation. Serious retrogression and side erosion has also been noticed near Taunsa Town and D. G. Khan - D. I. Khan road bridge. Large amount of flood volume from the second largest catchment area among major hill torrents would exceed the capacity of flood irrigation, the outfall channel to the Indus should be maintained.

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* Main Report on "Flood Management of D.G. Khjan Hill Torrents" 1984, National Engineering Services Pakistan Ltd. (NESPAK)

(4) Sori Lund Hill Torrent

Several number of wahs are offtaking from this torrent. The flood water is diverted into these wahs by putting small low level earthern bunds which always get damaged by floods. As a results, flood flows are diverted unequally or move down to the Indus without being diverted for irrigation but giving damages to the D. G. Khan Canal system.

(5) Vidore Hill Torrent

The torrent has three main branches namely Phullar Branch, Suchani Branch and Chhabri Branch. The distribution among the three branches is not in accordance with their water rights, because of the absence of a distribution system. Some diversion bunds were constructed by Irrigation Department during the year 1979 and by ABAD in 1981 - 82. Even these works do not ensure proper distribution. The excessive discharge so escaped into one of the branches, washes away small diversion bunds and other distribution structures for basin irrigation. The flood flow ultimately reaches D. G. Khan Canal where it crosses the canal through hill torrent crossings. After crossing the canal the flood water causes serious damage to the crops and other infrastructure in the canal command area. Effective flood management measures are required for the proper distribution of flood flow.

(6) Sakhi Sarwar Hill Torrent

This hill torrent after emerging from the hills near Sakhi Sarwar Town fans out and splits into seven branches. It has a tendency to flow towards north due to non-erodable high bank on the right which acts as a spur. This has resulted in developing deeper channel on the left side which consequently takes major part of flood flows to the 'Non-Haqooq' area leading to D. G. Khan Canal without being used for basin irrigation.

(7) Mithawan Hill Torrent

Below darrah, the torrent splits into three main branches. One is a 'Non-Haqooq' channel whereas the other two have equal shares. In order to divert flood water into 'Haqooq' channels, a bund known as Hadwali bund is constructed on the right bank of the torrent upstream of trifurcation site. This bund generally get breached and major part of flood flow finds its way into 'Non-Haqooq' branch which ultimately reaches Dajal Branch. Cross drainage capacity is inadequate as a result of which breaches occur on both the banks of Dajal Branch. In case, the Hadwali Bund is not damaged, major part of floodwater flows down to D. G. Khan Canal through Sharti wah highly developed channel of Northern Branch without doing any basin irrigation. The flood flow reaching D. G. Khan Canal is generally in excess of the capacity of hill torrent crossing. The accumulated floodwater breaches the canal banks and causes heavy damages to canals, crops and other infrastructure.

(8) Chachar Hill Torrent

This torrent has a well defined channel of about 17 miles (27 km) length from darrah to Dajal Branch and a number of wahs offtake from the right and left bank provide basin irrigation facilities to the pachad area lying between the toes of hills and Dajal Branch. The floodwater into the offtaking wahs is diverted by constructing small leading bunds and Wakras in the bed of the torrent. These low level bunds get damaged whenever the flood flows exceed the manageable limit and major part of flood flow finds its way to hill torrent crossings at RDs 177 + 300 and 186 + 100 of Dajal Branch. The floodwater after passing through hill torrent crossings enters the canal command areas where it is joined by the floodwater of Kaha Hill Torrent. The combined floodwaters then flow down along the right bank of Dhundi Kutab Canal and cause serious damage to canal, its structures, distributaries, crops and other property in the area. The floods area required to be managed in upper area as far as feasible.

(9) Pitok Hill Torrent

The water of this torrent is brackish and is neither fit for agricultural nor for drinking purposes. Moreover, the silt brought down by the floods of hill torrent contains salts which are injurious for the lands and crops. This is the reason that there are no wahs or basin irrigation facilities on this torrent. After leaving darrah, the flood water finally reaches right bank of Kadra Canal where a breaching section has been provided for disposal of flood flows across the canal. This floodwater after crossing the canal flows to the Indus River in the form of a sheet flow. In the proposal of Dajal Branch Extension, two hill torrent crossings having a capacity of 255 m^3/sec have been proposed for disposal of flood flows across the canal but no provision has been made for its further disposal. The floodwater and the silt brought by the torrent are very injurious to crops and the lands. Suitable measures for disposal of floodwater to River Indus area needed.

(10) Sori Shumali Hill Torrent

The water of this torrent is also brackish like Pitok Hill Torrent. The silt brought by the floods of this torrent contains salts injurious to the fertility of the land. The floodwater is, therefore, neither fit for drinking nor for agricultural purposes. The floodwater of the torrent is required to be properly managed to save the canal irrigated area from soil salinity.

(11) Zangi Hill Torrent

This torrent emerges from Darrah about 15 miles (24 km) north of Rojhan-Kashmore Road. The flood flows after travelling about one and half mile (0.8 km) from Darrah has a tendency to flow towards Non-Haqooq area of Chak Dilbar. In order to check escapages to 'Non-Haqooq' area an earthen low level bund is constructed through 'Kamara' labour. This bund gets damaged even in medium floods. Further down about two miles (3.2 km), the torrent splits into two branches. Flood flows at present are being used for basin irrigation through different wahs/wahis by construction of small earthen bunds/wakras in the bed of these natural channels. This system works satisfactorily during low floods only and in case of higher floods these diversion bunds get damaged. Suitable dispersion structures at the three main distribution sites area required for proper flood management.

(12) Sori Janubi Hill Torrent

This is the last torrent on the southern side of Rajanpur District of D. G. Khan Division. Two miles (3.2 km) below 'darrah' the torrent is divided into two branches, one of which goes to 'Non-Haqooq' area. Flood flows are diverted into Haqooq channel by the construction of bund, known as Manga Ganda at the head of 'Non-Haqooq' channel. Small earthen bunds are constructed to divert flood flows for basin irrigation. This system generally works during low flows. In the event of abnormally high floods, Manga Ganda breaches and almost entire flows move down to Indus River. After the construction of proposed Dajal Branch Extension, the area on its left presently dependent upon the flood flows of this torrent will receive canal supply and the remaining culturable area from the toe of hills and the canal will be small and would have negligible flood absorption capacity. For proper management, major part of flood flows would be required to be escaped through escape channel.

3.8.2 Socio-Economic Constraints

Rainfall in the Study Area is not sufficient for cropped agriculture and all development potential lies in the exploitation of water resources. The two main areas available for increasing agricultural production are the pachad and the riverine land along the Indus. The agricultural component of water development projects ranges from high potential for tubewell development in the riverine tract to moderate agricultural potential from flood-recession water diverted from the hill torrents in the pachad.

The traditional approach to agriculture in the pachad involves the construction of earthen or rock structures across major channels where the streams emerge from the last ridge of the Suleiman range onto the pachad. These structures direct water into major channels where smaller structures divert water to smaller channels. Small obstructing fills are placed at several points along tertiary channels to flood bunded areas which are cultivated. These works and operations have traditionally been under the control of chiefs (sardars). With the out-migration of labor to the canal-commanded areas during the 1960s and to the Middle East during the 1970s and 1980s, however, the social structure has changed and the ability of the sardars to regulate labor and water flow has diminished. The highly erosive streams have changed channels and left many areas dry, while flows in specific channels have greatly intensified to the detriment of agriculture in the canal-irrigated areas.

The socio-economic context for barani agriculture in the Study Area can be summarized by a discussion of access to land, the composition of farm income and agricultural marketing, all of which have already been touched upon in the present.

First, the size of a farm affects its efficiency in the use of resources, the amount of income it can generate, and the potential technical innovations that it can adopt. There are, in the pachad, a large number of small farms, though proportionately less than in the Punjab as a whole. According to the 1980 Agricultural Census, about 63 per cent of holdings in the districts of D. G. Khan and Rajanpur (excluding the tribal areas) consisted of farms of less than 12.5 acres. The corresponding figure for the Punjab was 71 per cent. At the other end of the scale, farms larger than 50 acres made up 4 per cent of the total number of holdings but occupied 30 per cent of the land. The corresponding figures for the Punjab were 3 per cent and 21 per cent, respectively.

Fragmentation is more than just an important source of increase in farm costs. Many farmers surveyed in the pachad reported having to walk 40 or more minutes to reach the most distant fragment and farms with two or three fragments comprised 46 per cent of all farms and 80 per cent of all fragmented farms. The corresponding figures for the Punjab were 41 per cent and 69 per cent, respectively. As farms have become smaller, because of the inheritance pattern which divides patrimonies unequally among offspring (two units to a son and one unit to a daughter, plus one eighth to a surviving wife or husband), most farmers have begun to cultivate more intensely but this requires increased investment in productivity-enhancing inputs.

The pachad may one day consist almost wholly of owner-operated farms. Their growth, and the corresponding decline in tenant and owner-cum-tenant operations, has continued over the last twenty years and such farms comprise 46 per cent of all farms, as compared to 37 per cent in 1972. Owner-operated farms in the Punjab made up 54 per cent of the total number of farms in 1980. Access to land is therefore becoming more difficult and land values appear to be rising.

The above data suggests that, at least from the point of view of farm size and tenure, the resource base of the Study Area is less constrained than that of the Punjab as a whole. Small farms make up a smaller proportion of all farms, though large farms account for a greater proportion of farm area. The number of owner-operated farms is also proportionately smaller than in the Punjab, signifying greater opportunities for tenants and landless farmers. However, farms in the Study Area are more frequently fragmented than in the Punjab.

In analyzing the changing composition of farm income, three aspects can be considered: crop-based income, livestock income, and income from off-farm employment. The importance of the farm as a source of income has been diminishing in the pachad and off-farm incomes have become an important part of total farm-family income, as farmers are being compelled to exploit new economic opportunities. Farmers react to growing pressure on the land and changing circumstances in several ways and one of them is the size of animal holdings. In the pachad, these are important and, except for buffalo, vary inversely with rainfall. The cyclical nature of crops, with peaks and troughs in the demand for labor, also encourages farmers to look for short-term, off-farm jobs. Barani farmers in general are qualified for little but unskilled labor but off-farm jobs, even so, pay a higher hourly wage than most farm work. The Farm Economic Survey of the Study Area suggests that crop-based income accounts for about 40 per cent of family income in the pachad, that income from livestock accounts for approximately 30 per cent, and that off-farm employment accounts for the remaining 30 per cent.

Finally, the scarcity of market outlets in the Study Area increases the cost of marketing. Most produce is handled through traders, commission agents and village shopkeepers. Much of the trade is handled at the farm level, since cooperatives do not provide such services, but open markets do operate in towns. The expansion of feeder roads in the pachad should in time improve the access of the rural population to market facilities.

Barani agriculture in the Study Area is profitable and competitive when sufficient moisture is available and good varieties are cultivated with the use of productive techniques on viable land. These conditions are not satisfied naturally and create a socio-economic environment that is the consequence, not the cause, of underdevelopment. The key to improvement of barani crop production in the Study Area is efficient management of moisture. This can be achieved through better management of surface water, using watershed management technologies, appropriate plowing to retain water, sound water-harvesting practices, and widespread timely use of tractors with suitable implements. With increased supplies of moisture, barani agriculture in the viable tracts of the pachad is well placed to realize a large, untapped, potential increase in yields, and achieve greater production.

The barani tract can be regarded as a challenging new agricultural frontier with a promising economic future or, alternatively, as a difficult, dependent, and marginal sector. Through the years, the Government of Pakistan has been deeply involved in the management of agriculture but it has not, however, treated the barani differently from irrigated areas. The above discussion suggests that barani farms in the Study Area are not unproductive just because they practice subsistence agriculture and that the farm practices adopted are, indeed, adapted to the prevailing natural environment. Opportunities for greater production exist, but the investments required are too large for the farmers to undertake without outside assistance, given the changes in social structure caused by out-migration and the consequent degradation of water control structures in the pachad.

CHAPTER 4 DEVELOPMENT STRATEGY

4.1 Basic Strategy for Development

The Study Area has about 1.23 million hectares of plain area and hilly catchment area of about 1.63 million hectares. The plain area consists of about 110,000 hectares of riverain area along the Indus, 390,000 hectares of canal irrigated areas by D. G. Khan and Dajal Branch Canals, 120,000 hectares of proposed Dajal Branch Extension project, 110,000 hectares of proposed CRBC project third phase and the remaining about 500,000 hectares of hill torrent irrigation area so called the pachad.

Major hill torrents of the Study Area, 12 hill torrents excluding Kaha hill torrent, have catchment area of about 1.36 million hectares and the pachad about 159,000 hectares of which only 11 % is cultivated every year. The land capability of the pachad at present is classified into marginal for agricultural development because of severe semi-arid climate and no soil conservation practices. However, the potential productivity of the land can be recovered through an irrigated and continuous farming, except such saline land located at southern part of the Study Area.

Industries in the Study Area are overwhelmingly agro-based and concentrated in the year-round irrigation area particularly in D. G. Khan Tehsil. There are also strong concentration of other social and economic infrastructures, whether roads, railways, government functions, into the canal-irrigated areas. A Farm Economic Survey indicates the strong incentive of farmers to increase their cropping area by means of stable irrigation water supply. Based on these conditions and the fact that approximately 90 per cent of the population live in rural areas, the basic strategy for development of the Study Area should be focused on the development of agriculture.

Main water resources of the pachad is, however, the floodwater from hill torrent. The groundwater potential for agriculture is limited small. It is practiced only small scale in the northern part of the Study Area and the area along the irrigation canal. Groundwater resources should be reserved for drinking water supply.

Available data indicate that the average annual runoff amount of hill torrent floods, as an available water resources, are within the range between 100,000 and 170,000 MCM. In other words, it is from 17 MCM/year (Saki Sarwar) to 780 MCM/year (Sanghar). Sufficient water resource is available. Only and the largest constraint for development is that this water resource is available but in the form of floods.

Specific peak flood discharge of 25-year probability is estimated with each hill torrent and ranges from 0.8 to 4.6 cms/km^2 which is not particularly large. However, corresponding to the large catchment area of 160 km^2 to 4,880 km^2, it will result in high peak floods from 520 cms to 3,740 cms giving large flood damages to the downstream areas. Flood damages are concentrated in the D. G. Khan and Dajal Branch canal irrigated areas and hindering the development of agriculture which is the only important industry in the Study Area.

4.1.1 Guideline for Strategy

The guidelines on the basis of which the development strategy is to be formulated are;

i) to give urgent priority to flood damages reduction in the canal irrigated areas as well as the pachad

ii) to make maximum use of flood water for agriculture in the pachad and

iii) to introduce measures for watershed conservation so as to achieve stable agricultural development, on a long-term basis, not only in the pachad area, but also in the watershed.

4.1.2 Review of Previous Study

Number of alternatives have been studied for the agricultural development of the pachad and the following measures are proposed components in the recent study.

i) Construction of dispersion structures at downstream and close to the darrah

ii) Afforestation in the watershed

The first measure is to distribute the flood water more effectively, without changing the historical practices and water rights, to the farm lands through solid and permanent structures of gabion and masonry. The floods are dispersed at upstream and do not reach directly to the downstream area. Thus, the flood damages will be minimized and flood water will be led into the pachad.

In spite of these merits, this measure will not always ensure the stable farming in the pachad.

i) Timing and magnitude of floods are not predictable and a scheduled farming will not be possible.

ii) Larger amount of flood water will be taken into wahs, from the improved dispersion structure, which may exceed the manageable limits of farmers for further distribution of water to downstream. Provision of flood escape structure to avoid breaching of bunds and to limit the maximum intake capacity within the existing ability of wahs and earthern bunds may also result in limiting the function of flood reduction. Therefore, in addition to the construction of dispersion structure, considerable length of off-taking channel (wahs) and number of distribution bunds have to be rehabilitated and improved until the distribution of flow become well within the farmer's manageable limit. Otherwise, the intaked flood flow may cause flood damage to the pachad.

iii) The hill torrent flood may change the course before it reaches the dispersion structure. After emerging from the gorges (darrah) into the piedmont plain, the course of flood flows is affected by natural and artificial features. High suspended sand and bed load of flood water (about 800 - 1,800 $m^3/km^2/year$) are deposited in its recession period as it flows into the unconfined course in the mild plain. These phenomena are more apparent in recession of large floods. The course of streams in case of small to medium floods are affected by sediment deposition from previous larger floods. After the construction of dispersion structures, flood flows will display similar characteristics both upstream and downstream of the structures. Flood flow may, at any time, change their courses again. Confinement of flood flows into channels by high embankments will also be subject to sedimentation which is costly to remove.

The second measure, afforestation in the watershed, is the method to supplement the disadvantages of the first measure. Selection of suitable trees was studied, however, actual implementation procedures such as nursery, planting, irrigation, measures against grazing etc. were not sufficiently discussed. In addition, neither did agricultural development in the watershed. Most of the watershed areas of hill torrents are not accessible by mobil except Vidore, Mithawan and Sakhi Sarwar.

It is therefore, concluded that the constructions of flood dispersion structures are an effective measure to control floods and to provide flood irrigation to the pachad, however, the project life will be limited short and it will not satisfy the ultimate goal of stable agricultural development in the pachad. It is considered as the first approach for development and more study is required for watershed improvement including afforestation.

What is required to realize the long-term stable farming in the pachad is, by measures for watershed conservation, to overcome the following two points and to which supplement the functions of dispersion structure simultaneously.

i) Improvement of the flood flow regime ie., reduction of flood peak discharge and prolongation of runoff period.

ii) Reduction of sediment yield from the watershed

By achievement of the above-mentioned, flood flows from the hill torrent will gradually be milder year by year, and this contributes to longer life-span of the dispersion structures. Once recovery of vegatation in the watershed d decreased sediment yield is achieved, project plans for reservoir construction, which were repeatedly proposed in the past, will become into the phase for economic evaluation.

The strategy for the development is summarized as follows.

i) Short-term cum urgent strategy (First Phase)
By construction of flood dispersion structures and rehabilitation of Wahs, eradication of flood damages in the downstream reaches and simultaneous restoration of the traditional flood irrigation system in the pachad.

ii) Medium and long-term strategy (Second Phase)
By simultaneous implementation of the watershed conservation measures and the afore-mentioned ones, achievement of agricultural development, recovery of vegetation and decreased sediment yield.

iii) Final strategy (Final Phase)
By planning of storage and flood control dams in the watershed, realization of stable farming, from the traditional flood irrigation to programmed irrigation, not only in the pachad but also in the watershed.

4.2 Watershed Management

There are two interrelated technologies; structural measures and non-structural measures.

4.2.1 Structural Measures

(1) Flood Control Dam

This is the complete measure to control and improve both flood flow and sediment runoff, which will realize the year round irrigation. Suitable topographic and geological locations can be found in each watershed areas with the help of satellite-emage maps. A number of plans for dam construction had been proposed in tha past. However, high sediment yield from the catchment of the dam will result in the requirement of larger scale dam construction which will not be feasible within the present project economy. This measure should accordingly be considered in the Third Phase of the development strategy when the watershed construction measures become effective to reduce the sediment yield from the catchment of the dam.

(2) Check Dam

Large scale check dam as a direct measure to reduce sediment yield (more than 15 m high dam) has the same characteristics with the flood control dam and should be considered in the strategy Third Phase after implementation of watershed conservation measures. There are several locations suitable for construction of medium scale check dam (5 m to 15 m high) which seems to have larger reservoir capacity but with relatively smaller construction cost. A series of low check dams (less than 5 m high) in an erosion valley is the most efficient measures to reduce the sediment yield from the river bed and shall be considered for construction from the beginning stage within the project economy.

Mechanism of low check dam is as follows. Natural river bed of the erosion valley is not stable and subjected under scouring and depositing of sediment. After the construction of a series of low check dams in a certain reach, the sediment will be trapped at behind the dam. The full sedimentation within a short time will occur and form 1/2 to 2/3 moderate river bed slope compared to the original river bed. The flood will leave a sediment deposit above the full deposition surface of each check dams. The next flood will score the previous deposit but create larger but flatter new deposition behind the dams. Thus as the deposition movement progressed, the erosion valley become wider and flatter and sediment production be reduced. If the valley is still active, the another series of low dams will be constructed above the new river bed. Finally, obtaining sufficiently smaller sediment yield or the valley become inactive, a medium to large scale check dam or flood control dam will be constructed at the valley to terminate the sediment yield from the valley. In case of Schesatobel Valley at Voralberg State in Austria, it was reported that 84 number of low check dams were constructed on the erosion valley during 1897 to 1923 and the river bed was raised by 40 m which has converted the valley wider, flatter and more inactive for sediment yields.

Gabion structures of wire or steel bar crates are preferable for the design of check dams in the Project Area. If the topography and geology allow, the construction of low check dam series should be assessed in the context of project evaluation.

4.2.2 Non-Structural Measures

Watershed of hill torrents are naked and barren area where erosion of land surface continues at an alarming rate depriving soil moisture and nutrient and resulting in heavy sediment yield and flashy runoff at downstream. Structural approaches to soil and moisture conservation, such as contour bunds, terraces etc., have generally failed in many cases because such measures are always to be site specific and too expensive to construct and maintain.

World Bank is encouraging to deploy a new technology for soil and moisture conservation using a vegetative system which has been subjected to long term test and met with the criteria of being low cost and replicable. Quated from the papers by R. G. Grimshaw[1] and a handbook[2] issued by World Bank, it is discussed below.

(1) Vetiver Grass Contour Hedges

"Vetiveria zizanioides", commonly known as Khus Khus in India, has been used as an effective vegetative hedge in the West Indies and Fiji for about 50

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1 / "New Approaches to Soil Conservation" R. G. Grimshaw, Chief, Agriculture Division World Bank, Washington D. C.

2 / "Vetiver Grass - A Method of Vegetative Soil and Moisture conservation":, World Bank Handbook

years. The contour lines are permanently fixed through the use of vegetative lines of Vetiver grass hedge. Vetiver grass is densely tufted, awnless, wiry, glabrous and perennial grass and has proven ideal for vegetative soil conservation measures in arid and semi-arid climate. Researchers at International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) found that Vetiver grass exhibits both hydrophitic and xerophytic characteristics. Vetiver grass contour hedges hold the runoff on the slopes longer than other methods, giving a chance to soak in over a wide area and recharge the aquifers. Natural terraces, of sometimes three to four meters high, are built up behind the Vetiver hedge and soil and moisture losses are minimized. Steep and rolling country, too steep or not suitable for cultivation of cereal or pulse crops, can be successfully planted to perennial tree cops on the contour when stabilized by Vetiver contour hedges.

A number of states in India are initiating this vegetative measure combined with contour cultivation. Other countries have started similar programs, such as Nigeria, using Vetiveria nigratana, and the Philippines and Sri Lanka with Vetiver zizanioides. Most recently, the People's Republic of China has started the project which will concentrate initially on protecting existing terraces and on reducing runoff and also initiate some trials for protecting tea gardens on very steep eroding soils.

Vetiver zizanioides has the following characteristics that make it ideal for soil and moisture conservation.

- It thrives under very wet (6,000 mm) and very dry (200 mm), from sea level to 2,600 m above MSL.
- It grows well as far north as 29 degrees, surviving frequent frosts and temperatures as low as -9 °C.
- The main constraint to expansion is the lack of nurseries and planting materials.
- It does not produce viable seeds or practically sterile; it has to be planted vegetatively, meaning that it will not become a weed in farmer's field.
- The plant is extremely drought tolerant; 'slips' for planting have withstood 60 days without rain.
- In dry areas, it normally takes two to three seasons with constant 'gap-filling' to establish the hedge.

- Once established, maintenance cost is virtually zero, and it is generally unpalatable to livestocks.
- It is fire resistant.
- It is resistant to most pests and diseases.
- So called vetiver oil can be taken from the roots. It is used as materials for perfume and medicine.

Feasibility Study Report on the CRBIP proposes the application of Vetiver grass for protection of canal embankment from erosion. The component consists of two element;

- a nursery operation for the production of Vetiver planting slips; and
- a planting out program to cut slopes and fills of the main canal

Nursery propagation of Vetiver grass increases the number of slips of about 60 with three harvests per year, giving output of 3.75 million slips/ha from a typical nursery planting density of 62,500 slips/ha. Assuming that Vetiver slips are planted at 10 cm centers in hedge rows, 375 km of hedge will be produced by one hectare of nursery per year. Cost analysis is also given in the said 1990 Report.

-	Nursery	20,000 Rs/ha
-	Planting	1,600 Rs/km

It is reported that vetiver grass grows wild in NWFP and riverain of the Indus. The wild growth, however, was not identified in the Project Area during the Study. It must be noted that Saccharum munja, which has quite similar nature to Vetiver grass, was identified (by Dr. Niel L. Martin, FAO, Pakistan) grown wild widely in the watershed of the Project Area. The Saccharum munja may alternatively be employed for contour hedge instead of Vetiver grass due to availability of seeds and seedlings in the watershed and the same dence root and strong drought tolerance as vetiver grass thought edible for animals. In the project planning, employement of some local varieties such as Saccharum munja shall also be examined.

4.3 Development Strategy

Deploying a new but proved technology for soil and moisture conservation, watershed management becomes possible and promising. The development strategy for pachad as well as watershed is then formulated.

4.3.1 Short Term Development Strategy

Short term development strategy aims at an early relief from flood damages on canal irrigated area as well as the pachad. At the same time, preparatory works for long term development program will be initiated. The implementation period should be within three years. Programs to be included are as follows.

- Constructions of dispersion structures, including rehabilitations and improvements of distribution facilities and other infrastructures in the pachad.

- Preparation for Vetiver grass or Saccharum munja plantation, including collection of planting materials, preparation of nursery field and initiating pilot operation.

4.3.2 Long Term Development Strategy

The strategy aims at the improvement of flood runoff regime and reduction of sediment yield through structural and non-structural watershed management measures. The implementation period is assumed to be 5 to 10 years. As the watershed management displays the favorable results, the life span of the project facilities at the downstream, such as dispersion structures, will be extended, which should also be counted in the project benefit. Short term and long term development programs should be implemented in parallel. In the evaluation of the Project, following measures shall be examined.

- **Vetiver grass or Saccharum munja contour hedge on the slopes of watershed.**
  The slope conditions will be carefully investigated and classified according to the slope gradient, soil cover, slope length etc. Vertical interval of Vetiver hedge will be 2 to 3 m.

- **Vetiver grass or Saccharum munja belts**
  Vetiver grass hedges are planted across a small erosion valley where the river bed materials are suitable for its growth. Making five to six rows of Vetiver grass hedges into one set, several to ten sets per one valley will be programed. According to the conditions of the valley, the Vetiver grass belts will be created together with the siries of low check dams.

- **Plugging of gully erosion**

Gully erosion is much observed on slopes in the watershed. It rapidly grows and directly works for increased sediment yield by large slope failure if left untreated. By plugging of initial small gullies with masonry or some other methods and simultaneous planting of the contour hedge, soil erosion will be prevented.

- **Low check dams**

A series of low check dams of gabion or masonry structure with less than 3 m high will be constructed in such small but very active erosion valley that has catchment area of less than 10 km^2. Vetiver grass belts across the valley and hedges on the catchment slopes will also be considered to combine with check dams.

- **Acceleration of farming activity**

There are small to medium scale piedmont plains spotted in the watershed, where agriculture depends on small perennial flow or torrent water. Beside this, many farming activities are observed along the torrent water courses. Farmers construct masonry bunds along the food of hill and torrent water courses or even across the valley. Farmers are paying considerable efforts to create and maintain their farm lands behind the bunds by reclaiming silt deposit. On the slopes in the watershed, Cynodom dactylon, Cenchrus ciliaris, Lasiurus sindicus, Saccharum munja and other grasses are observed. They are damaged by excessive grazing and so is shrub. By implementation of contour hedge with Vetiver glrass, conservation of soils and soil moisture can be achieved. Introduction of rotational shifting grazing, recovery of vegetation on the slopes and implementation of systematic livestock raizing are therefore most important. Orientation and guidance of the above for the farmers are much required. Some assistance may also be considered for them in supply of grass seeds.

For planting of contour hedge with Vetiver grass or Saccharum munja and implementation of the rotational shifting grazing in the whole watershed, cooperation by farmers is indispensable. In addition to the orientation and guidance, effective demonstration shall accordingly be exerted in some model areas for the purpose.

- **Monitoring and evaluation**

Structural and non-structural measures for watershed management are generally site specific and depend greatly on weather condition. Progress of watershed management should be monitored from the beginning of implementation and monitored results should be feedbacked and evaluated for necessary alternative measures.

4.4 Project Formulation

4.4.1 Project Priority

The previous sections discuss that priority should be given to flood damage reduction to the existing canal systems, the improvement of agriculture in the pachad and the demonstration of watershed management technologies. The major hill torrents in the Study Area can, accordingly and from the point of project economy, be classified into 3 groups.

Group 1 High potential for agricultural development but low return from flood control

- Kaura
- Vehowa
- Sanghar

Group 2 High to medium potential for agricultural development and high return from flood control

- Sori Lund
- Vidore
- Sakhi Sarwar
- Mithawan
- Kaha
- Chachar

Group 3 Medium to low potential for agricultural development and low return from flood control

- Pitok
- Sori Shumali
- Zangi
- Sori Janubi

Therefore, in spite of considerable potential for the development of their catchment areas, the hill torrents in group 1 are accorded second priority in project formulation.

(1) Group 1

The catchment areas of the hill torrents in this group are characterized by higher rainfalls, about 350 mm/year, than those of other hill torrents. This, together with larger catchment area, gives rise to small amount of perennial flows of about 0.7 cms to 1.0 cms at Vehowa and Sanghar, respectively. The farm lands of the pachad irrigated by these perennial flows are maintained in better conditions than others (see Table 3-6). Tubewells are observed in the pachad of Vehowa hill torrent. However, groundwater availability is limited.

The Chashma Right Bank Irrigation Project (CRBIP), Phase three, is programmed for implementation under international finance. Flood damages to the canals of CRBIP, however, cannot be envisaged at present. It will cover approximately 56,000 hectares in the pachad along the Indus and will provide year-round irrigation. Remaining pachad area is then, 11,390 ha, 13,100 ha and 8,240 ha for Kaura, Vehowa and Sanghar respectively. These are smaller than those of group 2.

Satellite Photographs reveal vegetation cover areas in the catchment area of Vehowa and Sanghar hill torrents and large possibilities seem to exist for the development of small to medium scale irrigation in those areas. However, the lack of access roads to the watershed, except for upper reaches from Baluchistan province, makes data collection and analysis impractical. The catchment area of Kaura hill torrent belongs to Baluchistan and N.W.F.P and most of Vehowa and Sanghar catchment areas belong to Baluchistan province. Moreover, the construction of a road network in such a large catchment area as that of Sanghar, the second largest of the 13 major hill torrents is 4,880 sq.km, cannot be undertaken in the context of this project formulation.

(2) Group 2

The hill torrents listed in this group cause direct flood damages to the areas irrigated by the D. G. Khan and Dajal Branch canals. A feasibility study for Kaha hill torrent has already bean carried out and was formulated as a single project. On the other hand, Mithawan hill torrent has also bean selected as a pilot project.

Project formulation for the remaining hill torrents in this group is urgently required to reduce flood damages. The catchment area are small to medium size and all located within Punjab province except upper reach of Chachar hill torrent. The catchment areas of Vidor and Sakhi Sarwar are accessible by road. Watershed management technology in the catchment areas of the hill torrents in group 2 can be easily demonstrated and results obtained within a comparatively short period because of smaller and accessible catchment area. Demonstration effects are also expected to be widely perceived because of the proximity of these hill torrents to the towns of D. G. Khan and Rajanpur.

In view of the high direct benefits from flood control, good potential for agricultural development in the pachad and quick promising results from the use of watershed management technologies, group 2 is therefore selected as the highest priority for development.

(3) Group 3

Rainfall in the catchment areas of the hill torrents in Group 3 is low. Average annual rainfall is approximately 200 mm and the climate is arid. Cattle grazing is the dominant agricultural activity in their pachad areas and none of the catchment areas of the hill torrents in this group is accessible by road.

In particular, runoff water from the Pitok and Sori Sumali hill torrents contains a high dissolved salt content of approximately 3,500 ppm originating from the gypsum formations in their catchment areas. It is not suited to agriculture.

Under these circumstance, group 3 is accorded the lowest priority. The construction of dispersion structures at sites other than Pitok and Sori Shumali should be assessed in the context of the implementation program for the Extension of Dajal Branch Canal project.

4.4.2 Selection of Project for Phase II Study

Candidate hill torrents are those listed in group 2, namely, Sori Lund, Vidore, Sakhi Sarwar and Chachar. Major features of these hill torrents are as follows.

		Sori Lund	Vidore	Sakhi Sarwar	Chachar
Catchment Area	(km2)	520	770	160	800
Average River Slope		1/29	1/40	1/29	1/90
Average Catchment Width	(km)	8.9	13.3	4.5	9.1
Mean Annual Rainfall	(mm)	227	252	215	239
Average annual Runoff	(MCM)	57.0	93.4	16.6	92.4
Annual Sediment discharge	(m^3/km^2)	700	1,100	1,000	600
Peak Flood (25-year)	(m^3/sec)	1,500	1,795	739	2,032
Population		34,530	55,410	25,992	18,250
Pachad Area	(ha)	13,860	19,350	15,690	23,220
Land Classification					
Class 1-3	(ha)	12,320	14,200	4,190	17,100
Class 4	(ha)	930	3,590	10,140	3,740
Class 5	(ha)	610	1,560	1,360	2,380
Cultivable (1-3)	(ha)	12,320	14,200	4,190	17,100
Uncultivable (4-5)	(ha)	1,540	5,150	11,500	6,120
Accessibility to Catchment		NO	YES	YES	NO

Land classification of the pachad shows that the lands for Sori Lund and Vidore are more fertile than those for Sakhi Sarwar and Chachar. Relatively extensive farming activities can be observed and groundwater exploitation by tubewell is practiced in the Vidore hill torrent area.

Topographic and hydrologic factors show more or less the similar characteristics on these hill torrents. Mean annual rainfall for Sori Lund and Sakhi Sarwar are rather marginal to the growth of Vetiver grass. Magnitude of peak flood discharge corresponds with the scale of flood damages at downstream. Watershed management will be easier and less costly for Vidore and Sakhi Sarwar because of easy access to their catchment areas.

Vidore hill torrent is deemed to be the most suitable site for project selection in view of agricultural development possibility (good land classification ,largest population), flood